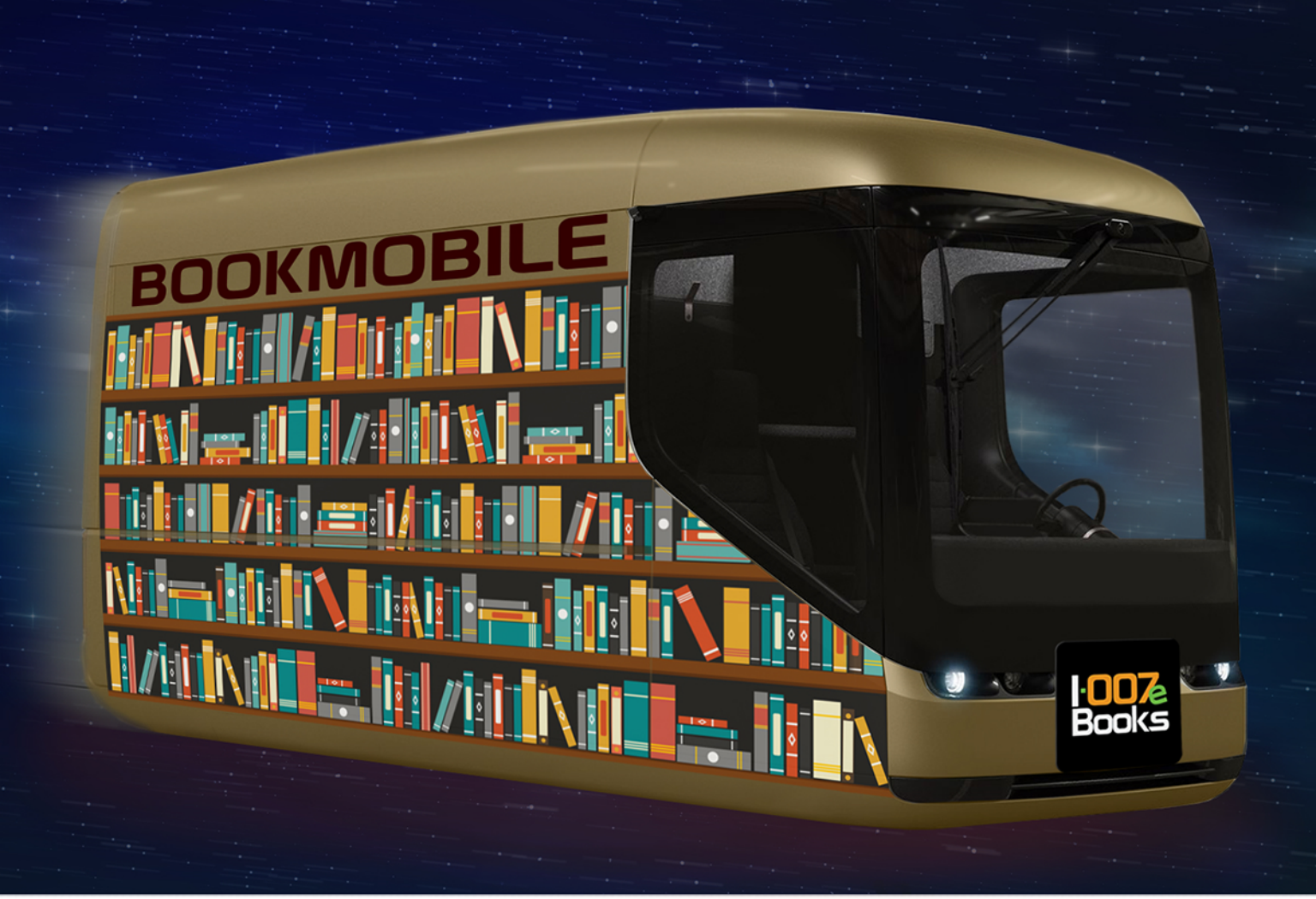
APRIL 2019

I-Connect007

PCB007 MAGAZINE

TAKING OFF WITH NEW TALENT IN THE PCB INDUSTRY



Our library is the bookmobile for the 21st century.

Registered members of **my I-Connect007** have access to our ever-growing library of eBooks, which now includes a wide range of topics from DFM to thermal management.

Instead of waiting for the bookmobile, though, our users download new titles with the click of a mouse. It's pretty awesome!

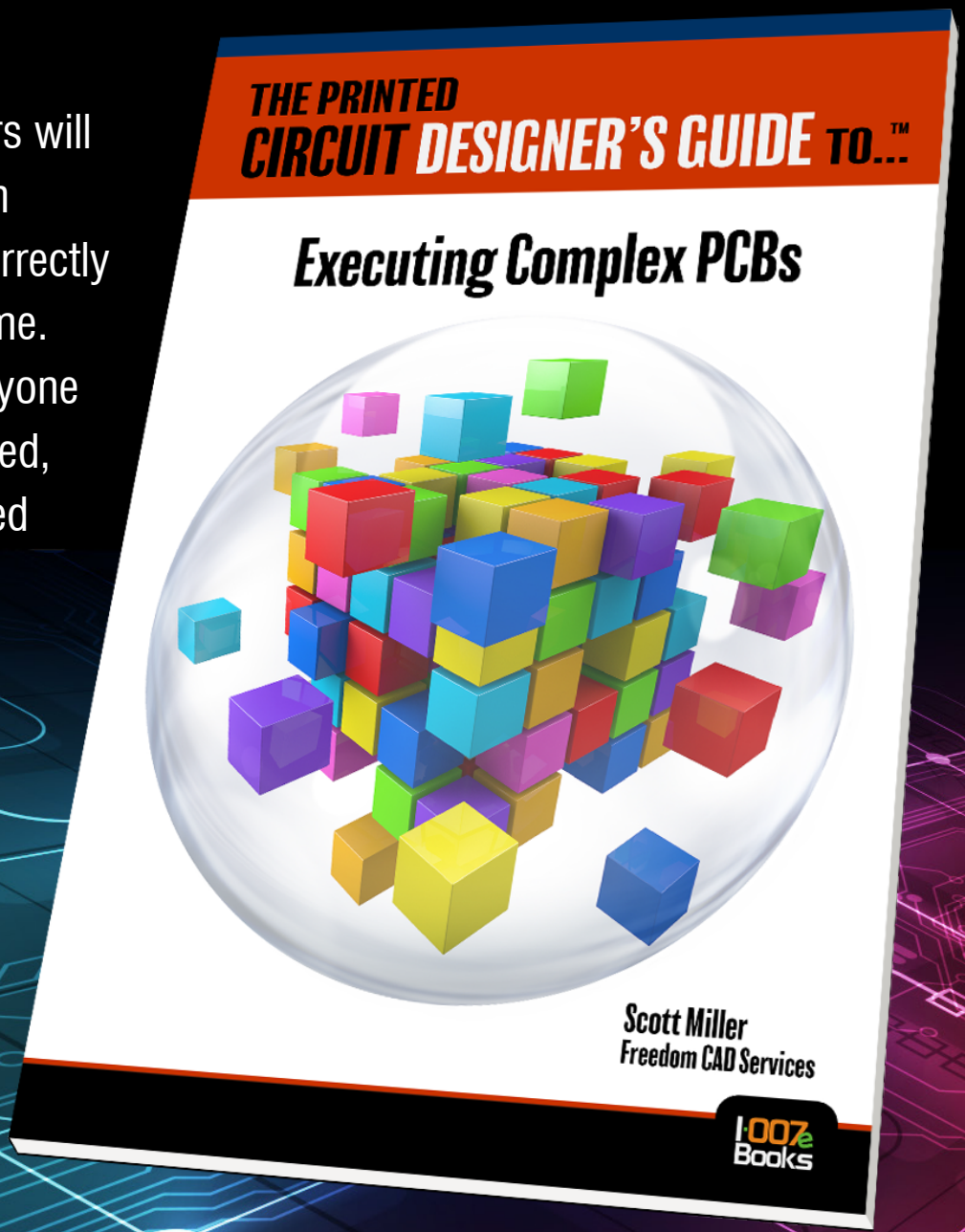
View our eBook library

my I-Connect007
GOOD FOR THE INDUSTRY

I-007e Books

Your how-to guide for making Rev 1 work.

In this book, readers will learn how to design complex boards correctly the first time, on time. A must-read for anyone designing high-speed, sophisticated printed circuit boards.



DOWNLOAD NOW

I-007e Books

I-007ebooks.com/ecd

PCB007 MAGAZINE

New Talent in the PCB Industry

As the electronics industry works to overcome an impending staffing and skills shortage, it will be the youth who will rise to the challenge, build on the work of the current industry experts, and move technology into a higher orbit. In this issue, we ride along with some advanced industry research under way by some highly creative engineering students who will directly affect the future of our industry.

10 **MakeHarvard: A Glimpse of Technology to Come**
by Kelly Atay

18 **University Students Point to the Future in Their Research**
Student Interviews

36 **SEMI's Cristina Sandoval on Mentoring and Retaining Young Talent**
Interview by Nolan Johnson

56 **Engaging the Future of Advanced Manufacturing: NextFlex and DuPont in Silicon Valley and Beyond**
by Brynt Parmeter and Emily McGrath

FEATURE COLUMNS:

30 **Calling All Scholars and Educators: IPCEF Launches Scholarship Program**
by Dr. John Mitchell

46 **New Engineering Talent Joining the Electronics Industry**
by Tara Dunn

64 **Merging the Best of Both Worlds: Young Superheros and Knowledgeable Wizards!**
by Didrik Bech

BÜRKLE

NORTH AMERICA, INC.

LAMINATION SYSTEMS FOR PRINTED CIRCUIT BOARDS

STATE-OF-THE-ART SOLUTIONS FOR THE PCB INDUSTRY INCORPORATING THE LATEST TECHNOLOGY.

Solutions for the PCB Industry

High quality and well proven presses and handling equipment

Contact:
Kurt Palmer
714-379-5090

INNOVATIVE POWER **4U**

burkleamerica.com

PCB007 MAGAZINE

SHORTS:

29 Researchers Discover New Material to Help Power Electronics

32 Creating Better Solar Cells

34 George Fox University: Teaching PCB Design to EE Students

54 Tiny Waveguides Could Enable Better Biomedical Devices, Wearable Displays

87 Agfa on Revolutionary Inkjet Solder Mask Applications

93 Atomic-scale Binary Logic Could Power Faster, More Energy-efficient Electronics

DEPARTMENTS:

97 Career Opportunities

106 Events Calendar

107 Advertiser Index & Masthead

ARTICLES:

70 Averatek on the Future of Additive and Semi-additive Processing
Interview with Mike Vinson

74 Electrolytic Plating: Filling Vias and Through-holes
by Mustafa Özkök, Sven Lamprecht, Akif Özkök, Dolly Akingbohungbe, Moody Dreiza, and Alex Stepinski

88 Vertical Conductive Structures, Part 1: Rethinking Sequential Lamination
by Joan Tourné

COLUMNS:

8 Youth in the Industry—Reaching New Heights
by Nolan Johnson

84 OSP Performance: Effect of Film Thickness and Microetch
by Michael Carano

HIGHLIGHTS:

44 PCB007 Suppliers

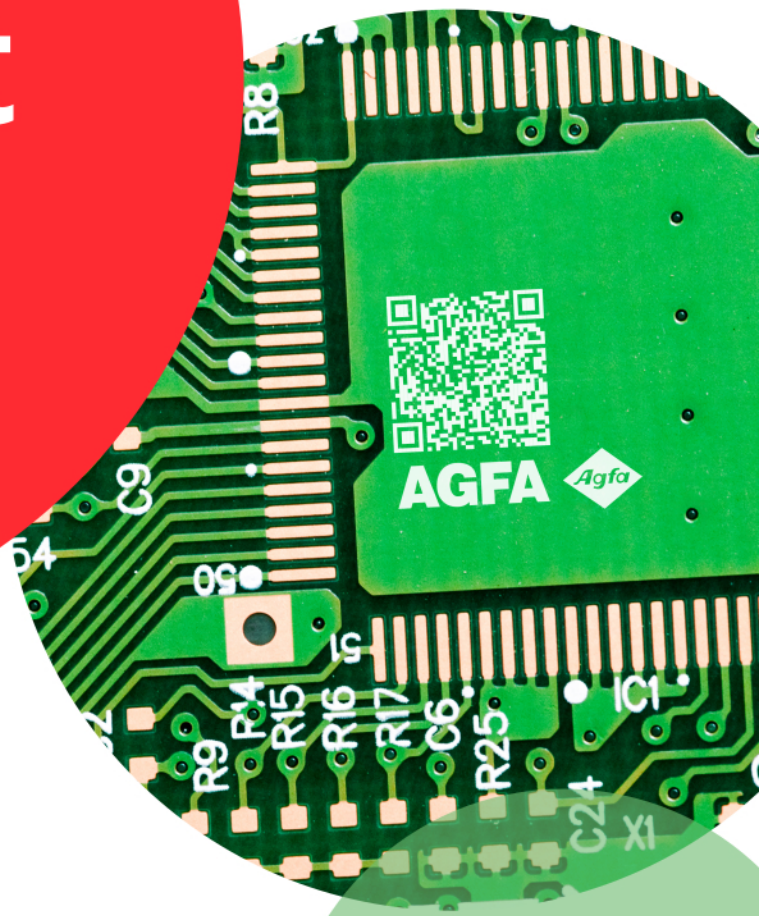
62 EIN007 Industry News

68 MilAero007

94 Top 10 from PCB007

DiPaMat
Inkjet Inks

- LEGEND
- ETCH RESIST
- SOLDERMASK



Be flexible
Go digital

- Variable data printing
- Fast
- Ecological
- Efficient
- Validated by PCB inkjet printer suppliers

RoHS COMPLIANT

UL

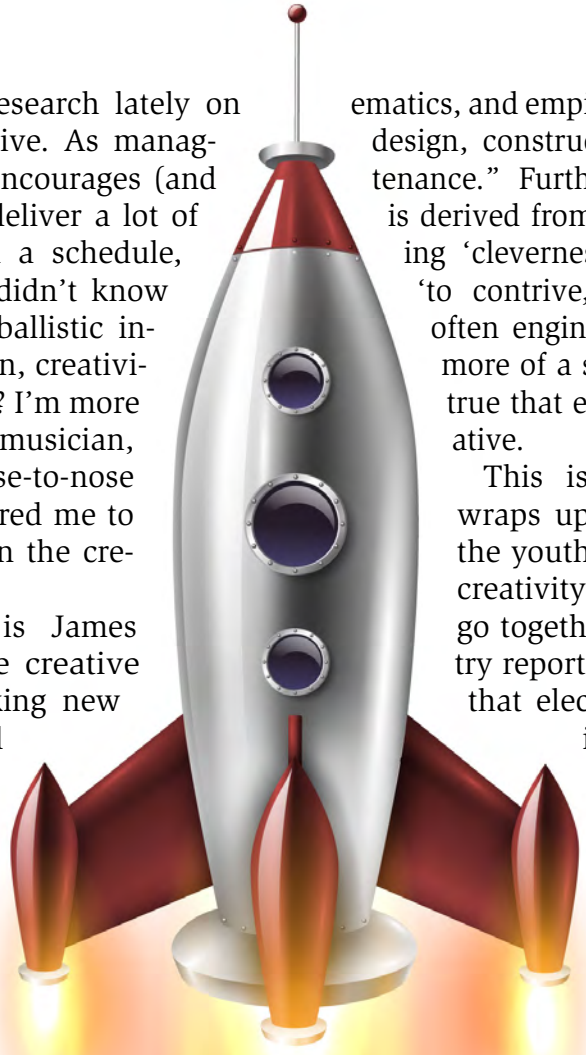
AGFA Agfa

industrialimaging@agfa.com

Youth in the Industry—Reaching New Heights

Nolan's Notes

by Nolan Johnson, I-CONNECT007



I've been doing some research lately on the process of being creative. As managing editor, this role often encourages (and sometimes forces) me to deliver a lot of creative material—and on a schedule, no less. In some ways, I didn't know I had it in me, this near-ballistic increase in my output. I mean, creativity is an artistic talent, right? I'm more of a mathematician than a musician, myself. But coming nose-to-nose with that assumption spurred me to look into other research on the creative process.

One creativity expert is James Clear [1] who wrote, "The creative process is the act of making new connections between old ideas or recognizing relationships between concepts." Clear continued, "Creative thinking is not about generating something new from a blank slate, but rather about taking what is already present and combining those bits and pieces in a way that has not been done previously."

Search for a definition of "engineering" and Wikipedia delivers this example: "…the application of knowledge in the form of science, mathematics, and empirical evidence to innovation, design, construction, operation, and maintenance." Further, "The term engineering is derived from the Latin ingenium, meaning 'cleverness' and ingeniare, meaning 'to contrive, devise.'" No matter how often engineers say that engineering is more of a science than an art, it is still true that engineering is inherently creative.

This issue of *PCB007 Magazine* wraps up our extended coverage of the youth in the industry. Youth and creativity are two words that tend to go together. Based on various industry reports, the ongoing staffing gaps that electronics manufacturers face is likely to get worse before it gets better. Unless, of course, industry-wide steps in leadership and creative outreach programs are enacted. And there are two pieces of hopeful news in all this.

First, industry groups are organizing. SEMI, SMTA, NextFlex, and IPC are all engaged in educational outreach and skill-based training programs. A number of these programs intentionally target the excitement of STEM creativity. Academic youth are being engaged in more

indirect ways, such as sponsored makeathons and hackathons.

Second, some university EE programs are increasingly adding practical manufacturing information to their curricula. We looked at one such program at George Fox University in *Design007 Magazine*. In this issue, we dive into discussions on some advanced university research being conducted by some highly creative engineering students that will directly affect the future of our industry.

This issue lifts off in Cambridge, Massachusetts, at MakeHarvard. This event drew student problem-solvers to the Harvard campus; gave them access to tools, materials, and expertise; and challenged them to solve a problem they selected on-site using ad hoc teams. Talk about creativity under pressure.

Next, I discuss research with three doctoral candidates and an engineering undergrad. These R&D projects were presented as a part of SEMI's program at the FlexTech/MSTC conference in February. Then, right on cue, IPC President and CEO Dr. John Mitchell brings us news of IPC's new scholarship programs.

My conversation with Cristina Sandoval covers the educational outreach programs ramping up at SEMI. Then, Tara Dunn's column follows up with some new talent entering the electronics field.

The NextFlex organization is also actively engaged in educational outreach (check out our interview with the Flex Factor team in the upcoming April *Flex007 Magazine*). Brynt Parmenter and Emily McGrath submit a detailed article on the ongoing educational partnership between NextFlex and DuPont's Silicon Valley Research Center.

Didrik Bech of The PCB Norsemen explores how youth and more experienced industry professionals can come together to create an extraordinary environment in your workplace. With a different take on creativity and innovation, Barry Matties and Averatek's Mike Vinson discuss the future of additive and semi-additive processes, which provides meaningful insight from an industry veteran.

Then, the teams at Atotech and GreenSource Fabrication bring us a report on their ongoing work to fill microvias using electrolytic copper plating. The authors presented this update at IPC APEX EXPO in January 2019; we bring it to you here. Also, Michael Carano's column looks at OSP performance concerning thickness and microetch.

We close with the first of a series of articles from NextGIn CEO Joan Tourné, discussing his company's research in rethinking sequential lamination, and their development of a "vertical conductive structure," or VeCS, process.

It's no accident that this issue launches with students (the youth in our industry) and wraps up with ongoing R&D by industry veterans. These new researchers, creators, innovators, and makeathon participants will drive our industry long after we have all moved on. The future of technological innovation seems to be in good hands. **PCB007**

References

1. Clear, J. "Creativity: How to Unlock Your Hidden Creative Genius," 2018.

Nolan Johnson is managing editor of *PCB007 Magazine*. Nolan brings 30 years of career experience focused almost entirely on electronics design and manufacturing. To contact Johnson, click here.

Sunstone's first-place winner, Team 42+2.

MakeHarvard: A Glimpse of Technology to Come

Feature by Kelly Atay

The second annual MakeHarvard engineering makeathon drew over 370 top students from around the world to compete for prizes while building engineering prototypes. This year's event was twice as big the inaugural year, and it was a thrill observing the prototypes of students from both the undergraduate and graduate levels at the 2019 MakeHarvard makeathon.

Making Makers

MakeHarvard was founded on a belief in the importance of maker experience collaboration, encouraging students to come together and turn their wildest ideas into something real. Applicants were not filtered on previous experience but looked at individually to create the best possible combination for a successful event and an opportunity for students to meet people of all engineering levels. Over a dozen competitions were available for students to register for, including Most Likely to Become a Unicorn, Kid's Choice Awards, Composite Materials Design Award, Clean Transportation Challenge, Best Use of Google Platform, and Best IoT Hack Using a Qualcomm Device.

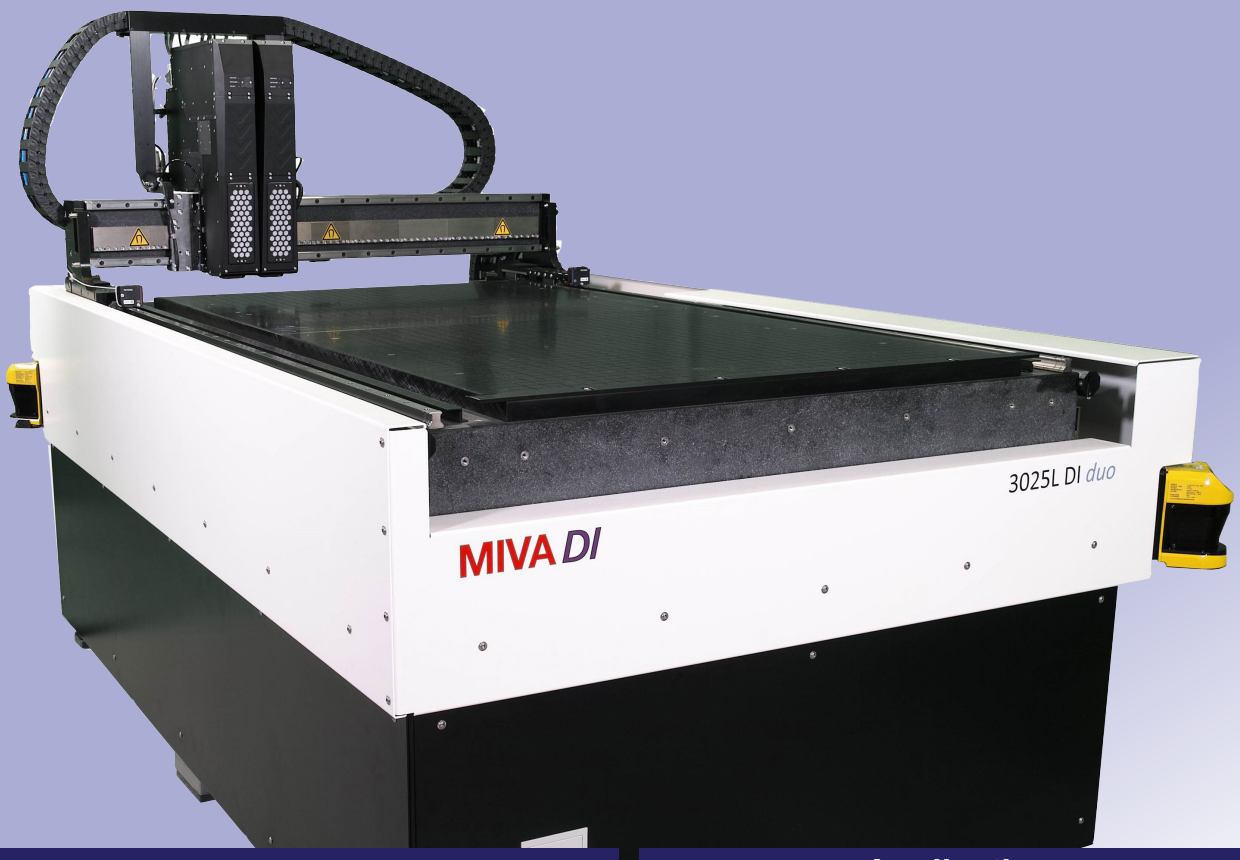
The event is an outshoot of the broader maker movement, which is essentially a tech-influenced, do-it-yourself community. It was informally created around 15 years ago around Make Magazine—a geeked-out periodical featuring lots of DIY articles for creations, such as

Figure 1: Watch a video of team 42+2's MakeHarvard submission, the Pipe Crawler.

MivaTek Global

Miva 3000 L

High Technology Imaging in a Large Format System



MIVA: LED DIRECT IMAGING - Large Format

Features

- **30" x 60" Standard Imaging Area**
- Up to 3 light engines
- 1 mil registration accuracy
- Small footprint for the imaging area
- 10, 25 and 50µ feature systems available
- Images all materials resist and soldermask
- A/B Registration: 1 mil over entire area
- Large Panel Size: up to 762mm x 1524mm

Applications

- PCB Inner Layer
- PCB Outer Layer
- Solder Mask
- Glass Emulsion
- Reel to Reel
- Silver Film

Globally marketed and serviced

MivaTek Global, 6 Dickinson Drive, Suite 215, Chadds Ford, PA 19317
Contact: Brendan F. Hogan, M (610) 620-3795, B.Hogan@MivaTek.Global
Chris Hrusovsky, M (612) 205-6113, Chris@MivaTek.Global
Website: www.MivaTek.Global

VCRs converted into cat feeders and 3D printers. Maker spaces and events have become more and more popular, inspiring startups and manufacturing innovation as well as clogging garages the world over with half-finished robots and potato cannons.

Mentors and Judges

Sunstone Circuits returned this year after sponsoring a judging category for the first MakeHarvard event in 2018. If you were there, you saw us—our team was hard to miss in our bright orange vests (Figure 2). Sunstone employees served as both mentors and competition judges.

As mentors, we were out and about helping students and answering questions (Figure 3). Students were full of questions, and we were eager to help. Sometimes, there were questions we didn't have complete answers for at the ready, but usually, we were able to suggest a place to find the answer. All the students needed was direction, and they were all over finding the solution. Problem solved.

Jess, one of the event staff at Harvard, said, "We really appreciate the enthusiasm Sunstone brings to MakeHarvard. We're so happy that everyone from Sunstone had a great time, and thank you for the t-shirts! Our team really loved the beautiful PCB trophy." Elton, another staff person, said, "You guys are definitely our favorite sponsors!"

Figure 2: Sunstone Circuits' booth being visited by students.


Figure 3: Sunstone representative Bob Tise (orange vest) works with students.

Award Winners

As judges, our Make it Matter category focused on innovative prototypes. The competition required makers to engineer, build, and document a working prototype with significant social, personal, or environmental impact that incorporated an Adafruit ESP8266 HUZZAH breakout board. Teams had 24 hours to come up with an idea and bring their creation from design to prototype.

It was clear that these students' flexibility, creativity, and speed gave us a lot to be excited about with this incoming generation of makers. We were amazed at the ideas these makers came up with for our category as well as throughout the event. Our team was also impressed by the speed with which participants built their prototypes—often having to quickly learn complex engineering skills formerly foreign to them. Within the allotted hours, they built prototypes meant to discover cracks and defects in pipes, clean oil, and output light, among others. The event was full of impressive designs and equally impressive prototypes that needed few adjustments before they could be put to use.

The student projects had all kinds of design elements, from software

on complex platforms and different programming languages to hardware engineering of all kinds. It was truly amazing to see what these teams could do in a short amount of time. The myriad of skills on display ranged from concept design to advanced coding with real-world platforms, such as AWS. Some projects featured mobile apps and websites. Further, we saw real 3D objects designed, printed, and integrated into projects with documentation that would make most corporate projects envious.

Judging for this event is tough because there were so many great ideas and prototypes that deserved recognition; it was nearly impossible to choose just one to award. Around 100 students comprising 20 teams competed in our category. In the end, the first-place winner for Sunstone's documentation competition was a robot pipe crawler designed by Team 42+2 comprised of Rajvi Shah, Dawson Rosell, Desmond O'Connor, and Kirsi Kuutti. Designed to crawl along pipes and detect cracks or other faults in the material, their prototype went through several iterations over the course of the event before the final version was submitted for judging.

Team member Rosell said, "MakeHarvard was an incredible experience. I got to work with people I had never met before, learn how to work with programs and boards I've never used before, and spend 24 hours problem-solving!" He continued, "This event presented me with an opportunity to think outside of the box and make the most of the limited materials we had to work with."

Team member Shah further added, "The Sunstone documentation challenge pushed us to our limits." He continued, "It made us solve a real-world problem by helping the industrial sector. Harvard University, our robot, and the Sunstone challenge were all about innovation and persistence, helping us make our passion into a possibility." Comments from Team 42+2 included, "At this hackathon, we learned new techniques during this challenge: how to program a web server on a microcontroller, solder pin headers to breakout boards, design gear ratios and drive trains, and using manufacturing techniques for different materials and SparkFun's ESP32 microcontroller."

Kirsi Kuutti summed it up by saying, "MakeHarvard was a hurricane of development. We free-handed a drive-train, salad-tossed a sensor interface, and fashioned a web app." Kuutti continued, "Fueled by sugary drinks and excitement to try new tech, we developed a prototype of a leak detecting pipeline robot. We found the Adafruit ESP8266 Huzzah breakout board was perfect for what we were trying to accomplish within this 24-hour window, and Sunstone Circuits was supportive with questions we had. It was a blast to work under pressure and create something awesome in a short amount of time."

Though Sunstone Circuits intended to award only a first-place prize, we awarded a second-place prize in our documentation competition to Sam Roquitte and Maxwell Stigman from Georgia Institute of Technology for their eL safety-enhancing adaptive lighting system for electric skateboards (Figure 4). We were im-

Figure 4: Sunstone's second-place winners Sam Roquitte (top) and Maxwell Stigman (bottom).

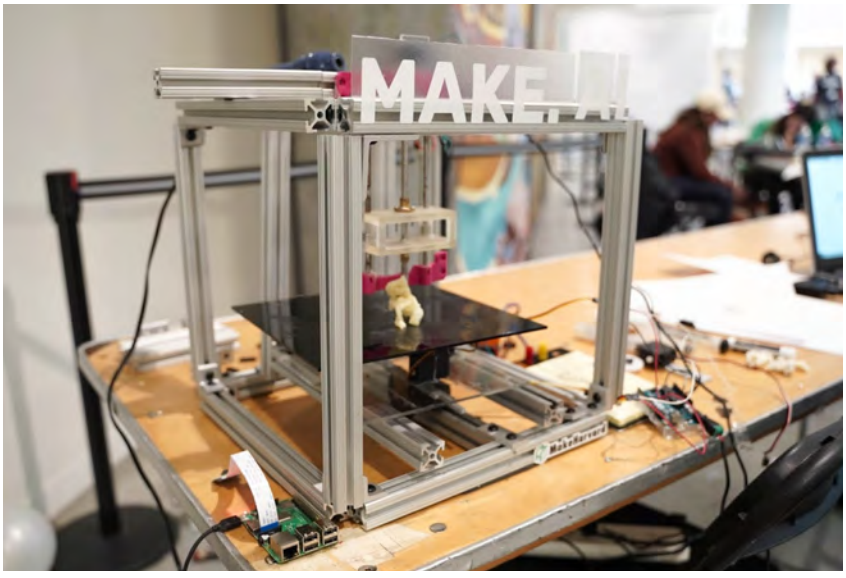


Figure 5: Some competitors arrived with their own equipment. This student-made 3D printer is one example of the home-brew gear on hand.

pressed by the relevancy of their design based off of a need they had experienced in their lives, and their willingness to learn new skills alongside the engineering flexibility they had to solve a real-world problem.

When reflecting on their MakeHarvard experience, Roquitte and Stigman commented, "We were able to build a very complete and polished project." Further, they said, "We learned some new soldering skills and Android studio/app development. We believe that this project could make traveling on electric skateboards much safer. We also believe that this will promote the use of electric skateboards, which are a clean and practical mode of transportation. We will be looking into developing that project further and potentially turning it into a product."

Other Impressive Prototypes

Outside of our competition category, three other prototypes that impressed us included:

- Hydrophobe unmanned surface vehicle (USV)
- Beam Print
- CocoGogo

Hydrophobe USV

Hydrophobe USV, a device meant to filter and clean oil with greater efficiency and simplicity than is currently used when oil spills, won the Composite Materials Design Award sponsored by Dixie Chemicals. Combining an oleophilic/hydrophobic composite filter with flow meters and pressure sensors, the device filters out water to only absorb oil while reporting success back to a laptop or computer. The students who built the prototype were largely unfamiliar with the Arduino language, soldering, and use of rapid prototyping, all of which proved central to their project. Overall, they managed not to just understand but master each and use them as needed for their prototypes. Team members included Katherine Nelms, Wyatt Phillips, Sabrina Meli, and Haley Higginbotham.

Beam Print

Beam Print by Team 46 was another standout prototype we observed that was built to simplify the laser cutting process and streamline rapid prototyping. None of the members of team members had experience in AR or app development, which were central to the success of their device. Team members Dieter Brehm, Sam Daitzman, Dhara Patel, and Jonathan Kel-

Figure 6: Beam Print team accepting the BMW Applied AR/VR Award.

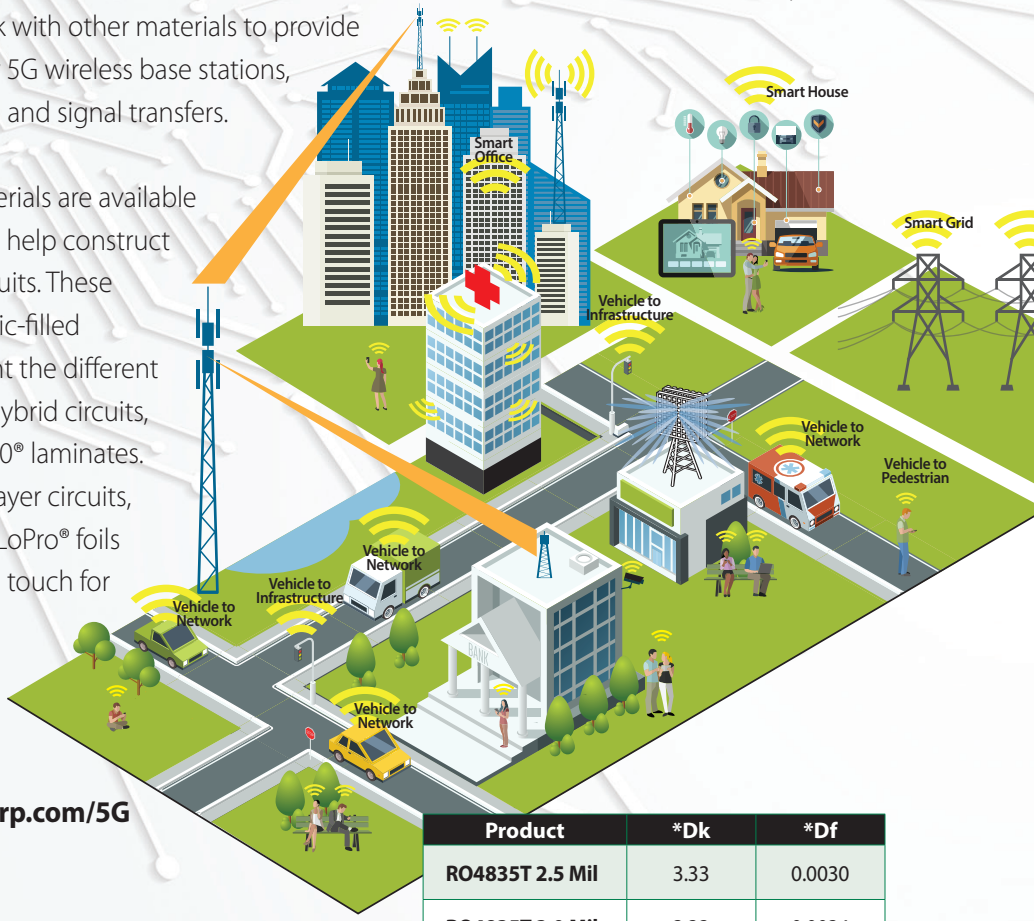
5G: Higher Frequencies!

Do you have the **right** circuit materials?

Frequencies at 28 GHz and higher will soon be used in Fifth Generation (5G) wireless communications networks. 5G infrastructure will depend on low-loss circuit materials engineered for high frequencies, materials such as RO4835T™ laminates and RO4450T™ bonding materials from Rogers Corporation!

Rogers RO4835T spread-glass-reinforced, ceramic-filled laminates are low-loss materials in 2.5, 3.0, and 4.0 mil thicknesses. They are well suited for millimeter-wave frequencies as part of the inner cores of 5G hybrid multilayer PCBs. They can work with other materials to provide the many functions needed by 5G wireless base stations, including power, signal control and signal transfers.

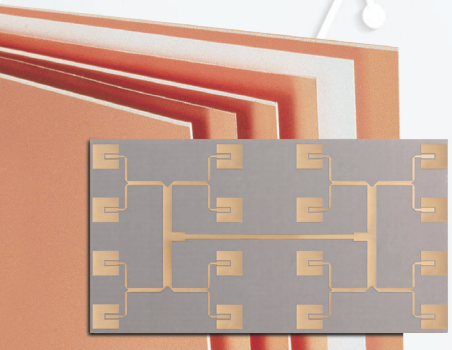
Rogers RO4450T bonding materials are available in 3, 4, and 5 mil thicknesses to help construct those 5G hybrid multilayer circuits. These spread-glass-reinforced, ceramic-filled bonding materials complement the different materials that will form these hybrid circuits, including RO4835T and RO4000® laminates. And for many 5G hybrid multilayer circuits, Rogers CU4000™ and CU4000 LoPro® foils will provide a suitable finishing touch for many hybrid multilayer circuit foil lamination designs.



5G is coming! Do you have the right circuit materials?
Learn more at **www.rogerscorp.com/5G**

Product	*Dk	*Df
RO4835T 2.5 Mil	3.33	0.0030
RO4835T 3.0 Mil	3.33	0.0034
RO4835T 4.0 Mil	3.32	0.0036
RO4450T 3.0 Mil	3.23	0.0039
RO4450T 4.0 Mil	3.35	0.0040
RO4450T 5.0 Mil	3.28	0.0038

** IPC TM-650 2.5.5.5 Clamped Stripline at 10 GHz - 23°C*



ROGERS CORPORATION
Advanced Connectivity Solutions

USA - AZ, tel. +1 480-961-1382 • EUROPE - BELGIUM, tel. +32 9 235 3611
www.rogerscorp.com

Figure 7: The audience members enjoying one of the sponsor's presentations.

Figure 8: MakeHarvard participant, Allan Cramblitt, sketches out a portion of his team's design.

ley won the Applied AR/VR Award sponsored by BMW. We wouldn't be surprised if this device or something similar to it becomes widely used in rapid prototyping.

Team 46 said, "We are incredibly proud of the work in our iOS AR app and our use of the microcontroller as a wireless network handler. No one on our team had any prior experience in AR or app development, so we learned a lot of technical skills related to these fields." When asked about future plans, they explained, "We hope to continue prototyping and to develop our software and hardware to complete more complex tasks."

CocoGogo

We were also impressed by the CocoGogo hand-cranked coconut shredder, though for different reasons than many of the other prototypes. CocoGogo was built in response to an opportunity one of the team's members saw when they lived in Tanzania where women spent hours shredding coconut by hand. The team behind the device proved design skills and a willingness to challenge the assumed rules could result in a simple solution. The PVC pipes, joints, and wooden box making up the shredder didn't involve software, yet the device won the Best Overall Award and the Kid's Choice Awards sponsored by Infosys. Team members included Jeremy Skoler, Mia Skaggs, Caroline Rausch, and Maal Bhat.

"We learned how to use many new machines, including the horizontal band saw and laser cutter, which were both very helpful for our device," commented the team. "We also learned the importance of rest in the design process. We came back to work more energized and eager to continue," they added. Moving forward, the team wants to "try and iterate on our design to make it work even better."

Conclusion

By the end of MakeHarvard 2019, the entire Sunstone team was exhausted but overjoyed by the success of the event. We saw numerous prototypes and met so many enthusiastic students, and the event was a great success. We are already busy discussing next year's MakeHarvard makeathon and how we can help make it better. Interested in being a possible sponsor next year? Email makeharvard@gmail.com. **PCB007**

Kelly Atay was born and raised in the Pacific Northwest and has over 30 years of real-life experience serving customers and helping them succeed. Kelly came to Sunstone Circuits in 2004 as a technical support team member and has held a few different roles at Sunstone. Now the marketing program manager, she enjoys being involved in all aspects of the customer story. To read columns from Sunstone, click here.

COMING MAY 21&22, 2019

THE BODY ELECTRIC

2019 MEDICAL ELECTRONICS SYMPOSIUM

The John A. Spitzer Conference Center at
Lorain County Community College in Elyria, Ohio

The human body is an extremely complex "electrical (neurological) system", with companies continuing their quest to understand and improve capability as related to neural interface, basically connecting the human body directly into computers! There is no question, capabilities in smart phone/watch technologies connected to the internet erases any doubt of the potential to connect people to computers.

With the brain being the human equivalent of the "MicroProcessor", semiconductor companies such as IBM, Intel, MicroChip and MicroSemi have been well aware of potential for connectivity. Others have taken knowledge of neural interface to help humans manage their internal electrical systems, including Medtronic, Philips and Abbott, with a range of pacemakers, defibrillators and neural therapies.

Expanding the potential scope of linking the brain to computers and to the internet has attracted the likes of Amazon, Apple, Facebook, Google, MicroSoft, Neuralink and others, adding to the list that already includes J&J, G.E., T.I., Stryker, and Edwards. MicroProcessors and other ASIC Chips, coupled with MEMS and Sensors, are now seen as the "next-big-thing" over the next 5 years looking at the Internet-of-Things (IoT).

This event will bring together experts to cover topics such as:

- Forecasting and Analytics
- MEMS, Sensors and Integrated Circuits
- Implantable Devices and Neural Interface
- Medical Robotics, Equipment, and Prosthetics
- Packaging and Board Level Assembly
- Advanced Materials and Reliability

For more information about event attendance, sponsorships, or exhibiting, please email **bcooper@meptec.org** with the subject line "The Body Electric".

Presented by

MEPTEC SMTA Surface Mount Technology Association

SMART MICROSYSTEMS™

Special SMART Microsystems Facility Tour Planned for Wednesday, May 22nd

VISIT SMTA.ORG/MEDICAL FOR MORE INFORMATION

University Students Point to the Future in Their Research

Student poster, Tony Varghese. (Source: flex.semi.org)

Feature Interviews by Nolan Johnson
I-CONNECT007

PCB fabrication is a technical business. There's chemistry, machinery, and complex processes that need to be followed in a competitive environment that changes constantly. Still, the industry continues down an evolutionary, rather than an revolutionary, path, but that may be changing. Cutting-edge automation, artificial intelligence (AI), machine learning, and Industry 4.0 are all part of the response to the increasing demands for printed circuit boards that are not only faster, smaller, and cheaper but also higher-frequency, lower-loss, more temperature tolerant, and higher reliability. In many cases, it will be unique and advanced research coming out of the university system that will help move the industry forward.

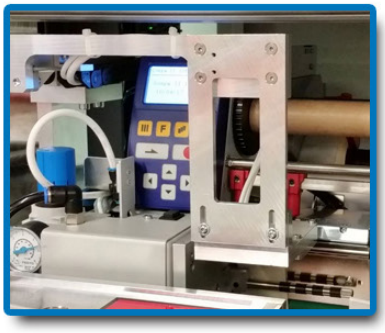
In this article, I introduce you to four students who are examples of the caliber of research being undertaken by the youth of this industry. Meet Goutham Ezhilarasu, Tony Verghese, Sameeksha Katoch, and Emma Pederson—three doctoral candidates and an undergraduate engineering student. I became acquainted with them at the recent FlexTech conference hosted in Monterey, California, by SEMI in February 2019. Among them, the basic research they're conducting includes the development of materials that can either act as a heat exchanger and a thermal sensor (Tony Varghese), AI learning techniques for equipment optimization (Sameeksha Katoch and Emma Pederson), and embedding ICs in flexible interconnect packaging (Goutham Ezhilarasu). These four students discuss their work, goals, and student careers.

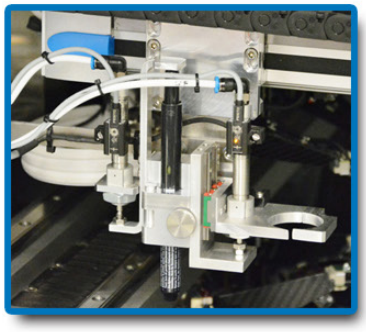
Nolan Johnson: What university do you attend, and can you tell me about your research project?

Tony Varghese: I attend Boise State University where I'm doing my Ph.D. I'm in the final year of my degree program, and my work is focusing on flexible thermoelectric generators, which produce electricity based on waste heat or temperature difference. They can also be used as a thermohaptic instrument, so it can produce heat and cold based on the direction you apply current to it. Finally, they can be used for temperature sensing.

Unrivaled Test Speed with Full Automation

Introducing the newly designed atg A8a with 8 test probes and a new high speed “lights out” automation for unrivaled throughput.





Highlights:

- Small footprint (6 square meters)
- Dual shuttle pick & place automation
- High accuracy combined with high test speed
- Pen or label marking option

Watch video

Get more info

atg

LUTHER & MAELZER

an Xcerra company

atg Luther & Maelzer GmbH
Zum Schlag 3 • 97877 Wertheim • Germany
Phone +49-9342-291-0 • Fax +49-9342-395 10
sales@atg-lm.com • www.atg-lm.com

Sameeksha Katoch: I'm a Ph.D. student at Arizona State University, working with Emma Pedersen, who is an undergraduate student. And she is working in the NSF Research Experience for Undergraduates (REU) program at the SenSIP center funded by the National Science Foundation I/UCRC program and industry members (i.e., Raytheon, NXP, Intel, Sprint, etc.). We do a couple of projects where a lot of undergraduate students can gain research experience. The NSF cyber-physical systems (CPS) project that Emma is currently working on is related to fault protection in utility-scale solar arrays.

Emma Pedersen: I'm pursuing a degree is in aerospace engineering at Arizona State University.

Goutham Ezhilarasu: I'm a Ph.D. student at the University of California, Los Angeles (UCLA). And I work on flexible hybrid electronics. I'm demonstrating flexible hybrid electronics using a process called fan-out wafer-level packaging (FOWLP), which is a technique popularized by TSMC (Taiwan Semiconductor Manufacturing Company). You demonstrate a full system by reconstituting a wafer around the dies. What I mean by that is you first assemble the dies on a wafer with an adhesive on top, and then you pour the molding compound and let it cure so that the dies are later embedded in the molding compound.

Then, we had separate conversations about their respective research. First up was Tony and his work on thermoelectric generators. Tony describes the current industry situation to give his work some context.

Tony Varghese: Most of the devices you see in the market are bulk; they are pretty solid and rigid. This project focuses on transforming them into flexible devices so that you can connect them into flexible sensors, and eventually have self-powered sensors and devices. The main property we are looking for in thermoelectric material is called the figure of merit (ZT), which is dependent on the electrical conductivity, thermal conductivity, and Seebeck coefficient of the material. In the first process, we develop this thermoelectric material using a screen-printing technique. We develop the material to get a ZT of one, which is very close to bulk devices. Our first goal was to replicate the value in the bulk devices using the flexible additive manufacturing technique.


Tony Varghese

We did that with the screen printing thermoelectric legs and were able to develop using a four-leg, 54 microwatts of power and with a temperature difference of 80°C and a power density of 18.8 milliwatts per square centimeter. That's a very high power density, and we can further improve the power density by stacking more legs on this smaller radius. So, that's where we came up with this aerosol jet printing because it has very fine features and they can print more than legs on a smaller area and improve the power density.

Another technique we use is photonic sintering. It takes eight to 10 hours for the normal thermal sintering of this material. With the photonic sintering, we were able to reduce it to milliseconds, so it is a very fast process. Now, you can print and sinter in a conveyor belt. You print it, upload to the photonic sinter, and it's done.

Nolan Johnson: It's fast, conveyorized, replicable, and reliable.

Varghese: And it reduces the cost considerably. The cost of manufacturing is almost 80–90% production. In a conventional process, all of this takes place in a semi-additive process. You have to press it and heat it, and again, it could take up to 10 hours to finish the process, and time is money. To do this, we make our own nanocrystals with the right material and tune the nanocrystal size and dimensions; then, we make it into an ink. First, we tune the ink properties to be compatible with aerosol printing.

Next, we study what substrate we're going to print. We study the surface chemistry of the substrate, check the conduct handling, and see how we can improve the wettability of the ink onto the surface and adhesion.

All of these properties are important for thermal sintering because the thermoelectric material and substrate that you're using on both have a different coefficient of thermal expansion. Photonic sintering has a very short time and high energy pulse. If you have a very different coefficient of thermal expansion, the materials will break apart and the filling doesn't stick very well to the substrates.

We can print onto flexible Kapton and tubular substrates. The idea is that if you have heat or a cold pipe, with the 3D conformal printing, one option is to print on a flexible substrate and wrap it around the tube. The other option is to print directly onto the tube. If you print directly onto the tube, you can harvest the heat coming out of the tube easier and more efficiently than by wrapping something around it.

That was the idea for conformal printing, and when we started doing that, we found that there was a lot of porosity inside the filling once we print because aerosol jet printing is more like spray printing. It can be random stacking of the material and evaporating solvent while printing on it so that it creates some bubbles and holes in the filling. We applied some isostatic pressing so that it would densify the filling, reduce the interface contact resistance, and allow more contact area. It also helps to have better photonic sintering.

Johnson: Is the idea to custom formulate nanocrystals, formulate them into an ink that works in an aerosol spray, and make sure that you've characterized the material you are using to match the ink for adhesion? Because it's an aerosol spray, do you have to do a little bit of compressing?

Varghese: You densify the filling so its electrical conductivity will be improved much higher than just spraying on it. It will densify and improve the conductivity by photonic sintering.

Johnson: So, you've characterized and treated an ink for a particular substrate.

Varghese: Correct. Once you optimize for Kapton substrate, the ink can be modified easily for other substrates, such as glass, transparent polymers, or even photo paper. It is important to modify the substrate surface to improve the adhesion between the material and substrate by using oxygen plasma and chemical washing of the surface.

Johnson: That's exactly what I was trying to ask. And then, of course, you also have all of the work with sintering.

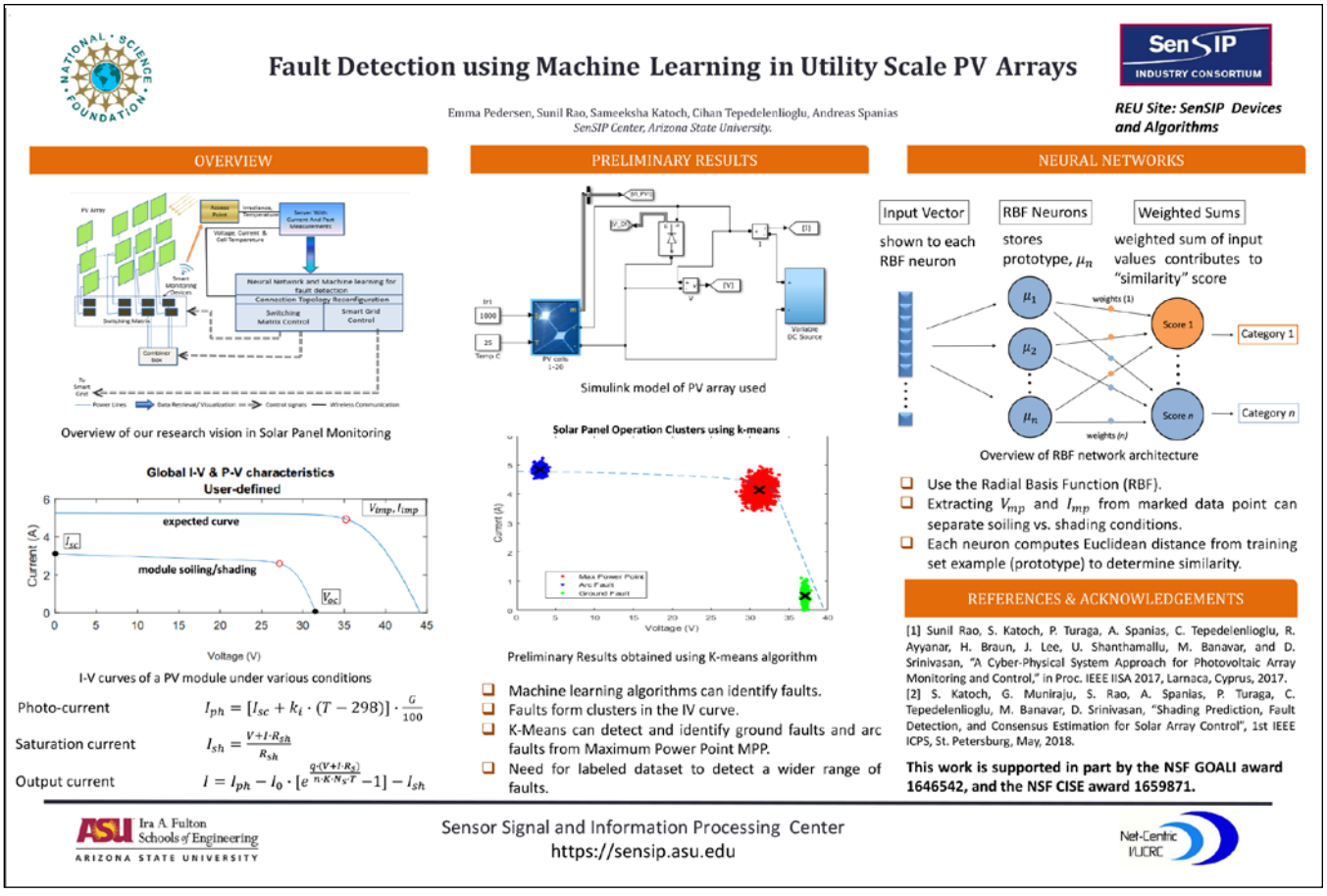
Varghese: Yes. We did a photonic sintering study. First, we made a model of the material to help us narrow down our sintering conditions. By studying the model with different energy and pulse duration, we can understand how much heat is generated in the material. Then, we compare the results with our experimental methods to see that it reduces the resistance and increase electrical conductivity at those conditions. Comparing the modeling and experimental study it is possible to fine-tune the sintering conditions to get the best material properties using photonic sintering.

Sameeksha and Emma explained their work next. While I can't say for certain that Emma was the only undergrad in attendance, she was the only non-doctorate student I met while there.

Nolan Johnson: Emma, tell us a little bit about the project.


Emma Pedersen

Emma Pedersen: We're trying to address is maximizing power output by changing the topology of the photovoltaic (PV) arrays. On each panel, we have a smart monitoring device (SMD) connected to a switching matrix. The smart monitoring



REU student poster competition by Emma Pedersen.

device picks up different inputs, such as irradiance, temperature, voltage, and current. But what's really cool about it is that it can switch topologies by itself through the switching matrix.

We've been using machine learning to help identify which faults are happening on the current-voltage (I-V) curve. With traditional clustering techniques, the actual data that we need is covered; the only thing that it will give us accurately is ground and arc faults while shading is difficult to identify. So, we need to monitor in a different way. Instead of an unsupervised technique, we need a supervised technique because it's important to know the type of fault.

Since we can't use the unsupervised technique, instead, we can do a classification technique where we have the input vector from the data that we collect from the smart monitoring device. And we create these prototypes models ourselves that will tell you how similar the features are to the actual fault. For example, in arc and ground faults, these are the specific characteristics that occur rather than just looking at the drop in the voltage and current. The algorithm will output how similar it is to each model. Specifically, it compares the input vector with each prototype, assesses output how similar it is, and then assigns a weight. This process will continue until the correct weights are found.

Johnson: What are some applications that you perceive for this work?

Sameeksha Katoch: Right now, what we're looking into is improving the power efficiency for the solar array. We have a small testbed (thanks to the NSF CPS project) with smart monitoring devices attached to each panel. Each panel can

Sameeksha Katoch

THINK TWICE

BEFORE PICKING YOUR PCB DESIGN FLOW.

PADS PROFESSIONAL IS SOFTWARE FOR **THE MOST DEMANDING ENGINEERS**

As PCB designs become more challenging, don't let your design flow become a career liability. PADS Professional is the high-grade software demanding engineers can count on to tackle the most complex projects.

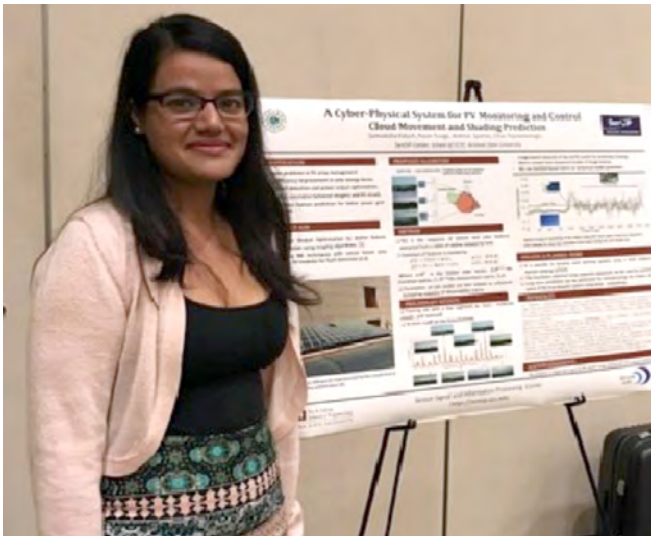
AVAILABLE FOR A LIMITED-TIME PROMOTION STARTING AT $8995*

*REGIONAL PRICING VARIATIONS MAY APPLY.

EVALUATE TODAY

Mentor®

A Siemens Business



Sameeksha Katoch with winning poster.

talk to its neighbors, and there is a relay connected to every neighbor. The connected relay means you can change the connections based on whether a particular panel is not working well, for example. If one panel is not efficient, you can bypass that panel. That's how you can change the topologies we can make connections between a different number of panels.

The questions that follow include how do you change those panels? How do you know when the topology is going to change? And when are you required to change the topology? One way is to study the panel's output over a period of time. You might see, for instance, that a particular panel didn't work up to its optimum. But that doesn't serve our purpose because already we've wasted a huge amount of time reading the panel values, so we try to automate this process.

The first thing we try to do is we have a cloud movement prediction algorithm. We use an approach called nowcasting, which predicts at what speed and in which direction the clouds are going to move. Based on that shading, we can change the topology. For example, a particular section of panels could become shaded, which means the power output will go down. We can bypass those panels.

Johnson: So, based on weather conditions that you have monitored and studied in the past, you have a predictive awareness of what's going to happen tomorrow and can be roughly prepared for it?

Katoch: Yes. Now, different faults need different kinds of topology. You have to identify a panel as faulty so that you can bypass it, and you cannot do it if you don't know whether the panel is faulty. To determine that, you use many automated ways, such as AI clustering techniques. That is an unsupervised machine learning technique with the two basic faults—ground and arc faults—unlike the normal panels. We have to identify three clusters of ground faults, normal working panels, and arc faults. In the case of shading and soiling, you see a similar I-V curve, only the voltage at maximum power (VMP) and current at maximum power (IMP)decrease.

Clusters will form around the same region, and that's where the system cannot differentiate. To solve this problem, we switch from unsupervised to supervised techniques. That's why we use a fully connected neural network. At this point, we have a training data set. And in the training data set, we have the relationship defined. For example, this particular kind of data gets generated when there's a ground fault, or this other kind of data is generated when there's an arc fault, shading, or any other faults.

Once the model has that set of conditions defined, based on the input features, the neural network output gives the type of fault. Then, we try to minimize the difference between the maximum power output from that vicinity to the power output that is generated. When you optimize this loss, the weights between the neurons are learned. Once the weights are learned, when new input comes in, these weights help identify which fault is causing the change. That's the basic idea. Emma has characterized three categories of outputs, which are scalable to much more faults. We also submitted papers and patents on this research.

Johnson: A lot of these fundamental concepts must be transferrable. For example, I have a personal interest in sailboats, which can be dynamic platforms and could easily stress solar panel

optimization. There are all sorts of optimization issues to deal with, including motion, sails creating shade, moving with the sun, etc. It's a much smaller, but perhaps even more dynamic environment than a large-scale solar power station.

Katoch: We are actually looking into extending this work to various types of different conditions, such as wind variations, humidity, dew point, temperature, etc., where other parameters also come into play. I am working on developing other applications using these parameters, so that's in our future.

I closed with Goutham and a further explanation of his work on fan-out wafer-level packaging.


Goutham Ezhilarasu

Goutham Ezhilarasu: In addition to what I mentioned earlier, initially, we have a silicon handler wafer on which we laminate a thermally debondable adhesive tape. We pattern alignment marks on the tape and complementary alignment marks on the dies to integrate. Then, we can use a standard pick-and-place tool to align and place the die on the tape. We have demonstrated less than one-micron alignment accuracy.

When we assemble the die, we pour our molding compound, which is polydimethylsiloxane (PDMS), a biocompatible, viscoelastic polymer. We use a second silicon handler wafer with another adhesive tape but at a higher debonding temperature, which we use to compression-mold the PDMS. Once we cure this, we heat the stack to the release temperature of the first adhesive tape so that it comes out. When the handler wafer debonds, we get a very flat surface.

Then, we deposit some stress buffer layers. The stress buffer layers are needed as you cannot directly metallize on PDMS due to CTE mismatch between copper and PDMS. We also lithographically pattern certain vertical structures called corrugations. Next, we use standard silicon processing to electroplate copper wires to a thickness of about seven microns, connecting the dies. We repeat this process by putting a dielectric, creating vias and the second metal so that we can get multiple layers of metal.

Nolan Johnson: It looks like a Mylar flexible circuit, but you have silicon components built into it. And as you're building up these layers, I can see what would normally be interconnects in each of those layers.

Ezhilarasu: Yes.

Johnson: How many layers can you do?

Ezhilarasu: We have shown two, but we are planning to go up to four. We do a bending test down to a one-millimeter bending radius. When we go higher, there's enormous strain. At the one-millimeter bend, when you have so many metal layers, the wires buckle, resulting in some delamination.

Johnson: A one-millimeter bend is a pretty aggressive test.

Ezhilarasu: It's almost like folding.

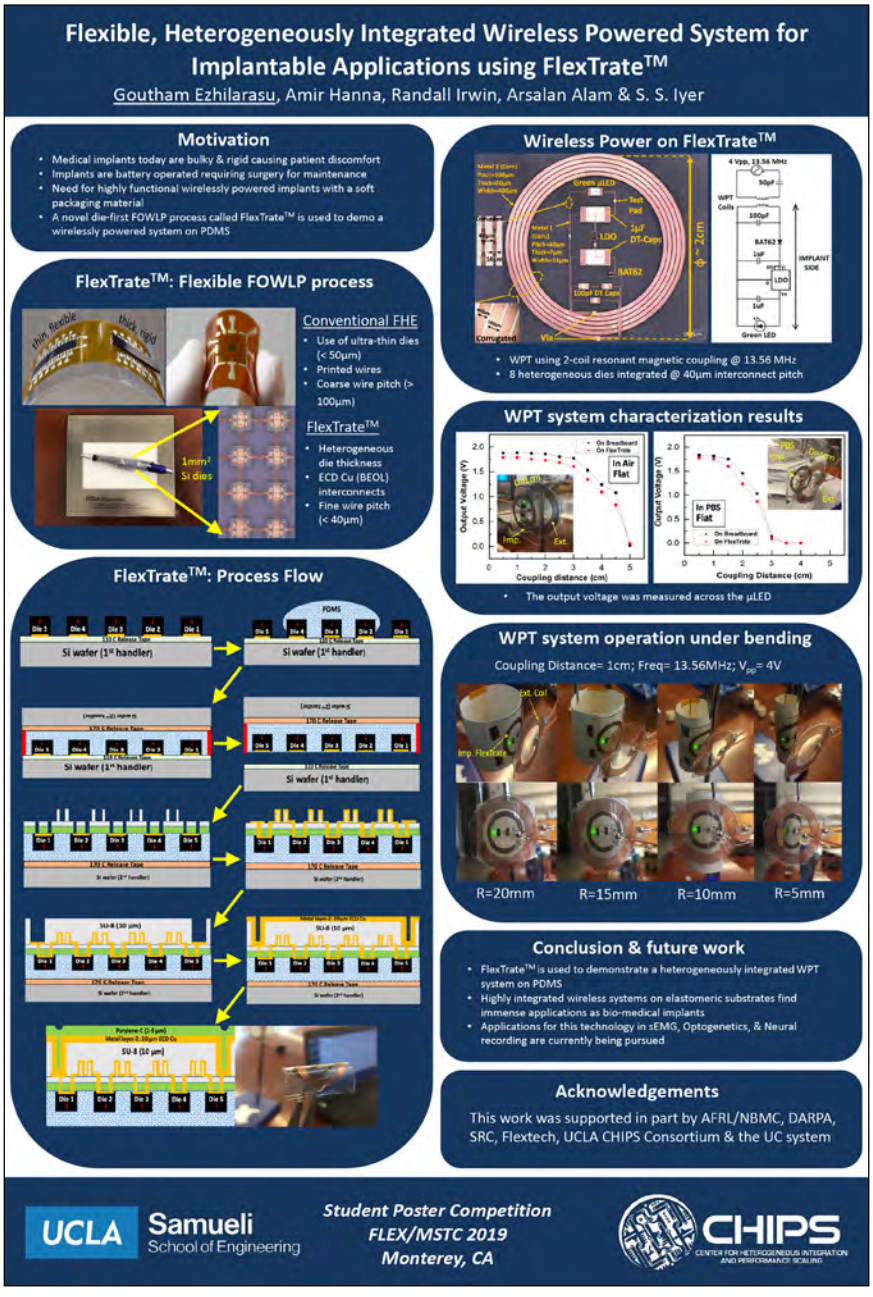
Johnson: This research is part of your work as a doctoral student. What's your intention once you finish your program? Are you pursuing this in the industry or moving on?

Ezhilarasu: Most of the work that was done can be pushed out into commercialization, which we intend to do since the process is well-established. We have already published several papers on this. We are also working with the medical school at UCLA to try to develop a neural implant. That's how we hope to demonstrate some real-world applications.

Johnson: Give me a sense for the complexity of the circuit you achieve. Are you able to go denser and more complex in this technology than what's currently out there in production?

Ezhilarasu: Yes, and I think that's one of the main selling points. Conventional flexible hybrids use printing to define the interconnects. The problem with printing is that you're limited by the wire pitches that you can achieve. You can typically achieve course pitches in the hundreds-of-microns range, as well as interconnects that have a higher sheet resistance because they are usually made with some sort of nanoparticle-based ink.

The main thing that limits the pitch that we can achieve is the die shift. What ends up happening is that when you cure the molding compound, it exerts forces on the die that can shift it by a small amount. Theoretically, that's what limits our wire pitch. We can demonstrate up to 20 microns interconnect pitch at the moment with the die shift that we have. But if we reduce the die shift further, and because we use silicon processing, there's no limit to what pitch we can attain. We can even go down to one micron.



UCLA student poster competition by Goutham Ezhilarasu.

Before we finished, I circled back around to Sameeksha and Emma who shared a bit more detail about the programs at Arizona State University that created this opportunity for them to attend FlexTech/MEMS Conference.

Nolan Johnson: Emma, what year in school are you?

Emma Pedersen: I'm in my second year of undergrad.

Johnson: And Sameeksha, you're a doctoral candidate?

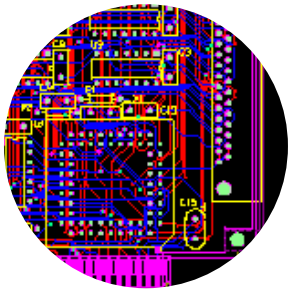
Sameeksha Katoch: Yes.

Johnson: You're obviously very involved in this program as a mentor, and this is just one of the projects that you're doing under the program. Tell me about the program.

Katoch: We have one program throughout the summer and one throughout the semester. In the summer, it depends on what project is underway in the lab, but our lab primarily works on machine learning and sensor analyt-

Having trouble keeping up with front-end demand?
We have people for that.

Here are six ways that outsourcing CAM and related front-end work can help manufacturers not only stay in business but also help them thrive:



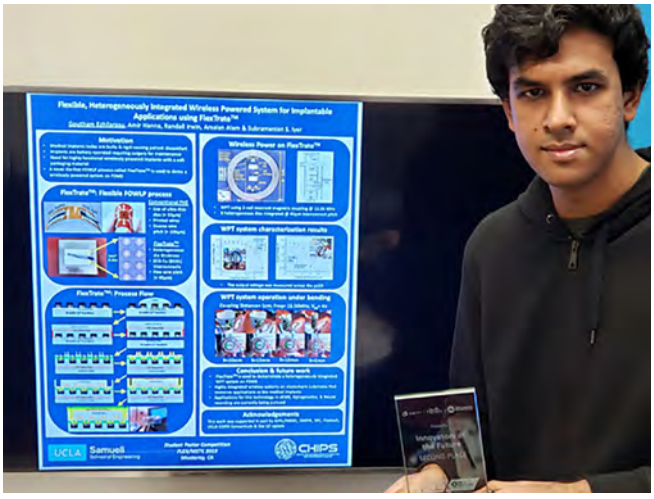
- **Increased on-demand capacity**
- **Improved automation**
- **Faster turn-around times**
- **Reduce costs**
- **Improved quality**
- **Ability to build redundancy in critical areas**

We deliver the highest quality PCB CAM and Mechanical CAD engineering services to customers around the world.

Find out how we can help you >

ENTELECHY GLOBAL

www.entelechyglobal.com



Goutham Ezhilarasu with winning poster and holding the award he received from the FlexTech Conference—Second Place Award "Innovation of the Future."

ics and using those tools for different applications. We teach undergraduate students introductory machine learning algorithm that they can use to get started with research.

We teach them the basics, such as training and testing, different loss functions, and unsupervised versus supervised techniques. These are very foundational, but undergraduate students don't have that exposure, so we give it to them along with hands-on practice on small datasets where we can manage them. Once they understand the concepts, they can scale to bigger datasets and real issues.

Johnson: You must be new to the program, Emma. What are your first impressions?

Pedersen: It's amazing. I love it so much.

Johnson: What was your objective in getting involved?

Pedersen: I really enjoy coding, and I felt like—especially in aerospace—they don't make you take many coding classes. I'm taking intro to Java right now just for fun. I'll use it later on, but I was more interested in the machine learning side of it, so it has been fun.

Johnson: What are your takeaways so far, and what have you learned doing this project?

Pedersen: I've learned an incredible amount of machine learning. I didn't have much experience coming in, so being able to see examples has been helpful. I attend a lot of seminars as well. And even just interacting with Ph.D. students who are on these projects is valuable, such as learning how to present a research project. So, I'm gaining skills in machine learning and technical topics that I will not get in classes in addition to practice with public speaking and giving presentations.

Johnson: Right. As we have this conversation, we're standing in the aisle for this conference with all of these professionals, vendors, Ph.D. candidates, and industry leaders walking by and asking you to explain your project. I'm sure it makes it very humanizing for you.

Katoch: Science can be used in many applications. Learning science doesn't help unless you know how to apply it to what you are doing.

Katoch: It took me some time to think about what applications this could have, and that is something I think a lot of students can learn thanks to the SenSIP REU programs. Students can gain the realization like I did that a single algorithm can be used in different ways, for example.

As we wrapped up, I asked each of the four students how they saw their research being applied, and whether they planned to continue in this research after their doctorate.Their responses were enthusiastic.

Johnson: Tony, is this technology production ready? Are you taking it to market?

Tony Varghese: We haven't completely finished it yet. I'm a student, so this is research and development. Next, we are planning to improve the material property. When we make the material, we can observe the powders are made of a different number of layers. So, our next step is to separate single layers from this group of materials and make an ink with it for print-

ing. Thus, when we print it, we have a better chance of improving the properties.

Johnson: When you're done with your program and have your doctorate, do you intend to continue with this work?

Varghese: I do. I acquired a post-doctoral position there, so I intend to finish up with a better result than what I have currently at the doctorate level.

Johnson: Congratulations, and thanks for walking me through your project. This looks very promising.

Varghese: Thank you.

Nolan Johnson: Sameeksha, do you plan to continue on this path of work after you finish school?

Sameeksha Katoch: I am working on a couple of different projects with deep learning model development for different data modalities, including EEG data classification, audio source separation, image subsampling, and texture and cloud movement prediction. All of these models have been optimized for time and computational complexity. I definitely think they can be scaled for use in commercial products.

Johnson: Goutham, do you have plans to continue with this research after completing your degree?

Goutham Ezhilarasu: Yes. I plan to continue research on flexible electronic packaging after my doctorate.

Similar research is taking place at technical universities worldwide. These three teams of university researchers were among a dozen or more present at the FlexTech/MEMS conference, with an untold number of teams not in attendance. Work continues with developing new and innovative temperature control and monitoring with industrial applications (Tony Varghese), software models that bring AI and machine-learning models to a wide variety of applications (Sameeksha Katoch and Emma Pederson), and packaging/interconnect methods (Goutham Ezhilarasu). The foundational pieces for the evolution of our industry continue. And somewhere, in all of this work, is a revolution waiting to happen. **PCB007**

Researchers Discover New Material to Help Power Electronics

A research team at The Ohio State University has discovered a way to simplify how electronic devices use electrons by using a material that can serve dual roles in electronics. Historically, multiple materials were necessary. The team published its findings in *Nature Materials*.

Their findings could mean a revamp of the way engineers create different kinds of electronic devices from solar cells to the LEDs in your television, the transistors in your laptop, and the light sensors in your smartphone camera. Traditionally, each part of the electronic device could only act as an electron-holder or a hole-holder, but not both. That meant that electronics needed multiple layers and materials to perform.

But the researchers found a material—NaSn2As2, a crystal that can be both an electron-holder and a hole-holder—potentially eliminating the need for multiple layers. The finding could simplify our electronics, perhaps creating more efficient systems that operate more quickly and break down less often. The researchers named this dual-ability phenomenon "goniopolarity." They believe the material functions this way because of its unique electronic structure and say it is probable that other layered materials could exhibit this property.

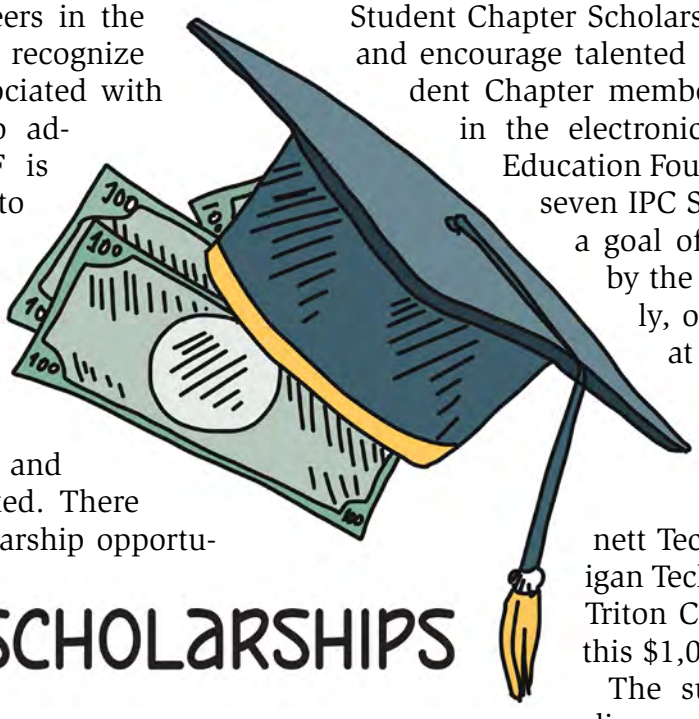
(Source: The Ohio State University)

Calling All Scholars and Educators:
IPCEF Launches Scholarship Program

One World, One Industry
Feature Column by Dr. John Mitchell, IPC—ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES

Formally launched during IPC APEX EXPO 2019, the IPC Education Foundation (IPCEF) focuses on strengthening and shaping the emerging workforce by providing educational opportunities, connecting the emerging workforce with industry opportunities, improving the perception of the industry, and offering scholarships to deserving students.

As we encourage careers in the electronics industry, we recognize that there are costs associated with educational pursuits. To address that issue, IPCEF is providing scholarships to students and teachers to provide growing sources of funding for eligible individuals. We opened the first of two scholarship programs to participants on March 4, and we are just getting started. There are currently eight scholarship opportunities available open to a small applicant pool based on eligibility requirements.



Our first scholarship, offered to educators, is the Michael V. Carano Teacher Excellence Award, supporting the professional development for secondary and post-secondary educators pursuing training related to the electronics industry. The Carano Award recognizes the extraordinary contributions that IPC Hall of Famer and highly sought after international professional development instructor Michael Carano has made to the electronics industry. The award includes a $1,000 scholarship and a one-year membership pass to IPC EDGE, IPC's online learning platform. Students can nominate their educator (e.g., teacher, professor, faculty advisor, etc.) for the Carano Award.

The second scholarship program, The IPC Student Chapter Scholarship, helps to identify and encourage talented and focused IPC Student Chapter members to pursue careers in the electronics industry. The IPC Education Foundation has launched seven IPC Student Chapters with a goal of 50 student chapters by the end of 2019. Currently, only student members at Auburn, North Carolina State, Sacramento State, Central Carolina Community College, Gwinnett Technical College, Michigan Technical University, and Triton College are eligible for this $1,000 annual award.

The success of the IPCEF relies on the partnerships between industry leaders and educational institutions, and IPC facilitates this unique opportunity for industry and education to prepare engineering students with knowledge specific to the electronics industry. Two partnerships that have led the way in this effort are Weller Tools and Calumet Electronics, each with a unique approach to the issue.

Leverage technology for competitive advantage:

it's what leaders do.

CapStone™ is the culmination of ESI's decades of laser-material interaction expertise and technology leadership in flex PCB processing.

Double your throughput and dramatically decrease your per-panel processing costs.

Adopt CapStone's new technology early...

and stay ahead.

esi®

CapStone™

From the leader in flex laser processing solutions.

For more information, visit us at www.esi.com

Weller Tools is sponsoring the annual student fee for IPC student members, providing students access to industry produced video courses, IPC standards, and the benefit of IPC membership including additional industry courses at member discounted rates.

Calumet Electronics, another critical industry partner, is helping college students at Michigan Technical University enter the electronics sector better prepared with specific knowledge and skills, giving them an advantage in the job market. Companies benefit because their job candidates come to the table with specific, industry knowledge.

As someone who values education on a day-to-day basis and as an academician (I hold an Ed.D.), finding ways to make education more available to more people is very important to me, particularly in the electronics industry, suffering from a critical skills gap. I am so encouraged by the support and generosity of the industry as we work to secure additional funding to make engineering careers accessible to interested students regardless of their financial situation.

We welcome your help and participation. If you are interested in sponsoring a name-branded scholarship to enhance the academic pursuits of the up and coming workforce, please reach out to Charlene Gunter du Plessis, director of strategic partnerships and programs, at CharleneGunter@ipc.org. You can also visit www.ipcef.org for more information.

Let's build a strong and competitive workforce together. **PCB007**

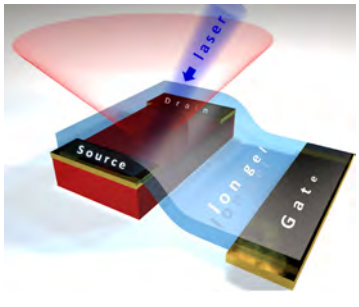
Dr. John Mitchell is president and CEO of IPC–Association Connecting Electronics Industries. To read past columns or contact Mitchell, click here.

Creating Better Solar Cells

Scientists from Rutgers University have found a new way to control light emitted by exotic crystal semiconductors, which could lead to more efficient solar cells and other advances in electronics. The study was published in *Materials Today.*

Their discovery involves crystals called hybrid perovskites, and they have shown great promise for use in solar cells. The finding could also lead to novel electronic displays, sensors, and other devices activated by light and bring increased efficiency at a lower cost to the manufacturing of optoelectronics.

The Rutgers-led team found a new way to control light (known as photoluminescence) emitted when perovskites are excited by a laser. The intensity of light emitted by a hybrid perovskite crystal can be increased by up to 100 times by adjusting the voltage applied to an electrode on the crystal surface.



"To the best of our knowledge, this is the first time that the photoluminescence of a material has been reversibly controlled to such a wide degree with voltage," said senior author Vitaly Podzorov, a professor in the Department of Physics and Astronomy in the School of Arts and Sciences at Rutgers University-New Brunswick. "Previously, to change the intensity of photoluminescence, you had to change the temperature or apply enormous pressure to a crystal, which was cumbersome and costly. We can do it simply within a small electronic device at room temperature."

Understanding photoluminescence is important for designing devices that control, generate, or detect light. The scientists discovered that defects in crystals reduce the emission of light and applying voltage restores the intensity of photoluminescence. An important next step would be to investigate different types of perovskite materials, which may lead to better and more efficient materials where photoluminescence could be controlled in a wider range of intensities or with a smaller voltage.

The study included lead author Hee Taek Yi in Rutgers' Department of Physics and Astronomy and co-authors Assistant Research Professor Sylvie Rangan and Professor and Department Chair Robert A. Bartynski.

(Source: Rutgers University)

WHAT DO ALL OF THESE LEADING COMPANIES HAVE IN COMMON?

atg LUTHER & MAELZER an Xcerra company

ATOTECH

Cerambus Technology Group

CHEMCUT BOUNDLESS INNOVATION | UNBEATABLE PRECISION

CIMS Creativity in Motion

COMETGROUP Technology with Passion

CYBEROPTICS

DownStream Technologies

ELECTROLUBE THE SOLUTIONS PEOPLE

esi Designed for Brilliance. Engineered for Production.

KIC Making Ovens Smarter™

KYZEN

MacDermid Alpha ELECTRONICS SOLUTIONS

Mentor A Siemens Business

MIRTEC

NANODIMENSION Electrifying Additive Manufacturing®

orbotech The Language of Electronics

pluritec

PULSONIX

rehm THERMAL SYSTEMS

schmoll asia pacific

ventec INTERNATIONAL GROUP 騰輝電子

VJ ELECTRONIX Process Control Solutions CONFIDENCE DELIVERED

環球集團 World Wide Group

They all benefit by advertising with us–PCB007 China Magazine.

Should your name be on the leaders' list?

GET STARTED NOW!

I·Connect007 GOOD FOR THE INDUSTRY

pcb007china.com

George Fox University: Teaching PCB Design to EE Students

by Nolan Johnson and Andy Shaughnessy
I-CONNECT007


Gary Spivey

We've all heard the stories about engineering students entering our industry with no idea how to design PCBs. It's not the students' fault; most aren't exposed to PCB design in their electrical engineering curriculum. But George Fox University (GFU) is an exception to the rule.

Gary Spivey is director of engineering projects at this Christian college in the Pacific Northwest, and his students learn to design and fabricate a PCB while also giving back to the community. Not surprisingly, these graduates get snapped up quickly. In this wide-ranging interview, Spivey discusses GFU's engineering curriculum, their cutting-edge lab facilities, and the need to teach students to think critically.

Click here to read the interview and view additional content showcasing youth in the industry in the March 2019 issue of *Design007 Magazine.*

(Source: I-Connect007)

Panasonic

Quality for Aerospace

Reliability and Robustness

Multi-layer circuit bord materials

MEGTRON6

MEGTRON7

Flexible circuit board materials

FELIOS

CMSE

From April 16th to 18th, 2019

Panasonic Booth at the 23rd annual CMSE

Place: Four Points by Sheraton (LAX) Los Angeles

Contact us

More information

DISTRIBUTOR IN NORTH AMERICA

MATRIX USA INC.

TORONTO • SANTA ANA • SANTA CLARA • CHICAGO • MINNESOTA

Visit our website at www.matrixusa.us

Partnering to go beyond.

Electronic Materials

Panasonic Corporation

SEMI's Cristina Sandoval on Mentoring and Retaining Young Talent


Cristina Sandoval

Feature Interview by Nolan Johnson
I-CONNECT007

Cristina Sandoval, manager of workforce development and university initiatives for the SEMI Foundation, discusses how two new programs, as well as a long-running high school STEM outreach program, are aiming to address the skills gap within the industry. Sandoval also explains SEMI's efforts to prepare students to enter the workforce and continuing to develop talent as young professionals join the industry.

Nolan Johnson: Can you tell me what you do at SEMI and what your program is about?

Cristina Sandoval: I manage two new key workforce development programs—the SEMI Mentoring Program and the University Connections Program. I also support our diversity and inclusion initiatives with Leslie Tugman, our VP of global workforce development and diversity. We created these new programs based on SEMI member feedback from an industry survey driven by SEMI president and CEO Ajit Manocha. Our Workforce Development and Diversity Inclusion Councils, consisting of SEMI member companies, helped create the vision and direction for these programs.

Johnson: So, this started with some survey information from members. What did you find out, and what are you trying to achieve strategically with these programs?

Sandoval: Our overarching goal is to address the talent shortage in the industry, and there are two main components to our strategy. First, SEMI is working to change student perceptions about our industry and generate more excitement about career opportunities. Our industry is competing for talent against recognized consumer-facing companies with much higher recognition. Meanwhile, our member companies struggle with a lack of awareness among students about the significant contributions our industry makes to technology and innovation. The second component is to reach talent that the industry hasn't tapped yet. We're reaching out to groups of students who may have little or no awareness of our programs or industry, so that they can see the many opportunities available to them.

Johnson: That seems to be a very common theme in the industry right now. Some other sectors of the marketplace are facing a quiet crisis because most of their workforce is 55 and above and/or ready to retire. Then, the demographic drops all the way down to 30 and below. Many companies are facing a skills and staffing gap, which could be a threat to their

UCE WET PROCESS LINE

Etchers

Scrubbers

Developers

PTH

Oxide Replacement

THIN CORE HANDLING • PC CONTROL • RELIABLE • LOW COST

CLICK TO VIEW OUR UCE WET PROCESS LINE

The leading European PCB Equipment and Parts Supplier

www.vikingtest.com
sales@vikingtest.com

Viking

survival. You're seeing the same issues within the SEMI membership as well?

Sandoval: Yes, companies want us to not only help diversify their talent pipeline but also increase it because they are facing a shortage of incoming workers too.

Johnson: Young people today may be receiving perspective from their teachers, parents, and so forth based on experiences back in the '90s, for example. Our industry doesn't operate like that today, and we need different skills. What are some of the changes in the workforce skill set that you're looking for?

Sandoval: SEMI is addressing the skills gap in the workforce via our new SEMI Works Program. Part of this initiative focuses on training and certifications to help provide the right skill sets to incoming and returning workers in our industry.

The SEMI University and Mentoring programs put more emphasis on a less acknowledged but vital skill set commonly lacking among students—the soft skills gap. Many students aren't confident in key skills, such as networking, self-presentation, interviewing, and resume building. When you combine a lack of interview skills and industry awareness with an inability to network, the result is a pool of students unsure about how to engage our industry or seek out lesser-known opportunities.

SEMI's university program hosts professional development sessions on campus to help students with those soft skills, and SEMI's mentoring program connects students to people who are senior within the industry who can help fortify those skills and connect them internally to their organizations.

Johnson: I didn't expect that. A lot of traditional thinking is that to prepare students for this industry, you load them up with STEM, but you're not doing that.

Sandoval: SEMI does have programs that focus on exposing students to STEM, but many of our programs do both. For example, SEMI's High Tech U (HTU) three-day STEM immersion high school gives students a view into a "day in the life" through hands-on interactive modules that also includes a soft skills component. This unique combination of STEM plus soft skills helps our programs stand strong. In fact, SEMI HTU is the longest running STEM immersion program in the country, going on 18 years.

Our mentoring and university programs target the existing technical talent pool of electrical, mechanical, and chemical engineers and bridge the gap to get them to come into the industry. And I have seen the impact of the mentoring program personally. My brother recently graduated with a chemical engineering degree, but he wasn't aware of all the different career opportunities that he could pursue within the industry.

SEMI connected him to an industry mentor who helped him figure different career paths, but more importantly, helped him overcome his

greatest challenge—interviewing. His mentor completely changed his perception of our industry and his career options. While my brother ultimately did not end up at a SEMI member company at this time, he has identified several companies within the industry that he will keep on his radar when he decides to look for his next opportunity.

Johnson: It's interesting that you mention that story because when I talk to manufacturers who are facing this challenge, they're making the point that the electronics manufacturing industry is not what it used to be. It's not Rosie the Riveter from the middle of the 20th century; it's digital and computer work. Today's manufacturing has a lot of clean environments to work in with carpets and cubicles. That changes the skill sets needed and the nature of the involvement for students. How are you engaging college students?

Sandoval: Right now, we primarily engage students onsite at our partner universities and via our mentoring program. During my interview with SEMI, I stated that this initiative, "…is going to be a journey. Students don't know who we are." At a recent event at Austin Community College in Texas, we had approximately 65 students in attendance. I asked them to raise their hands if they had heard of SEMI before the event—none of them raised their hands. I then asked if they understood what the microelectronics industry does, and maybe eight out of 65 raised their hands.

Clearly, the lack of brand and industry recognition are major issues we need to address via our student engagement. To accomplish this, we offer programs both virtually and onsite to expand access to our audience. We host events on a wide variety of topics, such as resume building, interviewing skills, networking, and a "day in the life." We also invite leaders of member companies to speak on the impactful technologies their organization are pioneering.

We capture information on program participants and invite them to join SEMI's student network. Once they're a student member, we provide access to our programs to help prepare them for and expose them to the industry. We are working on building a database that will give our members more direct access to students coming through our programs.

Once, I talked to a student on campus who said, "Well, isn't the semiconductor industry dying?" I said, "No, it's going to be a one-trillion-dollar industry by 2030." The perception of the industry is not a good representation of the truth. Through these programs, we start building brand and industry recognition, but it's going to take some time.

Johnson: In what ways can companies get involved with what SEMI is doing?

Sandoval: There are many ways that members can get involved. The easiest way is mentoring. We conduct onsite lunch-and-learns at member companies and share information on volunteer opportunities. We also offer the opportunity for people to become a mentor and mentee as the program is open to both university students and developing professionals in the industry. Part of our strategy to help our industry addresses retention. With our mentoring program, we can both attract and retain talent in the industry. This mentoring program begins engaging at the university level and continues to be a resource as students grow into young professionals.

Another way that companies can get involved is to recommend speakers to present at campus events. We're happy to facilitate event opportunities; we have the framework ready

so that speakers need only show up. Speakers can share information about their company while enlightening students on the meaningful work being done in the industry. This type of opportunity gives member companies recognition while they help improve student perception of the industry.

SEMI will also offer networking events to our members in late 2019 that will provide direct access to the students we are engaging in our programs. Look for these opportunities at our Workforce Development Pavilion at SEMICON West and in late 2019.

These are just the first set of initiatives that we've started to tackle. We're in phase one, but there are a lot of different things that we can do as an industry to help with that retention once we get that talent there.

Johnson: How many universities are you working with?

Sandoval: We have partnerships with approximately 50 universities and are working towards building a portfolio of over 100 universities by the end of 2019. We built a scorecard weighing factors such as programs offered, student population, location, and other key features to ensure we are partnering with the right universities.

To increase and diversify our talent pool, we created a tiered approach. Our defined tiers dictate the level of engagement with different universities. The scorecard determines the tier of each school, but we will still offer virtual (webinar) offerings to all of our partner universities in addition to other resources. Both programs are relatively new, and we are open to ideas and suggestions as we build out our offerings, so feel free to reach out to me [csandoval@semi.org]. Our mentoring program launched in July of 2018, and the university program launched in November, but we are growing rapidly.

Johnson: So, you're working to help the students put together soft skills. And at the same time, you're looking for speakers from our in-

IT-170GRA1

IT-170GRA1 Value Proposition

- Halogen Free
- Best in class performance in its space
- Best in class CAF performance
- Very attractive price to performance ratio
- Pass MRT-6 requirements
  - -CAF > 1000 hours
  - -0.65mm pitch equivalent, no thermal issue
- Available with RTF and 2μ copper which provides additional performance on a very solid platform
- Df = 0.0075 @10GHz

Intel Purley Mid-Loss Solution – IT-170GRA1

Futures

Halogen free mid loss, Df < 0.01
Tg 180°C by DSC, low CTE

Applications

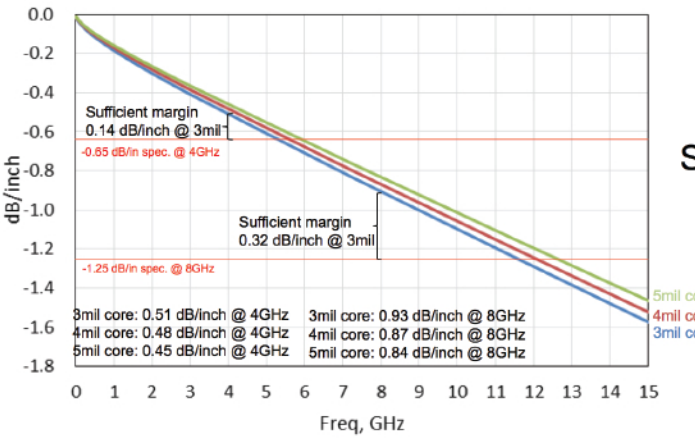
Server/Storage/Switch (10G, 40G)
Backplane, Telecom
Base station

Feature — *Purley Platform Mid-Loss Solution – Hi Tg*

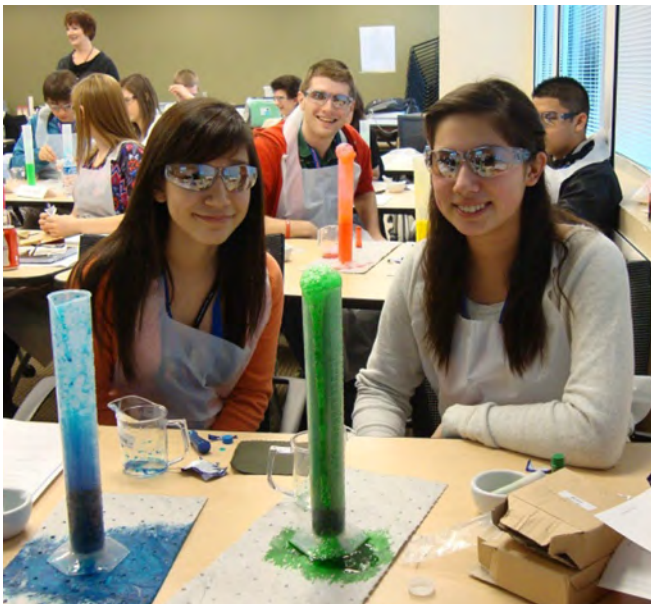
General Properties

Items	Methods	IT-170GRA1
Tg (℃)	DSC	180
T-288 (w/ 1 Oz Cu, min)	TMA	60+
Td-5%(℃)	TGA 5% loss	380
CTE (%), 50-260℃	TMA	2.4
Peel strength (lb/inch)	1 oz	7.0
Water absorption	D-24/23	0.1
Dk: 2-10 GHz	Bereskin	3.96 – 3.99
Df: 2-10 GHz	Bereskin	0.0073 - 0.0075

IT-170GRA1 Insertion Loss



ITEQ



dustry. Some readers may conclude that you're walking that line between technical knowledge and talent recruiting. Is that an accurate assessment?

Sandoval: SEMI is not recruiting talent but connecting talent! We recruit talent to our programs that offer SEMI members opportunities to connect. SEMI is focusing on teaching students professional skills and giving them knowledge on career paths available to them in the industry. Another thing I remind members is that companies hire from a variety of college majors, not just STEM disciplines. I'm happy to take mentors and volunteers from all business departments because we are going to need HR personnel, data analysts, etc.

Johnson: Support functions from the industry.

Sandoval: Exactly.

Johnson: When a student finishes the mentoring program and is ready to go out into the industry, what's your vision for their takeaway?

Sandoval: Students will see our industry with a new lens. Like my brother, they will walk away from our programs with a positive perception of our industry, new connections, and an interest in previously-overlooked career paths. After participating in our programs, students will be better prepared and connected. Once students meet the people doing amazing, innovative things, they will realize joining us will give them the opportunity to shape the future of technology and innovation.

Johnson: Thank you, Cristina. This has been very enlightening.

Sandoval: Thank you. **PCB007**

SAVE
50% ON
Your First Year's Membership!
First-time IPC Members Only.

START WITH THE STANDARDS

Quality.
Reliability.
Consistency.
IPC.

3 out of 4 Members say IPC has Increased their Quality.

Join today at **startwiththestandards.ipc.org**.

An IPC membership will help you manufacture your products at the highest level of quality and have a noticeable impact on your bottom line. In fact, 3 out of 4 current members say IPC has increased their quality[1] and 60% of companies who use IPC products and services estimate that they've experienced an annual economic impact of savings from tens to hundreds of thousands of dollars[2]. So, as you manufacture products that make life better for all, make your operations and output better with an IPC membership!

[1] Source: TechValidate survey of 609 users of IPC. Published: Jan. 5, 2018 TVID: C96-ADC-FD2.

[2] Source: TechValidate survey of 303 users of IPC. Sample comprises Large Enterprise, Medium Enterprise, S&P 500, Global 500, Fortune 500, and Small Business electronics industry organizations. Published: Jan. 9, 2018 TVID: BDB-191-596.

IPC®

#StartWithTheStandards

Supplier Highlights

Isola Executive Vice Chairman and Acting CEO Travis Kelly on the Upcoming Year ▶

Isola Executive Vice Chairman and Acting CEO Travis Kelly discusses the recent milestones for the company, including the leadership transition. Travis also outlines his agenda for the upcoming year and gives an update on Isola's new facility in Chandler, Arizona.

EPTE Newsletter: Metallization of Nonconductive Substrates ▶

There were significant technical progressions with chemicals and surface treatments used in electroless plating over the last decade. Now, plating chemicals provide a secure bond strength with the metallic layer on the inert surface of plastic substrates.

Selective Solder Mask Deposition by Inkjet ▶

Pete Starkey spoke with Joost Valeton, product manager for PiXDRO inkjet printing equipment with Meyer Burger, about their newly configured inkjet printer for PCB applications and bringing awareness to opportunities using selective solder mask deposition.

Insulectro Sees Growth and Opportunities in Printed Electronics ▶

Judy Warner speaks with Tim Redfern, Insulectro president, and Kevin M. Miller, VP of sales, about growth in the printed electronics market, the direction Insulectro is going, and opportunities for North American PCB suppliers.

DuPont Expanding Production of Kapton® and Pyralux® ▶

The new assets will expand production of DuPont Kapton® polyimide film and Pyralux® flexible circuit materials to meet growing market demand in automotive, consumer electronics, telecommunications, and defense.

Insulectro Supplier Oak Mitsui Names Michael Coll Technical Director ▶

One of Insulectro's best-in-class suppliers, Oak Mitsui Inc., has hired industry veteran Michael Coll as technical director.

Nano Dimension Dielectric Ink Receives Patent ▶

Nano Dimension Ltd. has received approval from both the U.S. and Korea Patents and Trademark Offices for the company's core technology of its dielectric ink.

Pluritec Partners: Information Systems, ECOSPRAY, and OCCLEPPO ▶

Pluritec VP of Sales Lino Sousa discusses the history of Pluritec and its relationships with information systems and ECOSPRAY. He also announces the purchase of the assets and identity of OCCLEPPO and describes the long-term plan for the integrated one-stop-shop.

Taiyo America Names Keiichiro Miyazawa New Business Development Manager ▶

Taiyo America Inc. has appointed Keiichiro (Kaye) Miyazawa to the position of new business development manager. He will be based at Taiyo America's headquarters in Carson City, Nevada, USA.

SteadySense Uses AT&S Technology and System Expertise ▶

SteadySense, a startup company based near Graz, has developed femSense® technology—an innovative and smart temperature measuring solution for medical applications.

ECOspray SYSTEM

pluritec

INTERNATIONAL SUPPLIES

powered by Occleppo

Machines for Printed Circuit Boards

Spray Coatings & Ovens

- Precision Spray Coating +/-5μm Thickness Control
- Up to 6 Colors on Demand
- Self Cleaning Spray Guns
- System Fully Automated with Process Control Logs
- 15 Minute FAST TACK OVEN

Drilling & Routing Systems

- Optical Drilling & Routing
- X-Ray Assisted Drilling & Routing
- X-Ray Optimizer
- Marking & Traceability
- Automated Flash-rout/Bevel

Prep, Plating & Finishing

- Pumex & Scrubbex
- 30+ Years of Service
- Digital Process Controls Deliver Precision, Accuracy & Repeatability:
  - DES & SES Lines
  - MecEtch & Multibond
  - Direct Metalization
  - OSP & ENIG
  - Electroless Tin/Silver

pluritec

www.pluritec.com | info@pluritec.com

New Engineering Talent Joining the Electronics Industry

Flex Talk

Feature Column by Tara Dunn, OMNI PCB

Last spring, Ross Olson, an undergraduate student at the University of Minnesota and member of the U of M Solar Vehicle Project team, attended the Geek-a-Palooza event in Minneapolis and displayed one of their race cars. Through coordinating that effort, I had the opportunity to get to know Ross, and recently sat down with him to talk about his interest in engineering and his thoughts on the future of the electronics industry, and to hear some great stories about his team experience with the University of Minnesota Solar Vehicle Project.

Tara Dunn: Ross, I understand that you have a somewhat non-traditional path into the engineering field. Can you give our readers a little bit of background on yourself and how you became interested in engineering?

Ross Olson: Absolutely. First, I'm a little older than your average undergraduate student since this is my second time being an undergrad. About five years ago, I graduated from the University of Wisconsin—Madison (I'm slowly making my way around the Big Ten) with a degree in finance and real estate and moved to Chicago to work in real estate development. I had an excellent job in Chicago and was privileged to work with some incredible people who I still really admire.

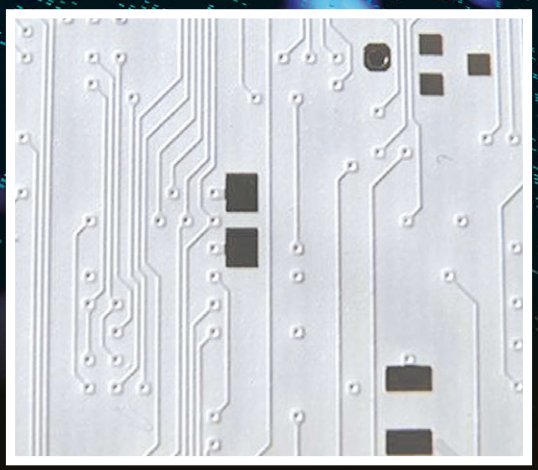
But back to your original question, I became interested in engineering during my first undergrad stint. I've always been inquisitive and

Figure 1: University of Minnesota Solar Vehicle Project team at the American Solar Challenge in the summer of 2018.

A BRIGHT FUTURE FOR LEDS

PSR-4000 CR01MW

- Bright White
- Excellent Crack Resistance
- Matte Finish
- Low Image Growth
- Excellent Chemical Resistance



PSR-4000 CR01MW after ENIG

TAIYO AMERICA
Your Ultimate Solution

Phone [775] 885-9959 • www.taiyo-america.com • info@taiyo-america.com

interested in science and math, but I didn't receive any sort of exposure to the engineering world while growing up. So, when I began college the first time around, I hadn't thought too critically about what I was going to school for or why I was even there. I essentially chose to go to business school by listening to everyone around me. I settled on real estate because I knew I could make a good living in the field, and UW—Madison has one of the top programs in the country.

I don't regret my time at Madison, (plug your ears, die-hard Gophers); I love that school. But a lot of us follow an educational path that we don't give very much thought to until after we reach the end of it, which is a shame. I wish I would have had more maturity and self-awareness before making a decision that significantly altered the trajectory of my life.

Dunn: That is so true. As a young, college freshman, you are expected to make decisions about your life-long career before having the opportunity to be exposed to new things you might not have yet experienced.

Olson: Yes. A large portion of my friends at Madison went to school for engineering. At one point, I lived with three other people, and I was the only one in the apartment not going to school for engineering. Through my junior year and onward, I was consistently exposed to the cool stuff (for lack of a better word) my friends worked on, included projects for class, organizations, and other side projects. I saw the types of jobs and internships they received and asked them a ton of questions about what they did in their roles. I found myself much more interested in the after-college opportunities my engineering friends had on the horizon than the ones I had. It did cross my mind to change majors, but as I said, I was already close to graduating by then, so I shelved the idea. I thought that my doubts would go away after I graduated and started making money in my career.

That brings me back to my time living in Chicago. I found myself deciding whether I should leave my job and stop making money in exchange for going back to school and spending even more money on education. Even though I knew I didn't want to do the job that I was at, it still was a difficult decision to make, especially because I was going to go back for engineering, which was an extremely intimidating major to jump into.

All the friends of mine that went into the engineering field were extremely smart, and at that point, I had my doubts that I would be able to handle the course work and rigor that was going to be required of me. I spoke to numerous friends and my family on multiple occasions about it and had plenty of sleepless nights trying to figure out my game plan. Eventually, I pulled the trigger, left my job, and went back to school. Now, a few years later, I'm here talking to you about my lengthy story. I typically keep it shorter by telling people who ask that I had a quarter-life crisis. I get some funny reactions.

Dunn: I bet that you do (laughs)! Once you were enrolled at the University of Minnesota, you joined the U of M Solar Vehicle Project team. We were lucky enough to have your team display one of the cars at last year's Geek-a-Palooza event, and for a few minutes, I was worried we would have no attendees inside the event be-

Figure 2: Ross charging the solar vehicle's battery before a race.

cause so many were checking out the car and talking to your team. How did you become involved with the team, and what has your experience been?

Figure 3: The University of Minnesota solar vehicle.

Olson: Of course. I love talking about the team! Being in your mid-20s and an undergraduate can be incredibly frustrating at times. But the thing about being older and having already been through this is that hindsight is on my side. I wanted to make sure that I got even more out of my experience at Minnesota than what I did at Wisconsin. I wanted to be more involved with either a professor's research or a student group, and I knew about the solar vehicle team at the U of M, which made the decision about how to get involved a little easier.

I decided to just jump right in regardless of the type of work because I thought it was a good way to get to know everybody on the team and show my commitment by helping wherever an extra set of hands was needed. My friend and I joined the team together at the same time, which happened to be right at the beginning of the build cycle of our previous car, Eos II, which was at Geek-a-Palooza. That meant that a lot, and I mean A LOT, of manual labor was needed at that time.

After a short period on the team, I was fortunate enough to become involved with the electrical design of one of the subsystems of the car. For some background, our team is broken up into two divisions: engineering and operations. The operations division handles most of the business side of the team while engineering obviously handles the engineering side. The engineering division is then broken up by discipline, including the vehicle dynamics team, aerodynamics and structures team, and controls team.

A lot of computer engineers fall into the controls team, which essentially handles all of the electrical systems on the car. From there, each team typically has subgroups that are broken up by functionality. For instance, the vehicle dynamics team has a suspension group and a steering group whereas the controls team has a battery group, a dashboard group, etc. Each of the subgroups in the controls team typically has a PCB associated with it. So, I was fortunate enough to be involved in PCB design and actually design one of the electrical systems in our car. The solar project really gives its members ownership in their work. I can tell you from experience that it's quite rewarding.

Dunn: How long is a typical build cycle for a car from start to finish?

Olson: I joined right at the start of our last car's build cycle, which would have been at the beginning of 2017. Whoa, that's over two years ago! That just hit me. And each of our cars operates over a two-year cycle. The first year is typically spent designing while the second year is used to build the car. We don't get a full two years to design and build each car because we race it in multiple competitions, one of which takes place in Australia. The World Solar Challenge is the largest solar car competition in the world, and it's a 3,000-km race through the Australian outback. Surprisingly, most of the journey is a little bit boring given that it's a flat desert, but we camp in the outback under the stars, so that's interesting.

Dunn: Wow, Australia? That must have been an exciting experience.

Olson: I was selected as a race crew member, so I was able to travel to Australia with the team in the fall of 2017, which was an incredible experience. Our team was amazing, and we got to bond with these people and develop relationships that we may have forever. We had around 20 people on our team. Typically, everyone is over there for at least a month, but most likely longer. A lot of us stayed and even traveled for a couple of weeks after the event was over.

Most of the team ends up taking the semester off. That made the decision to go difficult given my age and desire to graduate as quickly as possible, but I don't regret it one bit. As I said, the whole experience was an absolute blast from the interactions with other solar car teams from all over the world to the stress of finishing the car and preparing the car. It's one of those experiences you hear about that sounds too cool for you to ever experience yourself. It's truly something that I will never forget.

Dunn: I'm envious of that experience. What a fantastic opportunity. I also know that you have been involved in a leadership role for the race team. Can you tell me a little about that experience?

Figure 4: Ross traveling in Australia and New Zealand while attending the World Solar Challenge.

Figure 5: Ross visiting Hobbiton in New Zealand.

Olson: As I mentioned, I became heavily involved with the team when I came to the University of Minnesota. I spent every minute with the team, which eventually led to me getting offered a leadership position. After I returned from the World Solar Challenge in the fall of 2017, I became the controls team manager, so I oversaw 20–30 students primarily majoring in electrical engineering, computer engineering, and computer science.

I learned a lot from my leadership role. It's funny that I went back to school for the technical nature of engineering and ended up with a management role. The time a leadership position requires took away from the time I would have rather spent working on the technical side of things. But overall, it was worth it. The position allowed me to push myself in new ways and showed me a lot about myself, including weaknesses I didn't know I had that I've been able to work on and strengths I didn't know I had that I've been able to foster. The role has given me confidence that someday I can handle a managerial role.

Now, I'm no longer the controls team manager; I've moved into the role of electrical advisor for the team,

Are you getting to the bottom of your via?

Prevent connection failures in thick PCB substrates with plasma treatment

New **VIA™ Series 2.5** cleans deep, narrow vias where other processes can't go

VIA™ Series 2.5
Plasma System

Contact us now to learn more
+1-925-827-1240 / info@nordsonmarch.com

nordsonmarch.com

Nordson MARCH

Figure 6: Ross grinding insulation. (Source: U of M Solar Vehicle Project)

which involves providing technical expertise and guidance rather than managing team members. I no longer deal with day-to-day items, such as running meetings; instead, I work more with our sponsors and assist with the technical challenges our members face. It has given me more time to work on my technical work. Right now, we're trying to finish up the design of our next car's electric motors as quickly as possible so that we can start manufacturing them and get them tested before our car needs to drive.

I couldn't have asked for a better student group to become involved with. The insight I've gained into real-world applications has been extremely valuable. Being on the team gave me my first exposure to PCB design—a topic that I initially knew very little about. I don't know if there's another student group on college campuses that offers its students what solar vehicle teams can because it incorporates almost every discipline of engineering and business. Our team has aerospace engineers, mechanical engineers, computer engineers, chemical engineers, industrial engineers, and computer science majors as well as finance majors, marketing majors, and accounting majors. It really is a team effort. It's probably the closest thing there is to running a business while you're a student except that you don't get paid and you don't have a budget (laughs).

Dunn: As a student interested in entering this field, what types of networking and internship opportunities have been available in the Minneapolis area? I know the medical field encourages a lot of job shadowing, so are there programs and opportunities like that available to help expose you to all the different facets of the electronics community?

Olson: At this stage of our careers, the primary resource for students would be something through the U of M. A lot of my classmates have received internships and co-ops through the career fairs. I had the privilege of participating in the U of M's co-op program where I received five credits and was paid while working. It's a great program, and the company that I matched with—PaR Systems—was a great fit. I thoroughly enjoyed working there and learned from some fantastic engineers.

As far as internship and job opportunities go for students, career fairs are typically your best bet. I can't stress enough that opportunities present themselves to individuals who take the initiative to put themselves into situations that foster that kind of interaction. For example, last fall, I had a rough semester. I took a few classes at the same time that I should not have taken together. Therefore, I kind of wrote off job hunting given the time it typically takes, and instead, planned to find an internship in the spring.

An alumnus of the team I knew from previous interactions approached me toward the end of the fall semester and asked if I wanted to interview at his company for an internship. The internship was in the industry I wanted to be in and provided the type of experience

I was hoping to gain from my final internship before graduating. I could easily chalk this up to getting lucky or being in the right place at the right time, but I don't think that's like the takeaway from the story, nor do I want the takeaway to be that something will always fall in your lap, so it's okay to be lazy about job hunting. The takeaway is that being involved, especially with the right people and groups, will present all sorts of unknown opportunities. Many times, networking is overlooked.

Dunn: Yes, as you saw at Geek-a-Palooza, I am a firm believer in networking and creating opportunities to meet others and build relationships. I am also a big believer in workplace programs for high school and college students. It sounds like having an engineering-based program available at the high school level may have helped you identify your interest in engineering at a younger age. Workforce programs are also gaining a lot of traction as we try to expose and encourage students to look at engineering as a career. What types of programs might have caught your interest?

Olson: You're right. As I alluded to in one of my previous answers, there weren't a lot of opportunities in electronics and engineering at my high school, and I wish there had been. It's interesting because a lot of my fellow students seem to have had some exposure in high school through their robotics team or something else. I don't have any idea what the percentage is, and maybe it's because we're in a metropolitan area of Minnesota, but I've noticed a difference here.

Overall, we're trending in the right direction as far as what is being emphasized in high schools. I played sports in high school, and I think it's beneficial to be a more well-rounded student. I'm not in education and I'm not claiming to be an expert on the subject matter, but I've seen a positive difference between when I was in high school versus the kids coming into college now.

I'm from Wisconsin, and I heard that my high school now has a technology lab space and is even teaching certain engineering courses now, which my younger cousins took. The classes may not offer the same depth as college-level courses, but it's still a good thing to expose students to all of these different subjects that may help them relate the material they learn in their math and science courses to modern technology and real-world applications.

As soon as I graduate and start working and finally have some free time again, one of the first things I want to do is get involved with a local high school or middle school with some sort of STEM team, and if a school doesn't have a program like that, I'd love to start one. Because, again, if something like that existed when I was in high school, I probably would have joined and maybe would have selected the correct major for myself on the first try.

The point I'm trying to make is any program that exposes students to science, engineering, and technology is great. When you're growing up, you form opinions about what is possible by looking at what and who are around you, such as projects, careers, etc.; it all shapes your outlook. Everyone's perspective is relative to their environment, so the more exposure to STEM, the better. Our reliance on technology in the modern world isn't going anywhere.

The point I'm trying to make is any program that exposes students to science, engineering, and technology is great.

I really like the idea of technical competitions like FIRST Robotics. It doesn't have to be robotics, but that's the most popular program. Any sort of competition where you can get students working together as a team to complete a project is a great way to incorporate competition while exposing students to STEM. The coolest part is being able to offer the students a tangible outcome to all the work they put

in because that's when it gets fun! When an activity sparks an interest in a student, they might choose it as a career.

Dunn: Through a few internships and your experience with the team, you have been exposed to multiple areas of the electronics and engineering space. What do you see as some of the challenges and opportunities for someone about to enter the field?

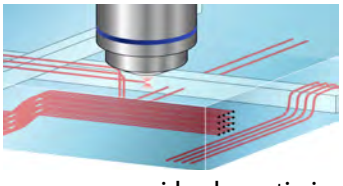
Olson: Without sounding too biased or using a cliché, an obvious answer is in the renewable energy area, and I don't just mean the jobs associated with the things that come to mind when you think of renewables, such as solar panels and wind turbines. I'm referring to any industry or business that may end up supporting the transition from fossil fuels to renewables. I try to stay away from buzz words, but another area I find quite interesting is the IoT space. As you've probably noticed, everything is a smart device these days. An insane number of devices now communicate wirelessly, but I still think there are plenty of opportunities for other businesses to utilize embedded technology for their specific application. Finally, there are still a ton of opportunities in the area of robotics and industrial automation. As technology continues to develop, certain operations will become possible to automate.

Dunn: Thank you for taking the time to sit down with me, Ross. I've enjoyed hearing your story and perspective.

Olson: Thanks again for asking me these questions. It has been a pleasure! **PCB007**

Tara Dunn is the president of Omni PCB, a manufacturer's rep firm specializing in the PCB industry. To read past columns or contact Dunn, click here.

Tiny Waveguides Could Enable Better Biomedical Devices, Wearable Displays



For the first time, researchers have fabricated optical waveguides just over one micron wide in a clear silicone commonly used for biomedical applications. The tiny, flexible waveguides can be used to make light-based devices such as biomedical sensors and endoscopes that are smaller and more complex than currently possible.

"Our flexible waveguides could be integrated into microfluidic lab-on-a-chip systems to eliminate bulky external optics needed to perform blood tests, for example. They might also deliver light for wearable devices such as a shirt featuring a display," said research team member Ye Pu of École Polytechnique Fédérale de Lausanne (EPFL) in Switzerland.

As reported in *Optical Materials Express,* the new optical waveguides are not only thinner than a piece of dust but also exhibit very low light loss when used with certain wavelengths of light. A light-based signal can travel through the new waveguides for 10 centimeters or more before an unacceptable degradation of the signal will occur.

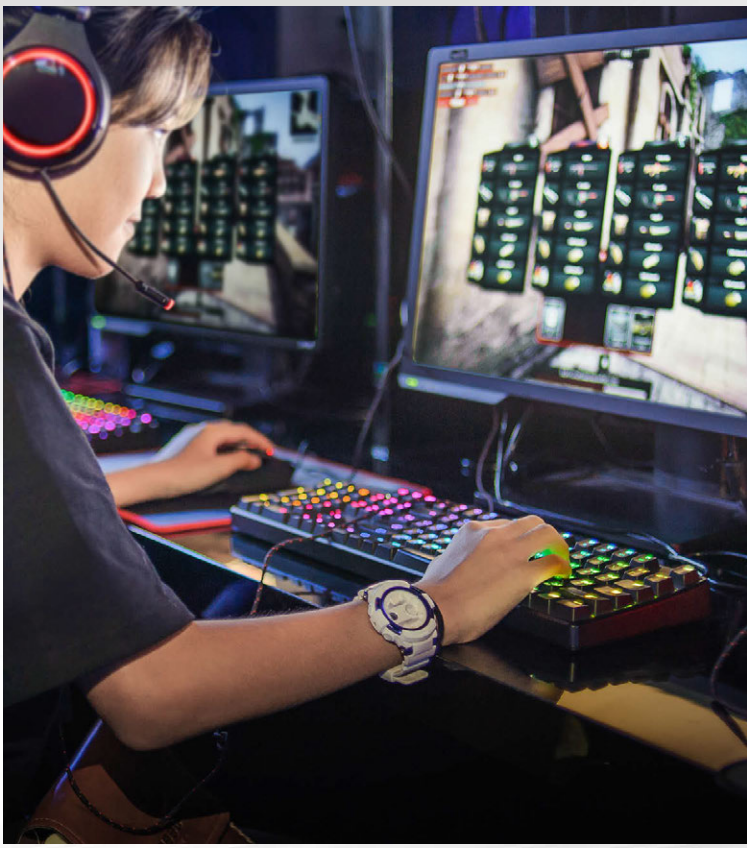
The researchers made the new waveguides by optimizing laser direct writing, a microfabrication approach that creates detailed 3D structures by polymerizing a light-sensitive chemical with a precisely positioned focused laser. Polymerization converts relatively small molecules called monomers into large, chainlike polymers.

The new approach does not require a photoinitiator, which is typically used to efficiently absorb the laser light and convert it into chemical energy that initiates polymerization. "By not using a photoinitiator, we simplified the fabrication process and also enhanced the compatibility of the final device with living tissue," Pu said. "This enhanced biocompatibility could allow the approach to be used to make implantable sensors and devices."

The new flexible waveguides could also serve as building blocks for photonic PCBs that use high-speed optical signals rather than electrical links to transmit data in computers and other electronic devices.

(Source: The Optical Society of America)

MacDermid Enthone



Working hard to perfect the circuitry that enhances your electronics at home.

CREATIVE, FORWARD THINKING, INNOVATIVE

The chemistries of today developing the electronics of tomorrow.

MacDermid Alpha ELECTRONICS SOLUTIONS

electronics.macdermidenthone.com

macdermidalpha.com

A Flex Factor class on AP Environmental Science from Abraham Lincoln High School in San Jose, California, pays a visit to the DuPont Silicon Valley Technology Center in February 2019. Teacher: Michelle Morella-Bennett (R).

Engaging the Future of Advanced Manufacturing:
NextFlex and DuPont in Silicon Valley and Beyond

Feature by Brynt Parmeter and Emily McGrath
NEXTFLEX

It is no secret that there will be a surge of career opportunities in advanced manufacturing over the coming years. One of the most critical challenges facing the manufacturing industry is how to showcase the potential of this field to attract the next generation of talent—Generation Z—into the workplace. Fortunately, organizations like NextFlex and companies like DuPont are forging powerful partnerships to create the future of advanced manufacturing by engaging youth with the innovation driving this sector.

DuPont, through their new Silicon Valley Technology Center, is the latest company to join NextFlex's flagship education and workforce development program—FlexFactor. NextFlex, America's Flexible Hybrid Electronics Manufacturing Institute, is an industry consortium with a mission to advance the manufacturability and commercialization of flexible hybrid electronics and catalyze the next-generation workforce. FlexFactor was designed to achieve NextFlex workforce development goals by engaging young people with the full range of opportunities in the advanced manufacturing and technology sectors. Working with future-thinking industry partners like DuPont, NextFlex is driving the development and commercialization of flexible hybrid electronics (FHE) and facilitating the creation of the next generation workforce.

FlexFactor addresses the complexities of workforce development by bringing the educational and industrial communities together. Through strategic partnerships between academic and manufacturing stakeholders, the program provides students with experiences and knowledge to understand what a career in advanced manufacturing looks like. The program also helps identify pathways for students leading into the field. Driven by a project man-

Integrate QA Solutions

Because one size does not fit all.

Integrate by Gardien is a fully customizable solution for all your quality assurance needs, be it AOI, testing, final inspection or even a combination of them. We understand your present and future needs and build unique, cost efficient solutions that match your requirements.

Gardien offers independent third party validation of a board's quality, along with proper documentation. We guarantee that you only pay for the boards that get our seal of approval and not for all the products tested.

Find out more here:
www.gardien.com/why-integrate

DOCUMENTATION

30+ YEARS EXPERIENCE

30 YEARS OF PCB INDUSTRY EXPERIENCE

GLOBALLY LOCAL

Flex Factor program student participants from Abraham Lincoln High School take in the displays at the DuPont Silicon Valley Technology Center on February 11, 2019.

ager who handles local coordination activities, FlexFactor acts as a hub for K–12, higher education, and the industry to easily plug-in and work together.

Through seven linked activities spread over a month, FlexFactor uses a project-based learning approach to engage students with advanced technologies and entrepreneurship. During the program, small teams of students are challenged to identify a real-world problem, conceptualize an advanced hardware product to address the issue, build a business model around it, and pitch their idea to a panel of representatives. Along the way, students engage with both industry professionals and higher education to inform their product concepts and learn about education and career pathways in the technology sector.

The program is designed to work within existing classroom structures and absorb subject-learning objectives. When layered over an English class, the program can be used to study rhetoric, messaging, and oral presentation. In environmental science classes, the program can be used to study how advanced technologies address environmental challenges. Robotics classes can expand the program out for additional weeks and use the extra time to build prototypes of their products.

FlexFactor's unique curriculum enables this STEM- and entrepreneurship-based program to align with non-STEM and business subjects. Through video modules and workbooks, program materials illuminate the conceptual underpinnings of hardware design, functional electronics, advanced materials, market needs, and business finance. The logic-driven materials enable students of any background to grasp the cardinal points of each discipline.

The resulting understanding helps students create a knowledge framework that allows them to identify and map critical relationships between a variety of subjects that are usually taught in isolation. This conceptual scaffolding provides a foundation into which specific STEM and business skills, such as design principals and statistics, can be embedded later. This approach inspires the next generation of engineers and technologists to be cross-functional thinkers who can readily engage business themes, such as market needs, as they iterate through product development cycles, ensuring technical features are not developed in isolation of user requirements. This type of global thinking will become more and more critical to employer and employee success across the range of manufacturing enterprise activities that define Industry 4.0.

FlexFactor is successful because student teams define their own topics, ensuring they are fascinated by and passionate about their focus areas. Themes like business statistics and basic material properties, generally compelling for only a select few primary school students, take on new meaning and relevance when studied as a means to address infant mortality in the third world. For example, how would a company go about resourcing, designing, manufacturing, and distributing a baby bottle integrated with bacteria-killing LEDs that could be used by families in parts of the world where drinking water is routinely contaminated? Complex practical and ethical dimensions are brought into the fold as teams struggle to

decide whether a large profit margin that will attract critical investors is an acceptable moral tradeoff when affordably priced products will save additional lives, for instance.

Because teams are challenged to determine their project focus, the program enables students to dig deep into their passions and interests in a way that conventionally-defined curriculums frequently don't allow. By providing this degree of agency over educational experience, the program simultaneously generates interest in STEM-based subject areas and channels that interest into the pathways that bring FlexFactor students back to our industry partners as future talent.

FlexFactor's class-based structure also allows the program to circumvent common issues that plague conventional STEM-based initiatives, such as lack of gender and racial diversity. By eliminating self-selection as a criterion for participation, the program engages populations of students who had not previously considered tech-based careers, catalyzing and orienting a diverse pipeline of talent and a new generation of industry leaders.

The program's high-impact touchpoints include field trips to both an industry partner, such as DuPont, and a college or university. Through active engagement with cutting-edge technology and higher education, students go through enduring and transformative experiences that translate the idea of a career from an esoteric concept to a visualized goal with a path to achievement.

DuPont's Silicon Valley Technology Center in Sunnyvale, California, hosts FlexFactor students every few weeks throughout the school year. Boasting an Innovation Center that showcases DuPont materials and interactive prototypes alongside operating application labs that can be opened for touring, the Center is the perfect venue to draw students into the incredible potential of the advanced manufacturing sector. Through a combination of personal engagement and immersion in the fascinating world of advanced technologies, the Center and its team bring advanced manufacturing to life.

Diverse and formidable topics—such as product design, material properties, environmental testing, and manufacturing processes—become approachable and understandable through the humanizing combination of engineers and showroom prototypes. Advanced drones created with lightweight polymers, hybrid-electric and autonomous vehicles, and other example products help students understand the purpose behind advanced materials. Over several hours, students are pulled into the potential of DuPont's advanced materials that can transform the way we build, travel, and communicate.

The most often-asked question by the end of the day is, "What do I need to learn to work here?" And after their industry tour, each class visits a college or university to learn exactly that. After spending a day touring a campus, meeting student ambassadors and instructors, and learning about STEM and business programs related to the advanced manufacturing field, students depart with the understanding they need to chart their own education pathways towards their career goals. "FlexFactor allows us to contextualize education pathways for students, and college becomes a tool for them to achieve concrete career objectives," explained Dean of Workforce Development at

Evergreen Valley College Dr. Maniphone Dickerson.

FlexFactor was piloted in the fall of 2016 with an English class of eight students in San Jose, California, at Evergreen Valley College. In the subsequent two and a half years, the program has expanded to 3,500 students across three replication sites, including Lorain County Community College (LCCC) in Ohio, and Calhoun Community College and Drake State Community and Technical College in Alabama. Working with industry partners, such as DuPont, Boeing, Jabil, Lincoln Electric, Thygos, AgriNomix, A.J. Rose Manufacturing, Fetch Robotics, BD BioSciences, and others, the program is expanding across labor markets throughout the United States to address workforce development gaps.

With FlexFactor's scalable framework and materials, each ecosystem in which it is deployed develops unique DNA that reflects local industry needs and opportunities but produces the same empowered and motivated students who become the architects of their own futures.

Overall, FlexFactor's agile approach to building the advanced manufacturing workforce of tomorrow is resulting in a wave of students who are aware of and responsive to the variety of technical, business, socioeconomic, and environmental factors that inform the successful design, manufacture, and sale of next-generation products. Through applied and immersive learning techniques, FlexFactor promotes initiative and comprehension, entrepreneurialism, awareness of the connections between disciplines, and the type of deeply analytical and creative thinking the advanced manufacturing sector is seeking in current and future employees.

For more information about DuPont's Silicon Valley Technology Center, visit www.dupont.com. For more information about how NextFlex's workforce development programs can help your community, visit www.nextflex.us/learning-programs/. **PCB007**

Brynt Parmeter is the director of workforce development, education, and training at NextFlex, and has a diverse background in both the public and private sectors. Before joining the private sector, Brynt served nearly 25 years as an infantry officer in the U.S. Army, rising to the rank of colonel.

Emily McGrath is the deputy director of workforce development, education, and training at NextFlex, and has a diverse background that includes experiences across government, industry, and education sectors. She attended Colgate University and Portland State University where she holds degrees in geography and GIS.

2019 Programs

NORTH AMERICA

CONFERENCES

May 14–16
Baltimore (Hanover), MD
IPC High Reliability Forum

June 3
Boston, MA
ITI & IPC Conference on Emerging & Critical Environmental Product Requirements

June 5
Chicago, IL
ITI & IPC Conference on Emerging & Critical Environmental Product Requirements

June 7
San Jose, CA
ITI & IPC Conference on Emerging & Critical Environmental Product Requirements

June 15–20
Raleigh, NC
IPC SummerCom featuring Panelpalooza

September 11
Philadelphia, PA
IPC E-Textiles 2019

November 5-7
Minneapolis, MN
IPC Electronics Materials Forum 2019

MEETINGS

May 21–22
Washington, D.C.
IPC IMPACT Washington, D.C.

June 15–20
Raleigh, NC
IPC SummerCom: IPC Committee Meetings

WORKSHOPS

April 29
Anaheim, CA
Export Control Compliance: Training Workshop and Regulatory Update

May 1
Rosemont, IL
Export Control Compliance: Training Workshop and Regulatory Update

May 3
Sterling, VA
Export Control Compliance: Training Workshop and Regulatory Update

WEBINARS

April 30
Production of Electronics Hardware with the Assistance of IPC Standards – Part 1

May 7
Production of Electronics Hardware with the Assistance of IPC Standards – Part 2

IPC TECH ED

Apri 2
King of Prussia, PA
Process and Acceptability Requirements: Utilizing J-STD-001 and IPC-A-610 Together

May 7
Milwaukee, WI (in conjunction with Electrical Wire Processing Technology Expo)
The Evolution of IPC's Cable & Harness Documents — IPC-D-620, IPC/WHMA-A-620 and IPC–HDBK–620

September 10
Huntsville, AL
Process and Acceptability Requirements: Utilizing J-STD-001 and IPC-A-610 Together

November 12
Raleigh, NC (in conjunction with PCB Carolina)
Design for Excellence: Design for Manufacturing, Design for Reliability, Design for Assembly and More

December 3
Anaheim, CA
Process and Acceptability Requirements: Utilizing J-STD-001 and IPC-A-610 Together

EUROPE

May 6–7
Nuremberg, Germany
IPC Tech Ed – Process and Acceptability Requirements: Utilizing J-STD-001 and IPC-A-610 Together

May 8–9
Nuremberg, Germany
PERM Meeting

June 5–6
Budapest, Hungary
i4.0 Connect Forum-Europe

September 23–24
Prague, Czech Republic
IPC Wire Innovation Conference

September 26
Paris, France
IPC Transportation Electronics Reliability Council Annual Meeting (ITERC)

November
Brussels, Belgium
IPC IMPACT Europe

November 11–12
Munich, Germany
IPC E–Textiles Symposium

ASIA

June 25
Suzhou, Greater China
IPC WorksAsia Automotive Electronics Forum

September 3
Beijing, Greater China
IPC WorksAsia Aerospace & Aviation Forum

WISDOM WEDNESDAY WEBINARS — Exclusive for Members

April 3 · April 17 · June 26 · August 21 · October 16 · December 18
May 8 · May 22 · July 17 · September 18 · November 20

For more information, visit www.IPC.org/events

Electronics Industry News and Market Highlights

APAC Manufacturers to Comprise 90% of Global PCB Market by 2020 ▸

The global market for PCB is expected to grow at a CAGR of 3–4% until 2020, according to procurement intelligence firm Beroe Inc. Technological advancements in product types and the predicted increase in demand for substrates are expected to be the key support factors for the growth of the global PCB market.

Global Wireless Telecommunication Carriers Market 2019 ▸

North America was the largest region in the global wireless telecommunication carriers market, accounting for 42% of the market in 2018.

Semiconductor Equipment Market to Grow at a CAGR of 7% from 2018-2026 ▸

The global semiconductor equipment market is projected to exhibit an impressive CAGR of 7.2% from 2018–2026, according to Coherent Market Insights.

Smartphone Shipments Expected to Drop in 2019 ▸

Worldwide smartphone volumes are forecast to fall by 0.8% in 2019 with volumes dipping to 1.39 billion. However, the smartphone market will begin to pick up momentum this year with year-over-year growth of 2.3% expected in the second half of the year.

Green Regulations Driving Growth of Lithium-ion Batteries ▸

According to data compiled by Grand View Research, the global lithium-ion battery market is expected to reach $93.1 billion by 2025 while registering a robust CAGR of 17% as well.

Global Small Satellite Market to Reach $30 Billion by 2026 ▸

According to Coherent Market Insights, the global small satellite market was valued at $2.92 billion in 2017 and is projected to exhibit a CAGR of 26.8% over the 2018–2026 period.

Small Business Hiring Remained Flat in February ▸

The Paychex|IHS Markit Small Business Employment Watch continued to reflect signs of the tight labor market. At 98.93, the Small Business Jobs Index was unchanged in February, remaining just below 99.

China's Power Semiconductor Market Posts 12% Growth ▸

TrendForce predicts that China's power semiconductor market will reach a size of RMB290.7 billion in 2019, a 12.17% growth compared to 2018, maintaining double-digit growth.

Global Semiconductor Sales Down 5.7% YoY in January ▸

Worldwide sales of semiconductors reached $35.5 billion for January 2019—a decrease of 5.7% from the January 2018 total of $37.6 billion and 7.2% less than the December 2018 total of $38.2 billion, according to the Semiconductor Industry Association (SIA).

Q1 DRAM Contract Prices Witness Sharpest Decline Since 2011 ▸

The latest analysis of the PC DRAM market from DRAMeXchange, a division of TrendForce, finds that most contracts are now monthly deals rather than quarterly deals with February seeing an unusual, large down-correction in prices.

ELITE MATERIAL CO., LTD

STRIVE FOR **EXCELLENCE**

www.emctw.com | EMC.INFS@mail.emctw.com

EM-890/ EM-890K Green Laminates are ready to transcend your future 200G and 400G applications

INDUSTRY'S FIRST HALOGEN FREE ULTRA LOW LOSS MATERIAL

World's largest producer of environmental friendly advanced laminate materials

The Best-in-class SI Performance
At least 5~10% lower insertion loss than competition

Ideal for multiple lamination cycles (>5x)

Compatible with FR-4 Hybrid Design for economical Hybrid solutions with EM-827 or EM-370(Z)

Excellent Thermal Properties for Ultra Fine BGA Pitch
(Pass 10X LF260 IR Reflow and IST > 2K 1K cycles with BGA pitch <0.7mm)

TECHNICA, U.S.A.

North American Master Distributor
1-800-909-8697 • www.technica.com

Merging the Best of Both Worlds:
Young Superheroes and Knowledgeable Wizards!

The PCB Norsemen
Feature Column by Didrik Bech, ELMATICA

A statement often seen on LinkedIn is as follows: "Your company is only as extraordinary as your people." It's no wonder why this saying is so popular because it is true. Any company is only as great as the people who embody it, ensure that strategies are developed and implemented, and bend over backward to create value for the customer and ultimately the company. Another old saying is, "Happy wife = happy life." The same goes for your employees; keep them happy, and they will take care of your customers.

The Most Important Asset in Any Company

Companies that dare be true to themselves, trust their employees, and provide direction, freedom, and responsibility to their most important asset—namely, their employees—are more likely to succeed. However, we can all rattle behind these positive words and agree with these statements. The real question is, "How do you actually create and sustain an environment that motivates and attracts people in the wave of Industry 4.0"?

The users of technology are changing, and at Elmatica, we go all the way back to 1971. It doesn't make us dinosaurs yet, but it indicates that we have been able to do just this—create and sustain an environment for motivating and attracting new ideas and talent. Every generation has renewed enthusiasm, creativity, and skills—some are new innovations, some are improvements of existing technologies, and others are disruptive [1].

Industry 4.0 is an automatic exchange of data between systems, and millennials are the first generation practically brought up with technical devices in all forms and facets of life. Consequently, they have the most experience and confidence working with technology along with familiarity with allowing machines to operate independently of active human in-

Ucamco
Former Barco ETS

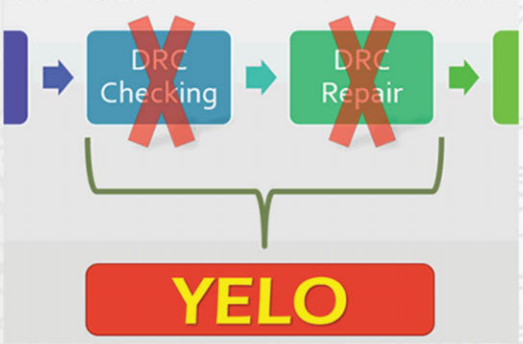
SOFTWARE | PHOTOPLOTTERS | DIRECT IMAGERS | NEWS | SERVICES | COMPANY | DOWNLOADS | CONTACT

Software

YELO

Yield Enhancing Layout Optimizer

- Optimizes board layouts within minutes
- Cuts back CAM cycle time & cost by up to 30%
- Lowers technology class improving manufacturability
- Reduces scrap and delivers a more reliable product
- Return on Investment within the first year



Read more

Need a Gerber Viewer?

Ucamco, caretaker of the Gerber format, presents its new Reference Gerber Viewer. Use this free online tool to view and/or check your generated/received Gerber jobs.

- Reads X2 attributes containing PCB fabrication data
- Imports Excellon and NC drill files

Go ahead and link your site to https://gerber.ucamco.com

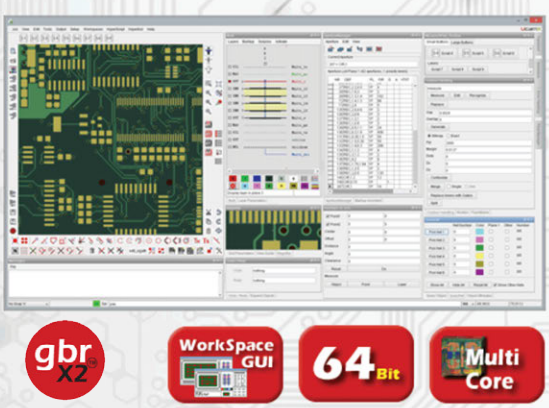
Software

UcamX

New ground-breaking CAM Software

- For Rigid, Flex and HDI PCBs
- New Graphical User Interface with Workspaces
- Optimal performance using Parallel Processing
- Multi Job Processing via load balanced Sessions
- Support for Gerber version 2 (X2) format

Read more



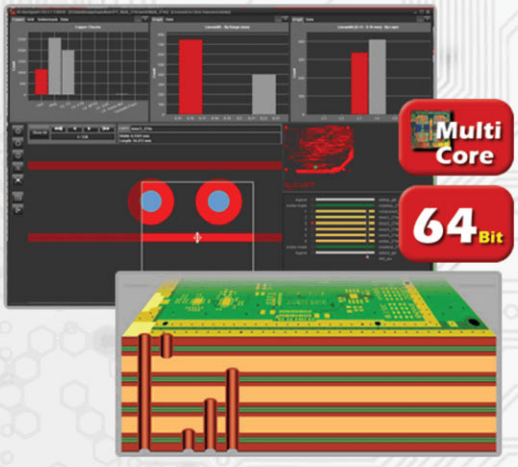
Software

Integr8tor

Automated data entry and design analysis

- Ucamco's 9th Generation Sales & Engineering Tool
- Field proven with more than 300 installations in daily production
- Seamless integration into any environment

Read more



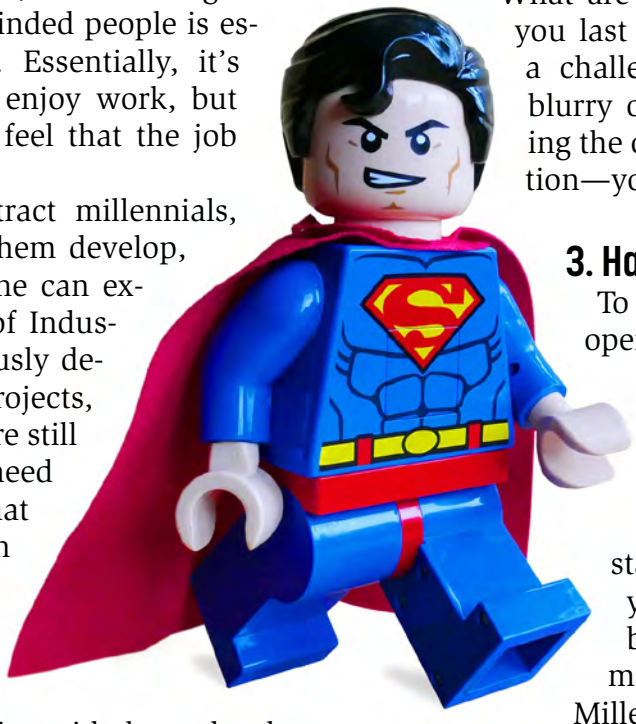
For more information please contact info@ucamco.us,
call (415) 508-5826 or check out our website at www.ucamco.com

teraction. This, combined with the technological development over the last 50 years, paves the way for Industry 4.0, AI, automation, and smart factories.

New Decade, New Approach

When I was a student and received my first job, the most important thing was to get a paycheck, offering me the freedom to do more of what I found interesting. But today's youngsters seem to have a different approach. Money and security are still vital parameters, but according to one report [2], they also seek to be part of the bigger picture. Values, flexibility, freedom, time off, and working with interesting and open-minded people is essential for millennials. Essentially, it's important for them to enjoy work, but it's more important to feel that the job has a purpose [3].

So, how can we attract millennials, keep them happy, let them develop, and blossom so that one can explore the possibilities of Industry 4.0 and simultaneously deliver on your existing projects, which in many cases, are still paying the bills? You need to create a company that appeals to millennials in relation to their background, experience, and how they see the world. The beauty is that this doesn't conflict with how development has been conducted in the past, but you can't just say you will do it—now, you actually have to deliver. Here are five tips to help.



1. Ensure Security

We all want security. If you're lying awake at night, wondering if you will have a job tomorrow, you will never produce at your top level. Your finances should be in order, although one should also notice that the new generation is often willing to be compensated in other ways, such as stocks if they believe in your values and ideas. This is a viable option for attracting the right candidates and can be implemented for both existing and new companies by either setting up new subsidiaries or offering them a stock option program.

2. Be Univocally Clear About Your Company's Values

What are your company's values, and what do they actually mean? How do you measure their use, and how should they guide the decision-making process in your company? This is where many companies fail. Fancy, show-off values with no connection to reality will not help. Are you wondering if your values are present amongst all employees? Simply ask, "What are our values, and when did you last actively use them to solve a challenge?" If what you get is blurry or uncertain, you are missing the cornerstone of your foundation—your values.

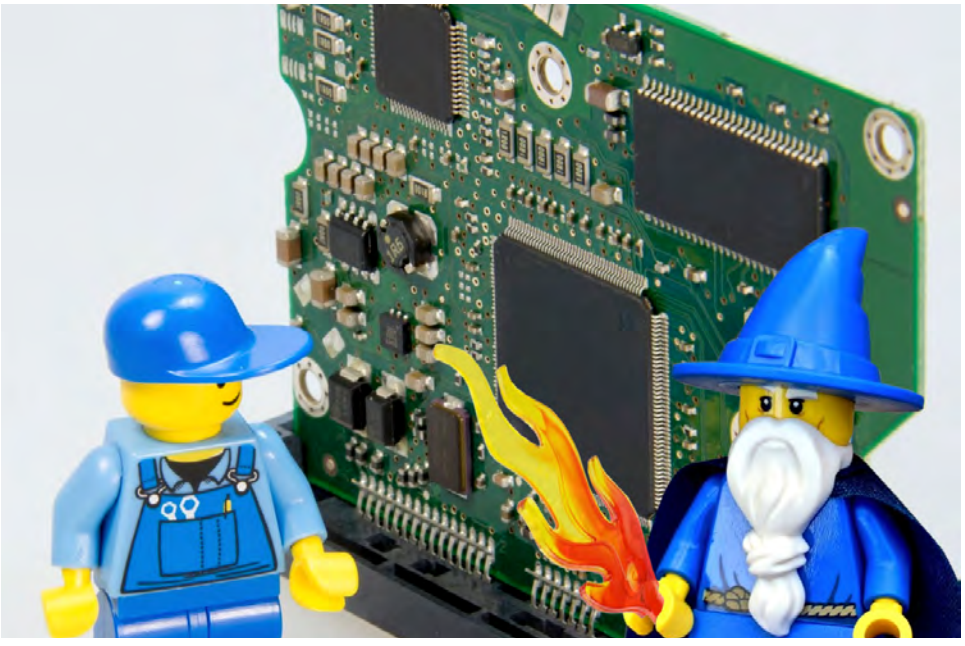
3. Have a Defined Mission

To induce motivation and cooperation, people need to know exactly what the mission and purpose of the company are. This might sound banal, but a clear and motivating mission statement, explaining what your business is aiming to be best at, is not as common as one might assume. Millennials want to be part of something bigger than themselves; they want to contribute to shaping the world and know how to get there. This is why a strategy for your environmental impact is important. To attract millennials with the experience and skill set your business needs to succeed in the wave of Industry 4.0, you need to tell them where you are going.

4. Set Clear, Inspiring Goals

Essential to all companies, goals should inspire and create a sense of fulfillment and happiness once achieved. People must identify with and be inspired by your company's

goals. Very few are inspired by financial values, quotas, and efficiency goals. However, having concrete, measurable, and inspiring goals will attract people who can identify with them. Perhaps the most famous goal every stated was by John F. Kennedy: "We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard. Because that goal will serve to organize and measure the best of our energies and skills. Because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one that we intend to win, and the others too." This is a concrete, finite, measurable, and common goal that brings people together and helps them feel like a part of the bigger picture—the key to attracting millennials.



5. Understand Millennials' Needs and Work Requirements

Millennials with skills crucial for developing equipment and processes for Industry 4.0 know that they are in great demand and that there is a shortage of supply. If you can ensure security and deliver on values, mission, and goals, then the final touch is to understand millennials' needs and work requirements. This has previously been solved by offering financial compensation; however, millennials are not primarily motivated by the financial aspect. Flexibility, vacation, maternity leave, and interesting tasks are often more motivating. Millennials are specifically interested in gaining access to knowledgeable and experienced colleagues learning how they can digitize their current process into Industry 4.0.

Creating an environment where sharing knowledge and experience is appreciated will be beneficial to a company because all parties will learn from each other. For example, Altium ensured this with great success by hosting AltiumLive events, attracting lots of young designers to their last event in Munich where attendees could design, play, share, and develop their skills.

Merging the best of both worlds—new talent, or young superheroes, with experienced industry leaders, or knowledgeable wizards—and achieving a good work-life balance based on flexibility and knowledge will create loyalty and trust, and those are the only two currencies you should want to have. **PCB007**

References

1. "Disruptive innovation," a term coined by Clayton Christensen.
2. "Millennial Careers: 2020 Vision–Facts, Figures, and Practical Advice From Workforce Experts," ManpowerGroup, 2016.
3. Hansen, M. T. *Great at Work: How Top Performers Do Less, Work Better, and Achieve More,* Simon & Schuster, 2018.

Didrik Bech is Elmatica's CEO. To read past columns or contact The PCB Norsemen, click here.

MilAero007 Highlights

Elmatica First Printed Circuit Broker to Become Member of FAD ▸

Elmatica will use its knowledge and experience to increase awareness of design rules and best practices.

GSPK Circuits Now Certified to EN9100:2018 Standard ▸

GSPK Circuits's Boroughbridge facility in North Yorkshire in the U.K. has been certified to the EN9100:2018 Quality Management Standard.

U.S. Air Force Delays E-3 AWACS Upgrade Program ▸

The U.S. Air Force has delayed the upgrade program of E-3G Airborne Warning and Control System (AWACS) aircraft, according to a report by Inside Defense.

SpaceX Crew Dragon Splashdown Marks Success ▸

NASA passed a major milestone in its goal to restore America's human spaceflight capability when SpaceX's Crew Dragon returned to Earth after a five-day mission docked to the International Space Station.

BAE Systems Receives IDIQ Contract from U.S. Navy ▸

The U.S. Navy selected BAE Systems to develop, secure, and integrate future cybersecurity, autonomous, and unmanned mission systems.

Raytheon to Expand U.K. Operations by Opening Two New Sites ▸

Raytheon U.K. will open a new office in London and a high-technology manufacturing facility in Livingston, Scotland, as part of its continued investment in Britain to create highly skilled jobs and diversify its technology portfolio in cyber intelligence, security, aerospace, and defense.

Lockheed Martin Develops World-first LTE-over-satellite System ▸

Lockheed Martin has developed a new LTE-over-satellite system designed to provide connectivity to remote regions, including areas without cellphone coverage, boats off-shore, or during natural disasters like hurricanes, wildfires, earthquakes, catastrophic floods, or volcanic eruptions.

Boeing Introduces New Unmanned System for Global Defense Customers ▸

Designed for global defense customers by Boeing Australia, the Boeing Airpower Teaming System is the company's largest investment in a new unmanned aircraft program outside the United States.

Astronauts Assemble Tools to Test Space Tech ▸

Technology drives exploration for future human missions to the Moon, Mars, and beyond. For spacecraft to journey farther and live longer, we'll need to store and transfer super-cold liquids used for fuel and life support systems in space.

High-tech Laser Scans Uncover Hidden Military Traverse at Alcatraz Island ▸

High-tech radar and laser scans have uncovered a hidden military traverse underneath the infamous Alcatraz penitentiary, according to research led by faculty at Binghamton University, State University of New York.

AS-9100D

PROTOTRON.COM
(888)847-7686

Your Passport to Global PCB Sourcing

We are pleased to announce that with the same fine service, quality, delivery and attention to detail that our customers have grown to rely upon, we are now adding a complete global solution to meet all of your needs, both today and in the future.

Our Solutions:

- *FLEX & RIGID-FLEX*
- *HDI / MICROVIA*
- *COMPETITIVE VOLUME PRICING*
- *PRE-QUALIFIED OFFSHORE PARTNERS*
- *QUICK-TURN PROTOTYPES*
- *COMPLEX MULTILAYER*
- *MIL-SPEC PRODUCTION*
- *SPECIALTY MATERIALS*

MORE INFO
Global PCB Sourcing
PDF DOWNLOAD

FREE BOOK
DOWNLOAD
I-007eBooks.com

Prototron Circuits

A COMPLETE GLOBAL SOLUTION

REDMOND, WASHINGTON • TUCSON, ARIZONA • GLOBAL PARTNERSHIPS

Averatek on the Future of Additive and Semi-additive Processing

Interview by Barry Matties
I-CONNECT007


Mike Vinson

Averatek's President and COO Mike Vinson talks with Barry Matties about the benefits semi-additive and additive processing can bring to the shop floor as well as some of the current challenges and limitations that continue to leave many manufacturers hesitant to implement the technology.

Barry Matties: Can you tell us a little bit about your company?

Mike Vinson: Averatek was a spinoff of SRI International. We began about 12 years ago. For the last seven years, we've been focusing on circuits for the printed circuit board industry in a variety of ways. One of the ways is with semi-additive processing. We have a particular ink that allows us to make very thin copper layers that we can then build upon for semi-additive processing. We can go back and etch away the very thin copper that we put on initially, and then leave the traces behind with virtually no deformation in the trace itself. So, that enables very fine pitch and very fine lines for circuits.

Matties: Additive processing is a fast-growing trend. What's the driver behind it?

Vinson: Yes, we're seeing a lot of interest now for additive as well as semi-additive processing, mainly trying to get the finer lines with less processing steps. With the additive process, you're not doing as much of the etching away. You don't have the chemistries or the materials to dispose of after the etching process. You can also limit a lot of those steps, decrease the amount of time spent, and minimize the damage done in those steps.

Matties: We see companies printing circuit boards completely through additive. They start with a solution and wind up with the board. It's a nice technology for rapid prototyping. If you want something, you design it in the morning and have it out by lunch. You can do this, but is this where we're headed?

Vinson: Many of those printing processes have some gaps where they're trying to get enough conductivity into the circuit to be usable in

Electronics Coatings for the Digital Era

ELECTRA

EMP110
Universal Direct Image Soldermask

- Widely used in medical, military and automotive applications
- Reputation for robustness and reliability
- Meets or exceeds high reliability standards

EMP110 Universal DI Soldermask is extensively used in production on the full range of direct image technologies on the market as well as offering a fast, tack-free exposure with conventional contact printers.

RoHS COMPLIANT

T +44 (0)1732 811118
info@electrapolymers.com
www.electrapolymers.com

most electronic systems. There is a good market for those low-conductivity kinds of products. But beyond the rapid prototyping, there are only a few applications that can really take advantage of it. Perhaps for some of the areas in the military or space travel where they need rapid repair, that would be very advantageous. However, we're seeing a need for more conductive circuits in very fine traces other than what a lot of printed technologies are bringing.

Matties: What's the challenge for someone who wants to move into an additive process?

Vinson: There are a few, and it really depends on what your end product is going to be. If you're trying for a more conventional product, the challenges are going to be in the equipment set and what you need to purchase to get into the additive process. With our process, it's less of the equipment set and more of the advanced lithography technology to make the finer circuits that we provide for.

With our process, it's less of the equipment set and more of the advanced lithography technology to make the finer circuits that we provide for.

Matties: Can you describe your process and how it works?

Vinson: With our process, we're putting down an extremely thin catalyst ink—one- or two-nanometer catalyst ink—that then we can build upon with a very dense electroless metallization. We can work with a variety of electroless metallizations—those that work well with the palladium catalysts. Then, we'll put on an electroplated circuit that is defined by photolithographic methods, usually. We have a couple of other methods that are currently under development right now that I can't go into too much detail on, but those should be able to take us down to the five-micron range.

Matties: What sort of growth do you expect to see in this market segment?

Vinson: Right now, it's a little slow because it requires not only our capability but the rest of the infrastructure to grow along with it. People are hesitant because the current infrastructure doesn't support everything that we can achieve. But there are a lot of leading-edge industries looking at our technology, and we're seeing a lot of the mobile markets adapting roadmaps that will require our technology or technologies that can deliver what we deliver.

Matties: What standards are in place or need to be put in place for this technology?

Vinson: One of the biggest issues that we see is a lot of the standards around adhesion, etc., that were developed for laminated circuit boards with laminated foils don't really apply when you're doing an additive process. So, we need to investigate how additive processes are evaluated in the simplest forms. A lot of the other requirements are currently in place once we have a finished product and are running it through thermal cycles and that sort of thing; those are pretty good.

Matties: In terms of reliability, you're talking about product testing. What sort of reliability comparisons are made between a traditional process and an additive process?

Vinson: One of the things in a traditional PCB is they'll do something like peel test where they'll use very thick copper and peel it off to see what kind of strength it had between the copper and substrate. With our technology, we're typically using very thin copper, so you won't be able to generate those same kinds of forces because the copper simply won't support it. In light of that, we think there's a need to investigate other methods for testing for this

adhesion before you get to something like thermal cycling.

Matties: When a buyer, OEM, or whatever the level happens to be is considering a change, what's the impetus for them to change? Is it the finer lines alone, or is there an economic advantage?

Vinson: There are some economic advantages to using less material. From that point of view, it's attractive, but the change in the line and processing is usually the biggest hurdle that they have to overcome to be able to adopt.

Matties: You mentioned cellphones earlier, which makes a lot of sense. What sort of qualification process is taking place and what duration do you typically see in that?

Vinson: We're not as familiar with what this next generation is going to be seeing in terms of qualifications, but we are seeing that things like microvias are now coming under a lot more scrutiny than they did in the past; they're evolving harsher testing for that. Because what we're doing with our technology will eliminate a lot of those problems at the source, we'll be able to better serve those markets. We've been doing multiple reflow tests, etc., to be sure that the microvias don't crack. We're going to see a lot more of that in the near future for these products.

Matties: Along the lines of testing, what yields should someone expect? Is this a high-yield process?

Vinson: Relatively speaking, yes, but like all new technologies, there's going to be a learning curve that everyone has to go through to increase their yields to an acceptable point. The other issue is that if you look at the yield as a per-circuit value instead of a per-square-inch or per-layer value, you'll find that the yield challenges in the future are going to be much higher due to a lot more circuits. Just talking to somebody today, they're looking at 10,000 I/Os on a device, and they're trying to circuitize that. Well, the yields on that product aren't going to be nearly the same as if you have a simple white goods board that you're trying to produce for a dishwasher.

Matties: How many fabricators that have already adopted this are out there?

Vinson: We have a couple right now that are in the process of qualifying it. We also have a number of products that are going into early production phase with companies. As far as actual volume production, we're still in the early stages of that.

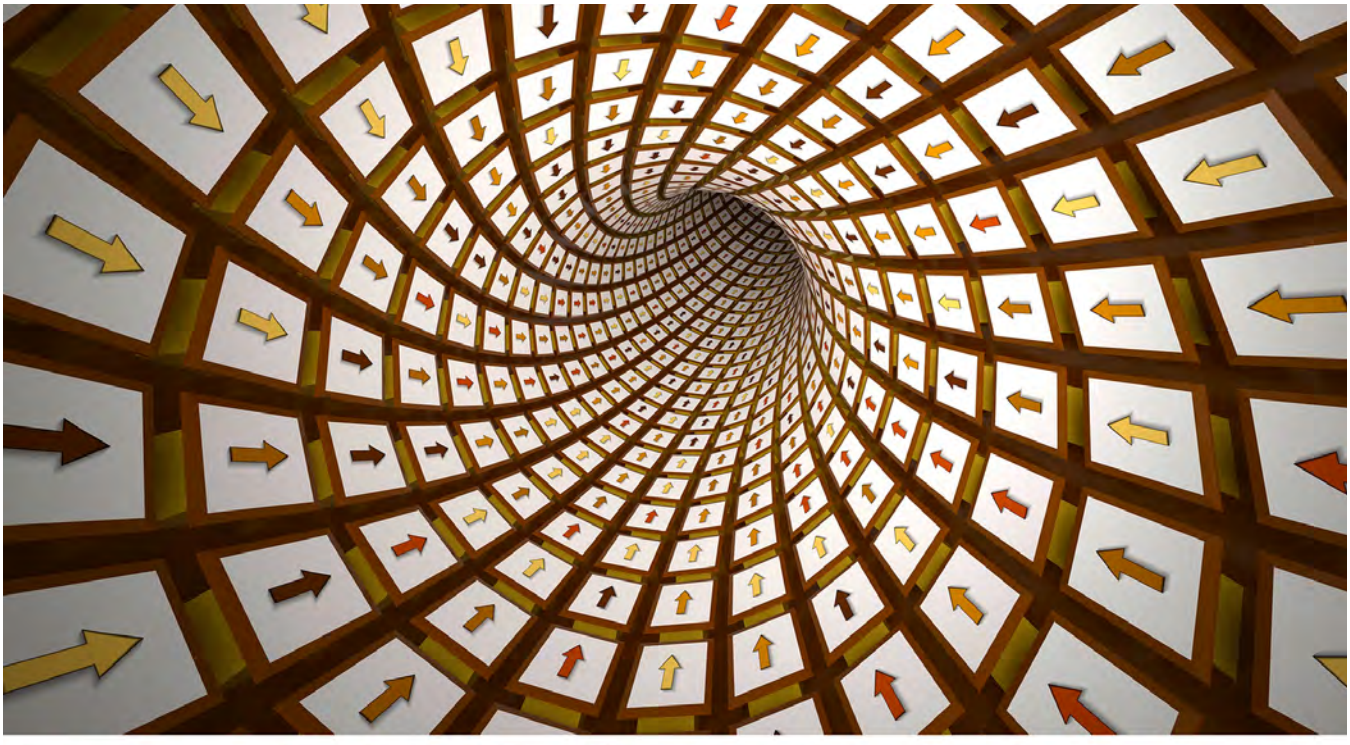
Matties: We'll be interested to hear updates. Is there anything that we haven't talked about that you want to add?

We think this technology trend will lend itself well to much thinner circuitry for the less complex products and also more viable technology for the more complex products.

Vinson: One of the things that we're finding when we go to smaller and smaller circuit sizes is that often, someone who's making a 16-layer or 10-layer board can go to a 10-layer or an eight-layer or six-layer board because they're doing finer lines and spaces now and don't have to use as many layers just for routing buses. We think this technology trend will lend itself well to much thinner circuitry for the less complex products and also more viable technology for the more complex products.

Matties: Great. Thank you very much, Mike.

Vinson: Thank you, Barry. PCB007



Electrolytic Plating: Filling Vias and Through-holes

Article by Mustafa Özkök, Sven Lamprecht, Akif Özkök, Dolly Akingbohungbe, Moody Dreiza, ATOTECH DEUTSCHLAND GMBH, **Alex Stepinski,** GREENSOURCE FABRICATION LLC

The electronics industry is further progressing in terms of smaller, faster, smarter, and more efficient electronic devices. This continuously evolving environment caused the development of various electrolytic copper processes for different applications over the past several decades.

This article describes the reasons for development and a roadmap of dimensions for copper-filled through-holes, microvias, and other copper-plated structures on PCBs. It will also discuss aspect ratios, dimensions, and results of plated through-holes used today in high-volume manufacturing for microvia and through-hole filling with electroplated copper. Furthermore, this article will also show feasibility studies of new electroplated structures for future applications, such as copper pillar plating on IC substrates.

Four Main Drivers

Four main drivers forced the chemical supply industry to introduce new electrolytic copper processes with the new feature of "filling" capability over the years. The first driver is the continuous miniaturization of electronics. The first blind microvias were introduced with HDI technology in the late 1980s and early 1990s. In 1996, the IC substrate market started to fill the microvias.

"Plugging" technologies were introduced to stack the microvias to save space or create via-in-pad structures. This plugging technology with conductive paste is very expensive because of the additional process steps required. In addition, this technology faced several disadvantages, such as "blow out," outgassing, smear, and other quality concerns. To achieve the necessary miniaturization benefits, the in-

ventec
INTERNATIONAL GROUP
騰輝電子

tec-speed 20.0

Dk 3.0-3.48

No More Compromises
Performance, Price & Availability

SUPERIOR
loss
characteristics

GREATER
reliability

UNRIVALED
high frequency
performance

Visit
www.ventecsolutions.com/tec-speed-20

ventec-speed

dustry has been leaning towards the completely copper filled blind microvia rather than a plugged microvia as the leading edge solution. Today, copper-filled microvias are the standard for almost all HDI PCB manufacturers.

The second driver is the thermal management on a substrate. One source [1] said it this way:

"As the power and packing density of electronic components increase, the amount of waste heat generated in a small space also rises greatly. This results in dangerously high temperatures, and thus increases the failure risk of electronic devices. Today, 55% of electronic component failures are caused by increased temperatures alone."

Solutions were needed to integrate features with high thermal conductivity to manage the heat transfer on the substrates from one side to the other to minimize hot spots on the electronic devices over a lifetime. Higher-performing chips tend to generate local hot spots, resulting in material degradation and premature field failure. Integration of thermal vias in high-performance electronics can minimize the occurrence of hot spots; therefore, their utilization in the industry has become more widespread.

In the beginning, thermal vias were nothing more than standard conformal vias, but the thermal conductivity was not good enough. Following that, plugging pastes were introduced to enhance the thermal conductivity of a standard through-hole. But in this case, similar disadvantages of plugging appeared. Meanwhile, complete copper-filled through-holes were realized in 2006 by bridge plating or X-plating technology. Today, completely copper-filled through-hole structures are at the leading edge of technology for thermal via structures because copper has almost the best thermal conductivity—and it has to be plated, nonetheless.

The third driver is signal frequency. Electronic signal frequencies in an electronic package or inside of a PCB are increasing over time and continue to do so. Stacked microvias and fan-out vias are becoming more and more of a disadvantage for the transmission of high-frequency signals due to creating resistances at high frequencies. Thus, the push of high-frequency applications further increased the demand for technologies like copper-filled through holes. Right now, 5G infrastructure is already using the copper-filled through-hole technology in the field of smartphones.

The fourth driver, especially for through-hole filling, is the quality-and-yield aspect. The alternatives for electroplated copper-filled through-holes require many additional process steps or new materials, such as plugging paste (explained in Figure 6 later in this article). Each of these additional process steps or materials introduces a variety of risks and manufacturing problems, resulting in a lower yield. Therefore, the "one-step" solution to fill through-holes with copper is the preferred solution without introducing new materials into the PCB.

Microvia Filling With Copper

The filling of microvias with copper was established as a standard in PCB HDI production more than 20 years ago. For example, there was the introduction of supervia filling technology with very low plated-copper thickness on the surface (Figure 1).

Meanwhile, the copper filling of microvias replaced many other filling technologies, such as plugging and capping realized by paste printing and overplating with copper (Figure 2). Both technologies—plugging and capping and copper-filled microvias—enable the so-called via-in-pad structure (Figure 3), which has the advantage for PCB designers. The advantages of the via-in-pad designs are also useful for high-speed designs.

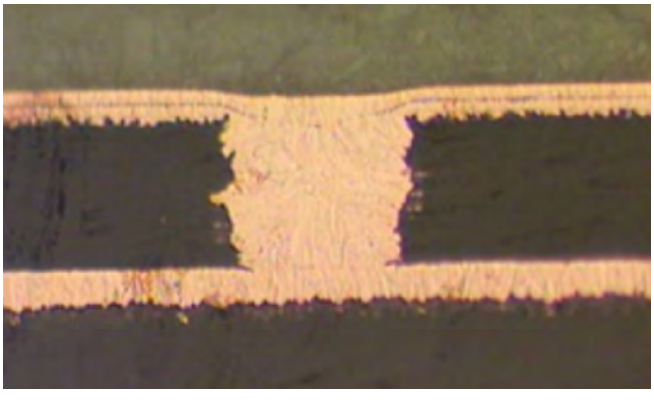


Figure 1: Patented "SuperFilling" technology.

Figure 2: Plugged and capped microvia [2].

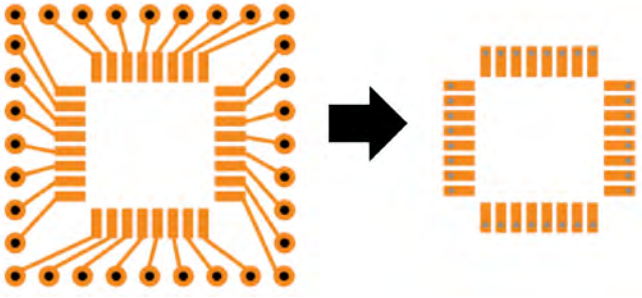


Figure 3: TQFP footprint with vias and via-in-pads [3].

Additionally, copper-filled microvias have significant advantages over plugging technology. For instance, the material inside the microvia is copper while other materials have the potential to outgas or introduce different CTE values. Moreover, voids in copper-filled microvias are far less common than with poorly controlled conventional plugging methods.

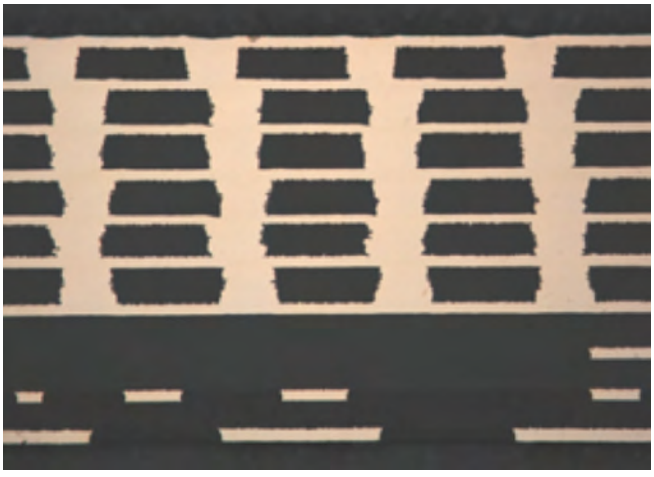


Figure 4: Any layer technology stacked and filled with electrolytic plated copper.

The development and introduction of copper-filled microvias opened the door to introduce any layer HDI technology (Figure 4), which enables copper-filled through-holes by stacking the copper-filled microvias. This kind of feature enables HDI board designers the flexibility to create complex signal paths through the PCB by just using copper filled microvias.

Today, almost all critical dimensions of microvias may be filled inclusion-free with copper. Table 1 shows the microvia dimensions that can be filled in horizontal and vertical

BMV Diameter [µm]	BMV depth [µm]																												
	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150
200	0,1	0,1	0,1	0,1	0,2	0,2	0,2	0,2	0,3	0,3	0,3	0,3	0,4	0,4	0,4	0,4	0,5	0,5	0,5	0,5	0,6	0,6	0,6	0,6	0,7	0,7	0,7	0,7	0,8
190	0,1	0,1	0,1	0,1	0,2	0,2	0,2	0,2	0,3	0,3	0,3	0,3	0,4	0,4	0,4	0,4	0,5	0,5	0,5	0,6	0,6	0,6	0,6	0,7	0,7	0,7	0,7	0,8	0,8
180	0,1	0,1	0,1	0,1	0,2	0,2	0,2	0,3	0,3	0,3	0,3	0,4	0,4	0,4	0,4	0,5	0,5	0,5	0,6	0,6	0,6	0,6	0,7	0,7	0,7	0,8	0,8	0,8	0,8
170	0,1	0,1	0,1	0,1	0,2	0,2	0,2	0,3	0,3	0,3	0,4	0,4	0,4	0,4	0,5	0,5	0,5	0,6	0,6	0,6	0,6	0,7	0,7	0,7	0,8	0,8	0,8	0,9	0,9
160	0,1	0,1	0,1	0,2	0,2	0,2	0,3	0,3	0,3	0,3	0,4	0,4	0,4	0,5	0,5	0,5	0,6	0,6	0,6	0,7	0,7	0,7	0,8	0,8	0,8	0,8	0,9	0,9	0,9
150	0,1	0,1	0,1	0,2	0,2	0,2	0,3	0,3	0,3	0,4	0,4	0,4	0,5	0,5	0,5	0,6	0,6	0,6	0,7	0,7	0,7	0,8	0,8	0,8	0,9	0,9	0,9	1,0	1,0
140	0,1	0,1	0,1	0,2	0,2	0,3	0,3	0,3	0,4	0,4	0,4	0,5	0,5	0,5	0,6	0,6	0,6	0,7	0,7	0,8	0,8	0,8	0,9	0,9	0,9	1,0	1,0	1,0	1,1
130	0,1	0,1	0,2	0,2	0,2	0,3	0,3	0,3	0,4	0,4	0,5	0,5	0,5	0,6	0,6	0,7	0,7	0,7	0,8	0,8	0,8	0,9	0,9	1,0	1,0	1,0	1,1	1,1	1,2
120	0,1	0,1	0,2	0,2	0,3	0,3	0,3	0,4	0,4	0,5	0,5	0,5	0,6	0,6	0,7	0,7	0,8	0,8	0,8	0,9	0,9	1,0	1,0	1,0	1,1	1,1	1,2	1,2	1,3
110	0,1	0,1	0,2	0,2	0,3	0,3	0,4	0,4	0,5	0,5	0,5	0,6	0,6	0,7	0,7	0,8	0,8	0,9	0,9	1,0	1,0	1,0	1,1	1,1	1,2	1,2	1,3	1,3	1,4
100	0,1	0,2	0,2	0,3	0,3	0,4	0,4	0,5	0,5	0,6	0,6	0,7	0,7	0,8	0,8	0,9	0,9	1,0	1,0	1,1	1,1	1,2	1,2	1,3	1,3	1,4	1,4	1,5	1,5
90	0,1	0,2	0,2	0,3	0,3	0,4	0,4	0,5	0,6	0,6	0,7	0,7	0,8	0,8	0,9	0,9	1,0	1,1	1,1	1,2	1,2	1,3	1,3	1,4	1,4	1,5	1,6	1,6	1,7
80	0,1	0,2	0,3	0,3	0,4	0,4	0,5	0,6	0,6	0,7	0,8	0,8	0,9	0,9	1,0	1,1	1,1	1,2	1,3	1,3	1,4	1,4	1,5	1,6	1,6	1,7	1,8	1,8	1,9
70	0,1	0,2	0,3	0,4	0,4	0,5	0,6	0,6	0,7	0,8	0,9	0,9	1,0	1,1	1,1	1,2	1,3	1,4	1,4	1,5	1,6	1,6	1,7	1,8	1,9	1,9	2,0	2,1	2,1
60	0,2	0,3	0,3	0,4	0,5	0,6	0,7	0,8	0,8	0,9	1,0	1,1	1,2	1,3	1,3	1,4	1,5	1,6	1,7	1,8	1,8	1,9	2,0	2,1	2,2	2,3	2,3	2,4	2,5
50	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1,0	1,1	1,2	1,3	1,4	1,5	1,6	1,7	1,8	1,9	2,0	2,1	2,2	2,3	2,4	2,5	2,6	2,7	2,8	2,9	3,0
40	0,3	0,4	0,5	0,6	0,8	0,9	1,0	1,1	1,3	1,4	1,5	1,6	1,8	1,9	2,0	2,1	2,3	2,4	2,5	2,6	2,8	2,9	3,0	3,1	3,3	3,4	3,5	3,6	3,8
30	0,3	0,5	0,7	0,8	1,0	1,2	1,3	1,5	1,7	1,8	2,0	2,2	2,3	2,5	2,7	2,8	3,0	3,2	3,3	3,5	3,7	3,8	4,0	4,2	4,3	4,5	4,7	4,8	5,0
20	0,5	0,8	1,0	1,3	1,5	1,8	2,0	2,3	2,5	2,8	3,0	3,3	3,5	3,8	4,0	4,3	4,5	4,8	5,0	5,3	5,5	5,8	6,0	6,3	6,5	6,8	7,0	7,3	7,5
10	1,0	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0	5,5	6,0	6,5	7,0	7,5	8,0	8,5	9,0	9,5	10,0	10,5	11,0	11,5	12,0	12,5	13,0	13,5	14,0	14,5	15,0

	AR: 0.50–2.00		Non critical aspect ratio
	AR: 0.03–0.49	AR: 2.01–3.00	Feasible aspect ratio
	AR: 0.20–0.29	AR: 3.01–5.00	Leading edge aspect ratio
	AR: < 0.5	AR: >5.0	Limited data

The numbers inside the cells reflect the aspect ratio (AR)

Table 1: Copper-filled microvias (dimensions that can be filled today).

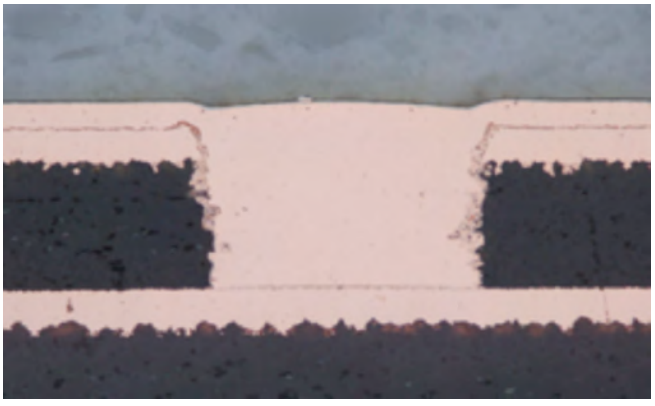


Figure 5: Copper-filled microvia cross-section plated with a leading-edge copper electrolyte.

plating equipment. The numbers inside the cells reflect the aspect ratios. The table represents the capability of various electrolytic copper formulations on the market. Each electrolytic copper recipe has its own characteristic abilities with regards to aspect ratio.

The leading-edge electrolytic formulation for microvia filling (Figure 5) has the following characteristics:

- Plated with a current density of up to 2.5 A
- Creates a ductility of 25%
- Tensile strength of 35 kNm²
- Dimple of less than 5 µm; plating time < 40 minutes
- 13 µm copper thickness on surface; at the same time, filling a 100*89 µm microvia completely

Through-hole Filling With Copper

The through-hole filling of holes with copper in mass production has its roots in 2005. The introduction of X-plating or bridge plating was the beginning. The bridging technology was developed to fill a through-hole completely with copper while avoiding inclusions. Such a completely filled through-hole does have many advantages for the design of electronic PCBs, such as thermal conductivity and signal integrity in high-frequency boards.

A filled through-hole may be realized in different ways. It may be plugged by a paste or filled by an electrolytic copper plating process. For larger hole sizes (i.e., diameter > 500 µm), the plugging by a thermally conductive paste is the main process used. For smaller hole sizes (i.e., diameter < 500 µm, feasible aspect ratio AR > 0.5 and < 5.0), the copper filling using the bridge plating technology shows many advantages compared to paste plugging. First, the bridge plating technology needs fewer manufacturing steps compared to paste plugging (Figure 6). This has a significant benefit for the production cost.

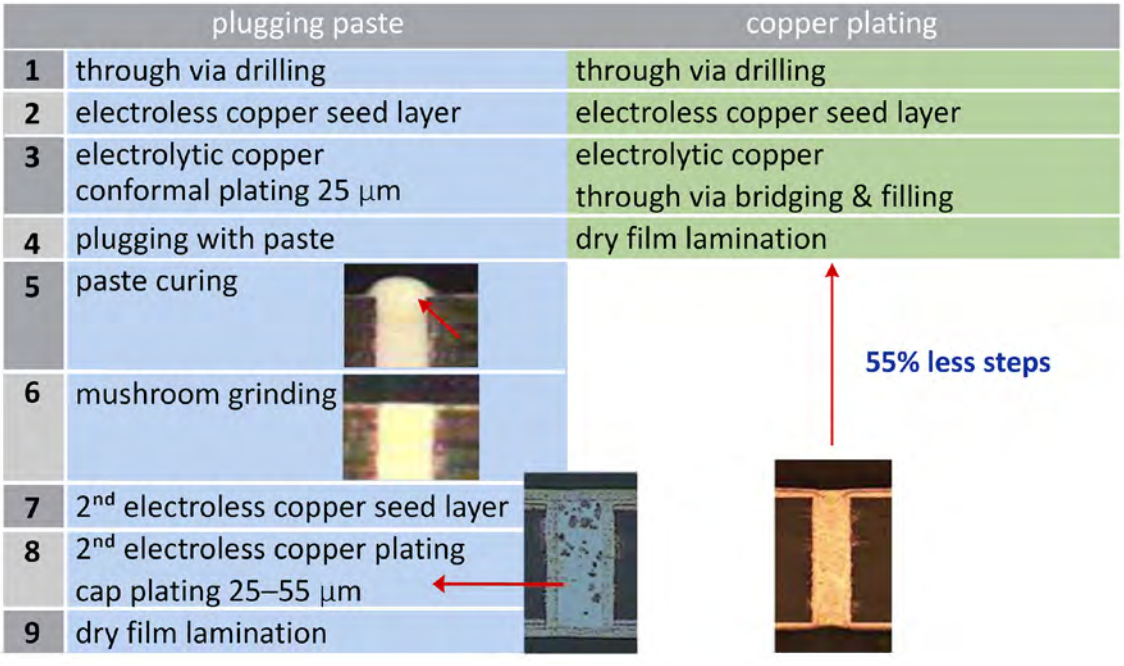
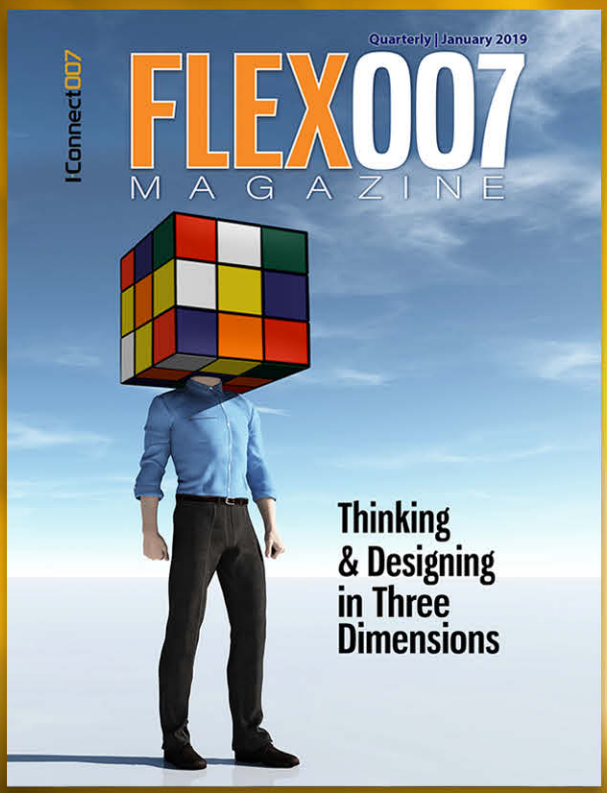


Figure 6: Plugging paste versus copper plating through-hole filling.



With original content dedicated specifically to flex system and PCB designers, electrical engineers and those responsible for integrating flex into their products at the OEM/CEM level, you won't want to miss a single issue of ***Flex007 Magazine!***

Subscribe **Contribute** **Advertise**

I·Connect007
GOOD FOR THE INDUSTRY

Layer Material	Thermal conductivity
Plugging Paste	~ 2–8 W/mK
Copper	~ 390 W/mK

Table 2: Thermal conductivity of copper versus plugging paste.

Layer Material		Total Thermal Resistance
25-µm copper on side wall		122 K/W
Filled with:	Plugging paste	116 K/W
	Copper	37 K/W

Table 3: Thermal resistance of copper versus plugging paste (e.g., 1-mm board thickness, 0.3-mm diameter, 25-µm copper barrel).

Bridge plating technology offers a further advantage in terms of thermal conductivity compared to filling materials. Copper delivers one of the best thermal conductivity properties compared to lower thermal conductivity properties of any plugging paste on the market (Tables 2 and 3).

This advantage enables PCB designers to reduce the number of thermal vias by about 70% while focusing on thermal conducting and cooling efficiency at hotspots.

As illustrated in Figure 7, there are three reliability concerns with plugged vias that are negated by copper plating. Whereas the void (1) and dimple (2) are related to process control (lower risk), the blistering (3) is related to material and dimension. The CTE mismatch of copper (16.5 ppm) compared to plugging paste (30–50 ppm) may result in a blister. These three phenomena on plugged vias have been investigated [4].

Whereas plugging with paste may create all three phenomena (Figure 7, right picture), the blistering phenomenon (3) is negated by using copper as the filling material. The formation void (1) can also be avoided fully using modern copper through-hole filling processes, which operate void-free. This is achieved using automated and sophisticated equipment controls during the copper bridging and filling process. Furthermore, the dimple (2) is also controlled below 5 µm with the right settings on the copper process. These avoidance techniques are simply not possible when plugging a through-hole via by a high-viscosity plugging paste enabled using screen print methods.

Bridge-plating technology works as follows. During the first copper electroplating plating process, a copper bridge is formed (Figure 8a). This bridge plating is the key to fill the hole. After this step, only two microvias on the top and the bottom are left, which will be filled with copper by one or more subsequent microvia filling steps (Figure 8b–c).

The copper bridge plating process works best with a horizontal copper plating process because the horizontal system offers key advantages in terms of fluid dynamics inside the hole. This promotes the generation of void-free plating results, very low plated-copper thickness on the surface, a much better copper uniformity, and higher throughput compared to vertical plating units.

The dimensions of through-holes that are achievable with filled copper are illustrated in

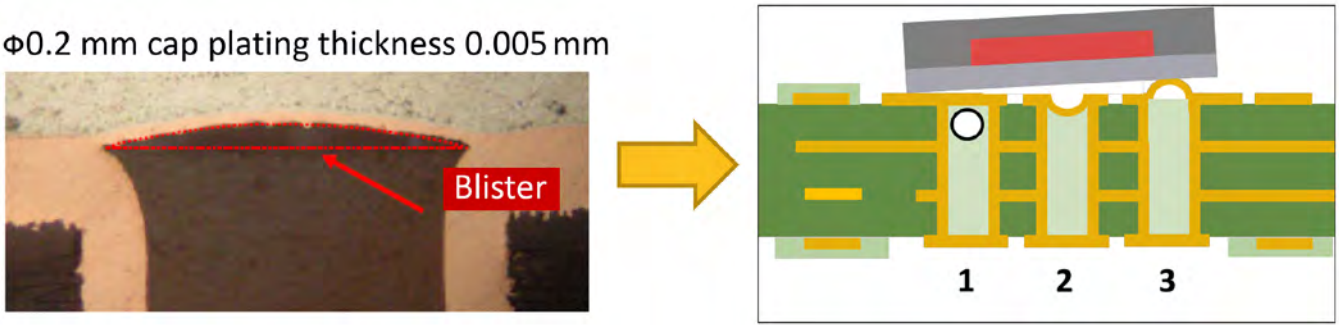


Figure 7: Plugging paste versus copper plating through-hole filling [4 & 5].

Figure 8 (a-c): Copper filling of a through-hole with patented "Bridge-Plating."

Hole Diameter [mm]	Board Thickness [mm]																				
0,50	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1,0	1,1	1,2	1,3	1,4	1,5	1,6	1,7	1,8	1,9	2,0
0,45	0,1	0,2	0,3	0,4	0,6	0,7	0,8	0,9	1,0	1,1	1,2	1,3	1,4	1,6	1,7	1,8	1,9	2,0	2,1	2,2
0,40	0,1	0,3	0,4	0,5	0,6	0,8	0,9	1,0	1,1	1,3	1,4	1,5	1,6	1,8	1,9	2,0	2,1	2,3	2,4	2,5
0,35	0,1	0,3	0,4	0,6	0,7	0,9	1,0	1,1	1,3	1,4	1,6	1,7	1,9	2,0	2,1	2,3	2,4	2,6	2,7	2,9
0,30	0,2	0,3	0,5	0,7	0,8	1,0	1,2	1,3	1,5	1,7	1,8	2,0	2,2	2,3	2,5	2,7	2,8	3,0	3,2	3,3
0,25	0,2	0,4	0,6	0,8	1,0	1,2	1,4	1,6	1,8	2,0	2,2	2,4	2,6	2,8	3,0	3,2	3,4	3,6	3,8	4,0
0,20	0,3	0,5	0,8	1,0	1,3	1,5	1,8	2,0	2,3	2,5	2,8	3,0	3,3	3,5	3,8	4,0	4,3	4,5	4,8	5,0
0,15	0,3	0,7	1,0	1,3	1,7	2,0	2,3	2,7	3,0	3,3	3,7	4,0	4,3	4,7	5,0	5,3	5,7	6,0	6,3	6,7
0,10	0,5	1,0	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0	5,5	6,0	6,5	7,0	7,5	8,0	8,5	9,0	9,5	10,0
0,05	1,0	2,0	3,0	4,0	5,0	6,0	7,0	8,0	9,0	10,0	11,0	12,0	13,0	14,0	15,0	16,0	17,0	18,0	19,0	20,0
	0,05	0,10	0,15	0,20	0,25	0,30	0,35	0,40	0,45	0,50	0,55	0,60	0,65	0,70	0,75	0,80	0,85	0,90	0,95	1,00

	AR: 0.50-2.00		Non critical aspect ratio
	AR: 0.03-0.49	AR: 2.01-3.00	Feasible aspect ratio
	AR: 0.20-0.29	AR: 3.01-5.00	Leading edge aspect ratio
	AR: < 0.5	AR: >5.0	Limited data

The numbers inside the cells reflect the aspect ratio (AR)

Table 4: Copper-filled through-holes (dimensions that can be filled today).

Table 4. This table is based on various commercially available copper electrolytes used in the latest generation horizontal plating equipment.

Current research and development efforts regarding copper through-hole filling cover the following topics:

- Faster processing time (cost driven)
- Plating less copper on the surface (cost driven)
- Increasing the uniformity (technology driven)
- Better filling performance, low dimple (technology driven)
- Keeping the void-free level (quality driven)
- Selecting parameters to plate higher aspect ratios

Other New Electroplating Copper Technologies

As the technology of filling microvias and through-holes is already established and in production, the electronics market requires newer features, such as pillar plating realized on IC substrates or smaller RDL (redistribution layer) structures, to enable panel level packaging (PLP) on the IC substrate level. That development has already progressed quite far. A newer equipment approach with recently developed copper electrolytes does enable these technologies. The first copper plating equipment of this new generation offers the following:

1. Plating of a target copper thickness of 6 µm on a 600x600-mm panel with a copper thickness distribution of less than 5% (Figure 9)

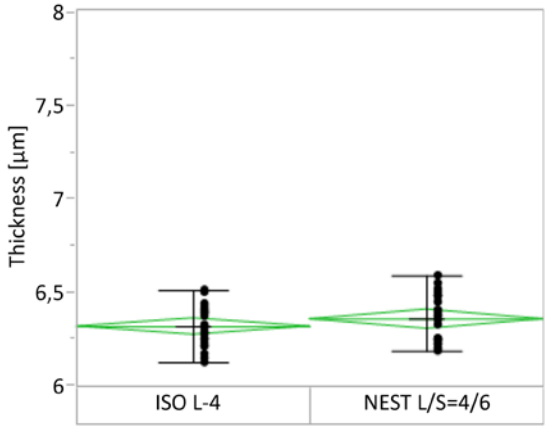


Figure 9: Achieved copper thickness distribution on a 600x600-mm panel.

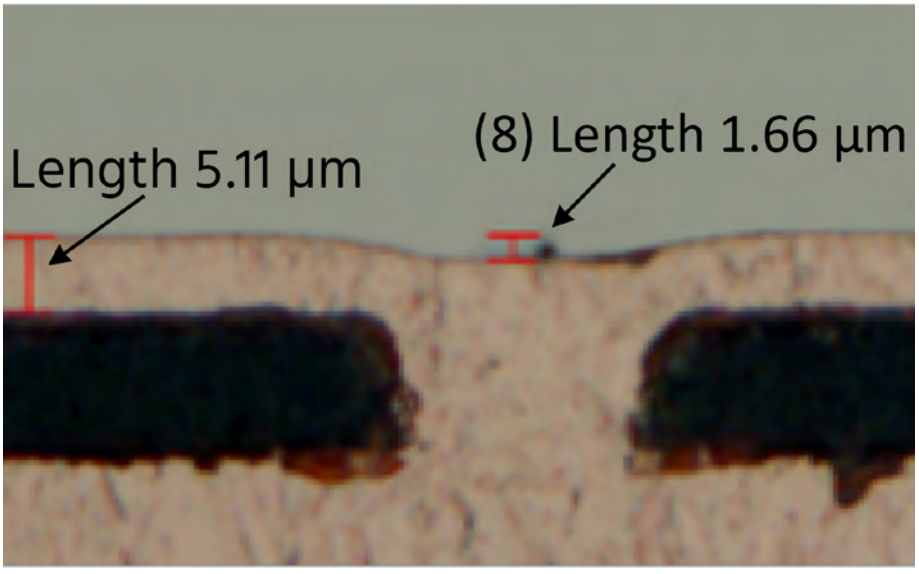


Figure 10: Achieved copper thickness distribution on a 600x600-mm panel.

2. Capable of filling microvias with a size of 15x10 µm by having only 5 µm plated thickness on the surface and a dimple less than 2 µm (Figure 10)

Furthermore, this new plating tool enables panel-level packaging technology on IC substrates. This allows the IC substrates industry to compete with the semiconductor wafer level packaging technologies and plate new features, such as copper pillars.

Summary

This paper presents the actual status of microvia filling and through-hole filling realized by electrolytic copper plating processes. The dimensions of microvias and through-holes that can be filled by electrolytic copper processes today were shown. Further, the copper-filling technologies versus paste plugging were compared and the benefits of the copper filling technologies have been illustrated. The scope of future developments in terms of microvia filling and through-hole filling have been addressed. Next-generation technology segments, such as panel level packaging (PLP) and plating of copper pillars on IC substrates realized by a novel electrolytic copper plating processes, were also considered. **PCB007**

References

1. Fraunhofer IZM website.
2. Würth Elektronik, chapter micro via filling.
3. Stack Exchange, chapter via-in-pad technology.
4. Sano, S. "Current state and future trends of PCBs in AVIO." Netherlands: Fifth EMPPS workshop, Ch. 3.1, pp. 11-14, 2014.
5. Lamprecht, S. "Plating a thermal runaway in PCBs: Solid copper through via filling." IPC workshop, Ch. 3.1, pp. 11-14, 2018.

Mustafa Özkök is the global product manager for panel and pattern plating and works in the Atotech office in Berlin.

Sven Lamprecht is the director OEM/EMS technology exchange for Atotech.

Dolly Akingbohungbe is a lead field service chemical process engineer for Atotech.

Moody Dreiza is the business director for electronics, North America, Atotech.

Alex Stepinski is the VP and officer of GreenSource Fabrication LLC.

Akif Özkök is an inventor and patent holder for Atotech.

Get the spark you need to tune up your sales team.

When an engine doesn't fire on all cylinders, performance is limited. The same goes for your sales team. We provide the spark to get your sales to the next level ...and beyond.

We've helped dozens of companies big and small improve their bottom line.

db MANAGEMENT GROUP

Learn how we can help YOU

207-649-0879 danbbeaulieu@aol.com

OSP Performance: Effect of Film Thickness and Microetch

Trouble in Your Tank

by Michael Carano, RBP CHEMICAL TECHNOLOGY

Two often overlooked performance attributes for organic solderability preservatives (OSPs) are the organic film thickness and the topography of the copper after microetch. Film thickness up to an extent is critical. However, the copper topography and surface preparation also play a role.

Thus, you should not overlook the critical nature of the overall OSP film thickness. Of course, thickness alone is not sufficient to ensure solderability. The uniformity of the organic film coupled with the film's ability to minimize oxidation are important as well. The topography of the copper surface influences the uniformity of the OSP film as well as its thickness.

Microetching

Ensuring a clean and properly etched copper surface is necessary to affect the uniform deposition of the organic film on the copper surface. Concerns with thinner organic film where there is significant roughness of the copper are well-founded. Internal studies have shown that hydrogen peroxide microetchants impart a smoother topography to the copper surface than persulphate-based etchants. It is recommended that excessive microroughening be avoided. The concern is that with excessive roughness on the copper, there will be areas that have an insufficient thickness of OSP. In these situations, the thin areas will be more prone to oxidation (Figure 1). Some chemical processes impart rather large roughness profiles, such as those used to enhance solder mask adhesion; these types of etchants should be avoided.

The previously described condition becomes more of an issue when the OSP film thickness is thin. But again, the thickness of the overall film does not necessarily imply that thicker is better. It is more about the uniformity of the

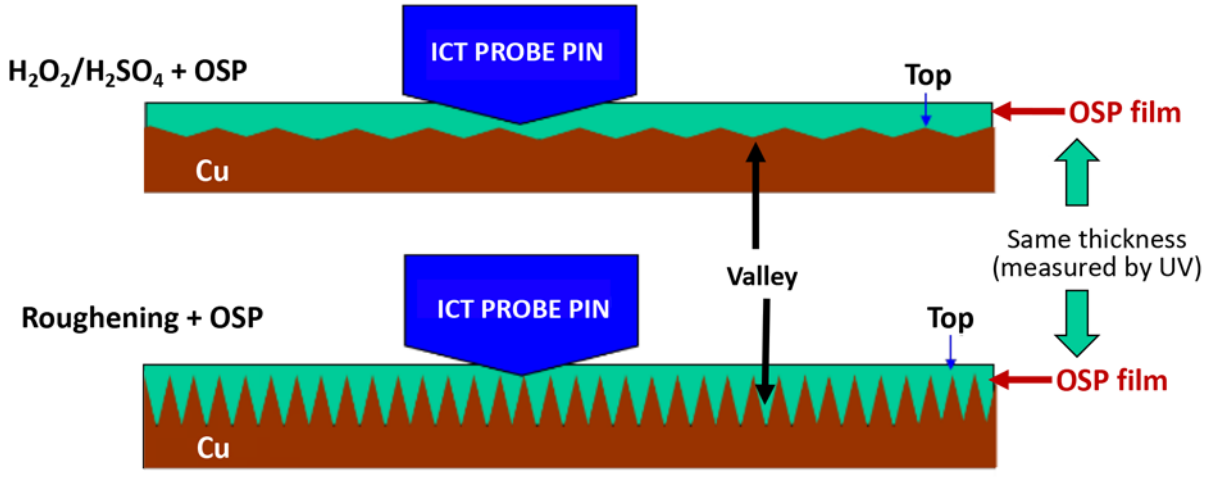


Figure 1: The bottom image shows excessive roughness leading to areas where the OSP film is thin.

Excellon

Manufacturers of precision Micro-Machining Solutions for over 50 Years

COBRA II

Hybrid laser system

689

6-station precision drilling and routing system

HS-1L DS

Single-station, dual spindle high-speed system

136L

High accuracy and speed

154L

Large panel applications

HS-2L

2-station, high speed

Move into the future with the latest innovations in Fabrication Technology from the Industry Leader!

www.excellon.com

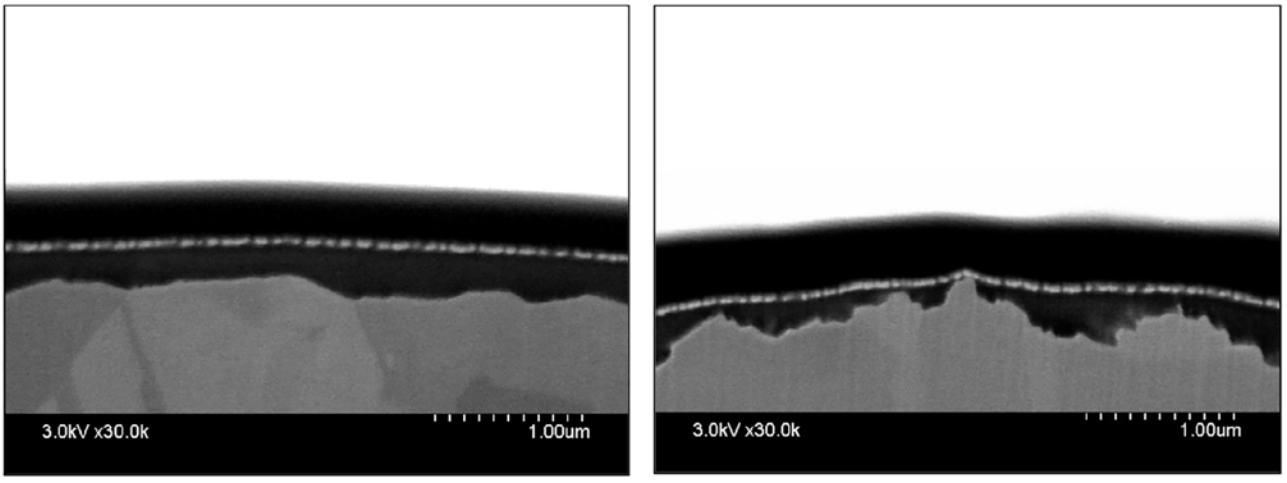


Figure 2: OSP film over a peroxide-sulfuric acid etched surface (L) and OSP film over a heavily microroughened surface (R).

OSP film and thickness over the peaks and valleys on the microetched copper surface (Figure 2). As a rule of thumb, an OSP film thickness of 1,500–2,000 angstroms (0.15–0.20 microns) is sufficient for lead-free assembly. However, that means minimum thickness over the thinnest areas of the profile.

To ensure sufficient operating window for lead-free assembly with OSP, increase the film thickness to 2,500–3,000 angstroms. Regardless, do not overlook the importance of surface topography and its influence on the solderability or surface preparation. Compare the two pictures in Figure 3; on the left is a copper surface is cleaned with scrubbing only, and on the right is the scrubbed surface with OSP. No other surface preparation was used.

Note the dark spots on the right image; these dark spots represent areas on the copper surface where the OSP is too thin or non-existent, which will lead to poor solderability. Again, ensure that the pre-clean line before OSP provides a clean, virgin copper surface with a uniformly etched surface. Ideally, 20–40 microinches of copper should be removed.

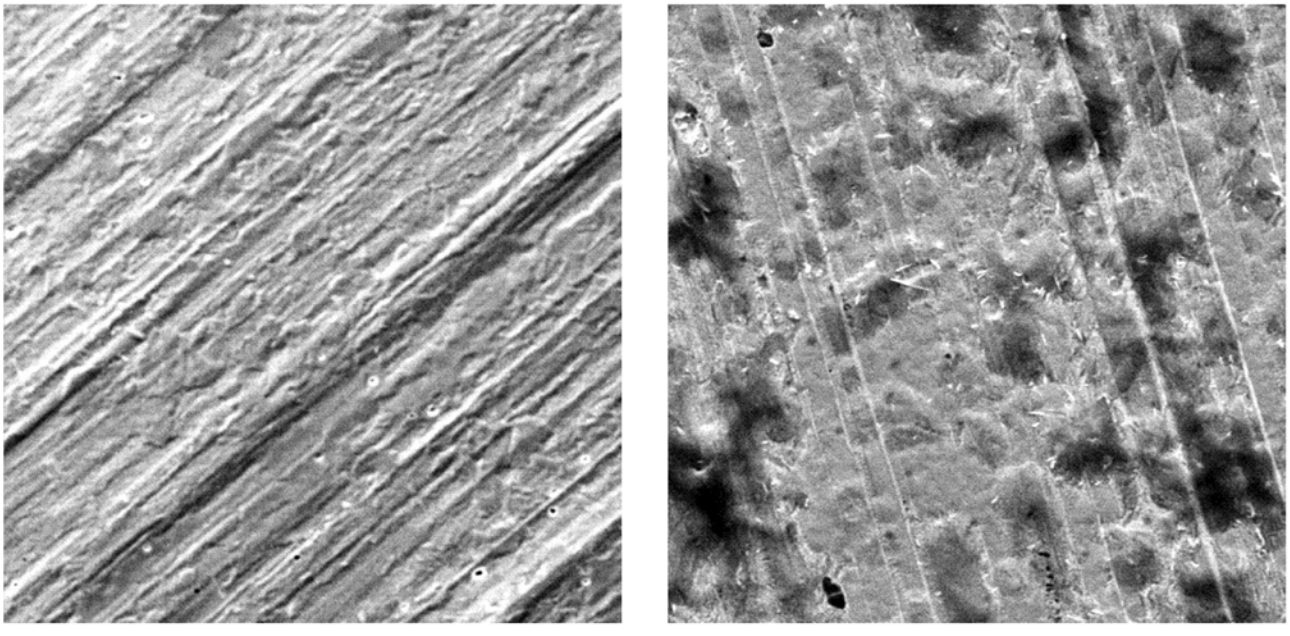


Figure 3: Improperly prepared surface with (L) a scrubbed surface and (R) a scrubbed surface with OSP.

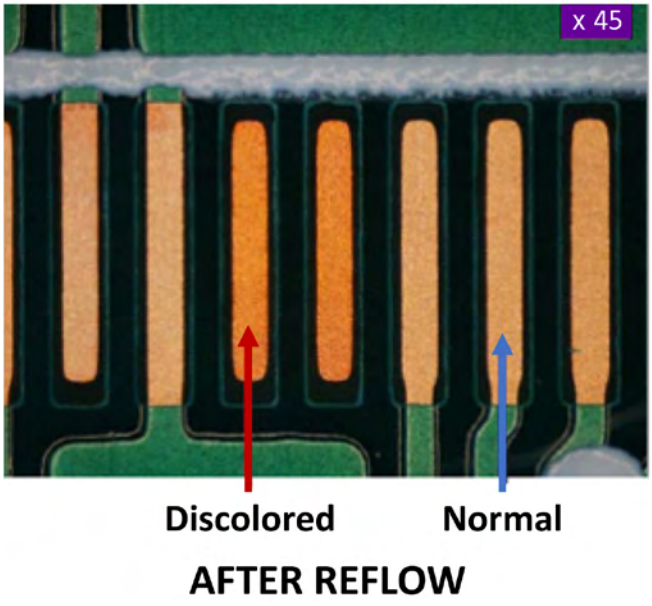


Figure 4: Surface showing both discoloration and normal copper surface after processing in OSP.

In case of insufficient microetching, the copper surface will show a dark color when exposed to air (Figure 4). The discoloration is due to the formation of cupric oxide. This type of oxidation will diminish solderability and further impact solder joint reliability. When the OSP film is too thin or not properly formed over the copper surface, oxygen can more easily reach the copper surface, which leads to discoloration. With increased exposure time and temperatures, the color of the copper layer changed from yellow to red-brown.

The discoloration is particularly troublesome when complex assembly and advanced packaging applications are in use. With respect to the latter, the solder ball attachment equipment must visually detect the solder ball point; in turn, this is required for the machine to be properly aligned with the OSP-coated bonding pad. The discoloration will interfere with the machine vision system and lead to low yields. While a light discoloration shown in Figure 5 will most likely not adversely affect solderability, such a condition will interfere with proper solder ball alignment to the BGA feature. **PCB007**

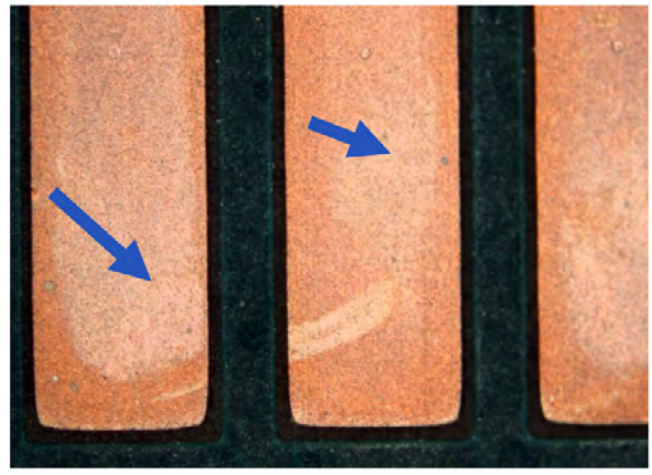


Figure 5: Slight discoloration of OSP-protected copper with arrows pointing to discoloration.

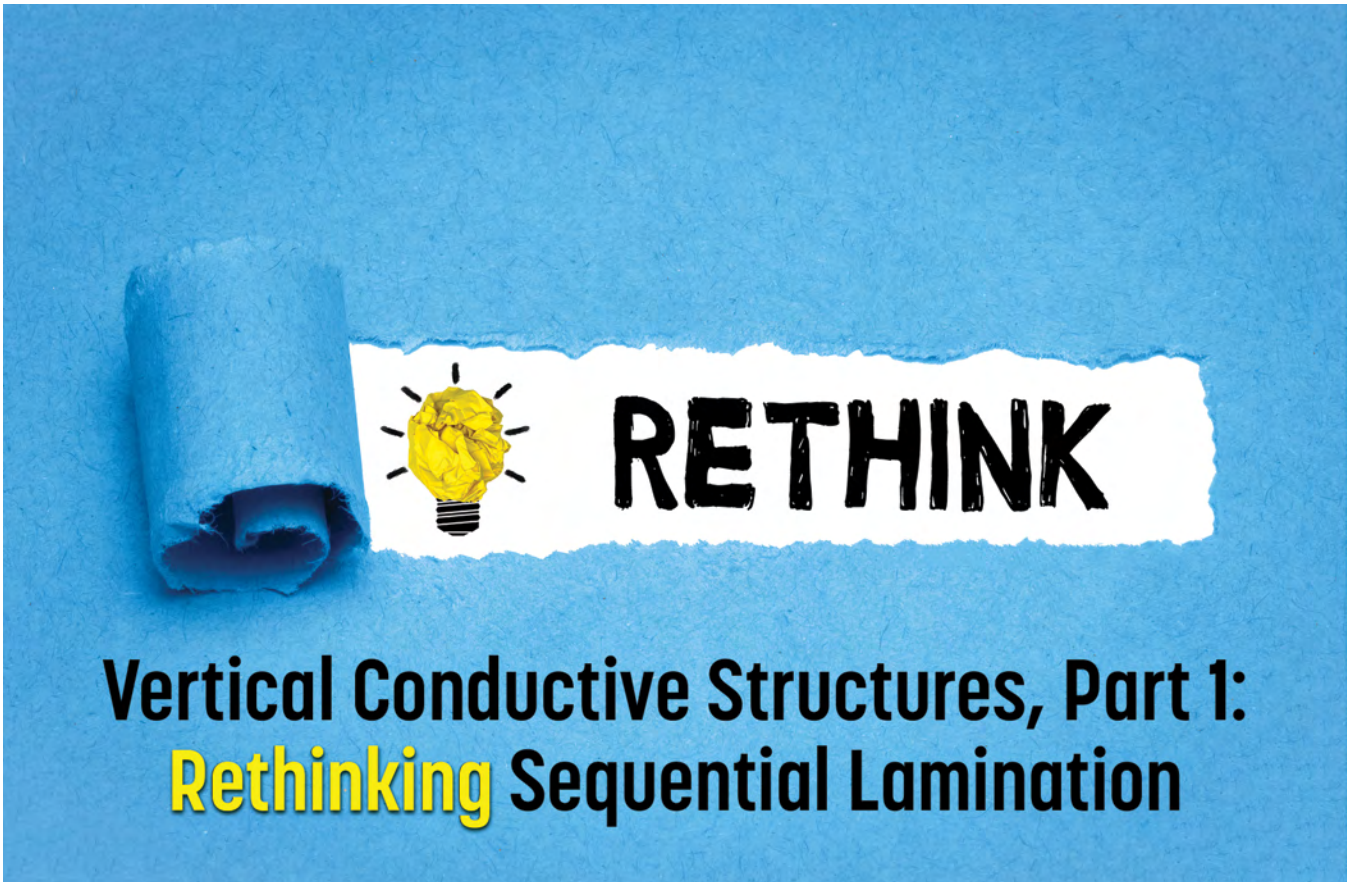
Michael Carano is VP of technology and business development for RBP Chemical Technology. To read past columns or contact Carano, click here.

Agfa on Revolutionary Inkjet Solder Mask Applications

Does inkjet solder resist have the potential for volume production? Mariana Van Dam, global sales manager of PCB imaging solutions, and Dr. Frank Louwet, business unit manager of advanced coatings and chemicals, speak with I-Connect007 Technical Editor Pete Starkey about Agfa's latest developments, plus some novel applications for inkjet etch and plating resists.

The group discusses inkjet solder mask development at Agfa, and how they are validating the ink at a selective number of customer sites over the past year. "Optimization between ink, printer, and software requires a lot of capacity. Cooperating at a specific customer site builds a lot of know-how, and the ink and system are tuned to one another. Doing this effort in parallel for all printers would be tough to organize, but we are open to cooperate with any and all worldwide," said Louwet.

To read th interview, click here. (Source: I-Connect007)



Vertical Conductive Structures, Part 1: Rethinking Sequential Lamination

Article by Joan Tourné
NEXTGIN TECHNOLOGY

Sequential lamination, as it is used today in high density interconnect (HDI) and derivative technologies, is constrained by the fact that one cannot plate a blind hole deeper than the diameter of the hole. A larger hole allows processes to plate deeper. In fact, this manufacturing constraint has made it a challenge even to reliably plate and process blind holes up to a 1:1 aspect ratio (AR).

NextGIn Technology, a technology company based in Helmond, the Netherlands, took up the challenge to redesign PCB lamination techniques to be easier to fabricate, to increase performance, and to lower fabrication cost in comparison to current technologies. The constraint set by NextGIn Technology was to use only current fabrication processes and tools available in the board shops. Using no new equipment, NextGIn set out to develop new processes for existing facilities. To do this, NextGIn needed to rethink the possibilities for what can be done with the capital equipment and processes. NextGIn has named this new process "vertical conductive structure" or VeCS.

Traditional manufacturing constraints stipulate that to plate deeper, a larger diameter hole is required. And yet, there is often no additional space in the board design for bigger holes. Perhaps the shape of the hole can be rethought. An oblong hole or slot, for example, would allow the hole to be cut up in multiple structures. The limit to plating is the size of the holes. One can plate a blind hole as long as you respect the AR of 1:1. Even the 1:1 AR can be a challenge to plate reliably, but to fit it into the current design footprint is not an option.

Cutting holes into multiple sections has been on the research and development agenda of the interconnect industry for some decades but work to turn the technique into a process has not been successful to date. NextGIn started by modifying the shape of the hole. An oblong shape structure was created that was broken into multiple sections to form the contacts. In the initial plating experiments, this oblong


PRINT ON DEMAND
ORDER NOW
Automation and Advanced Procedures in PCB Fabrication
Happy Holden
DOWNLOAD NOW
I-007e Books
I-007eBooks.com/automation

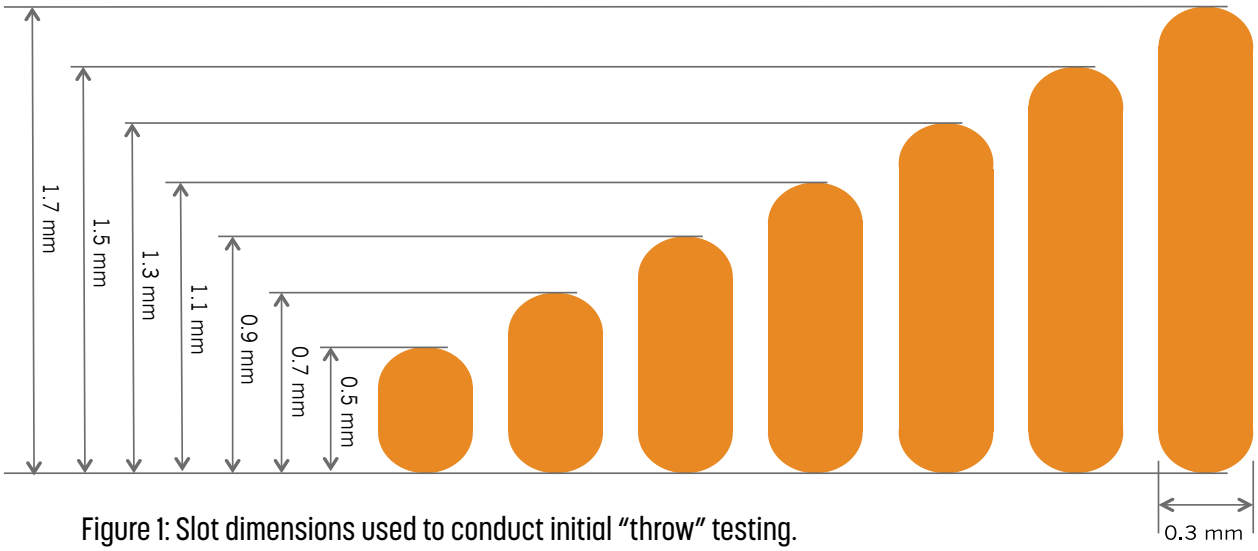


Figure 1: Slot dimensions used to conduct initial "throw" testing.

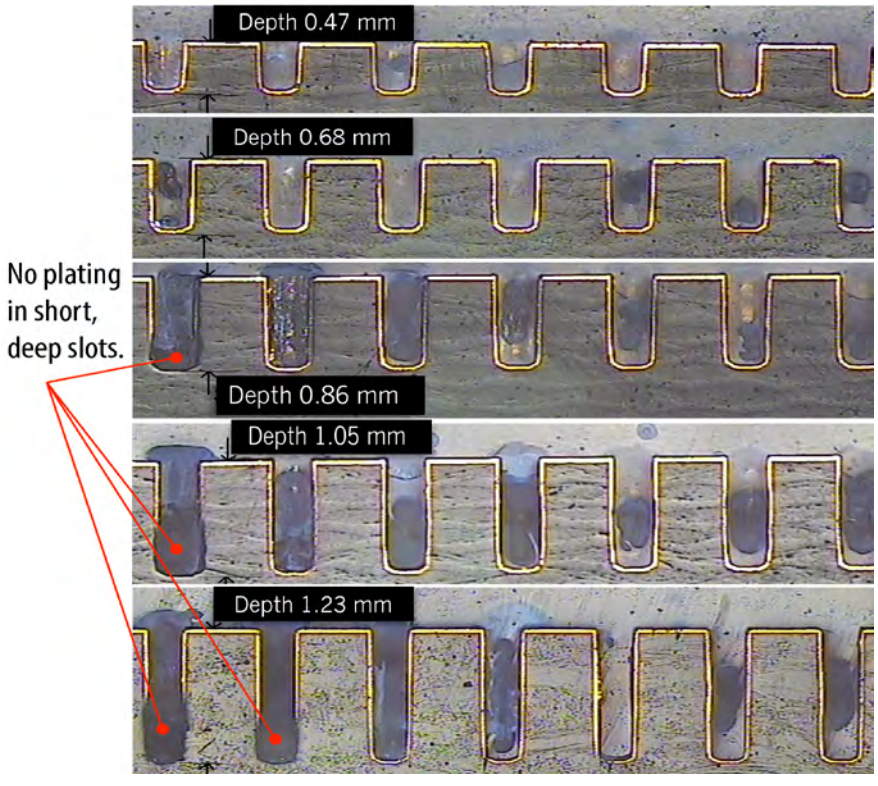


Figure 2: Test results, demonstrating that the more a slot resembles a circle, the shorter the plating "throw" capability.

shape showed good to average "throw" in the blind slots (Figures 1 and 2).

Our results showed that the longer the slot, the easier it is to plate. Shorter and deeper slots tend to exhibit a threshold beyond which they experience a lack of plating. The threshold is defined by the depth and length of the slot. Presently, we target an AR threshold of maximum 4:1 in our designs with a ratio of slot length to slot width at a minimum of 3:1.

An interesting development from this initial work is that the AR definition for a blind slot now requires an additional dimensional variable. Along with slot width, depth, and the new parameter, length. Ultimately, the objective is to create deep slots up to 2 mm for regular circuit boards and even 3 mm for more advanced products. In addition to the slot depth, NextGIn's experiments concentrated on slot diameters in the region of 0.2–0.5 mm. NextGIn selected this range because larger slot widths are not as useful with respect to BGA component footprints, and smaller width slots—width of interest—are difficult to form reliably for production due to the stability and useful life of the mechanical drill bits.

Copper Plating Tests

Naturally, plating thicknesses in the slot need to comply with industry standards. In Figure 2, the cross-sections show the results of plating a

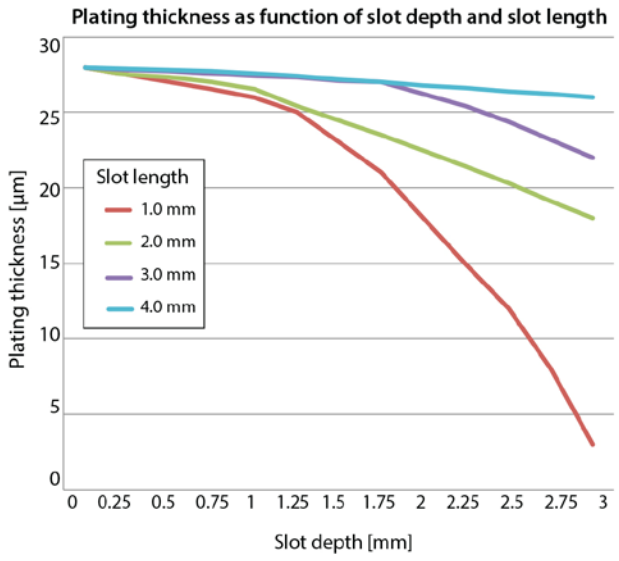


Figure 3: Plating thickness as a function of slot depth and length.

blind structure with simple panel plating systems under standard, everyday conditions.

Figure 3 shows plating results with respect to the slot length and slot depth. Note that for these tests, NextGIn used plating processes at standard parameters and chemistry types. The method of plating was electroless copper followed by a panel plate to the required copper thickness in the slot targeting a thickness of 25 µm.

The data shows that there will be a limit in terms of the length/width ratio to the depth of the slot in the order of 2 mm deep with a slot length of a minimum of 1 mm and a slot width of 0.5 mm. Longer slots will extend the plating capability of the slot (Figure 4).

Note that for application specific process reasons, this work has only addressed copper plating; the plating of the etch-resistant tin is

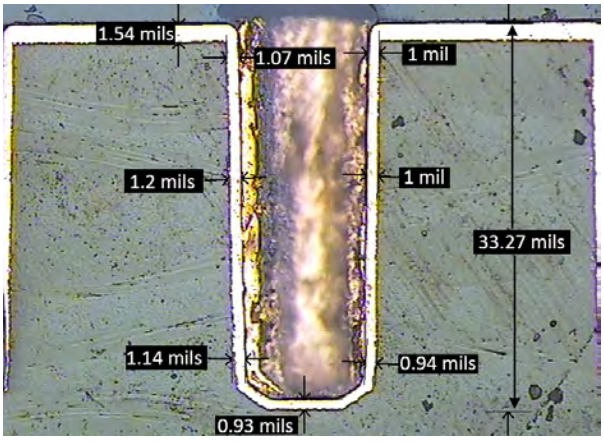


Figure 4: Example of a plated slot with a slot width of 0.3 mm.

not currently a focus. This choice was made because the applications chosen for this technique at present will fill the slots before finishing the external layers.

Plating Deep Blind Structures

Next is plating deep blind structures. This process accesses the internal layers without breaking through the opposite side of the board, which also avoids multiple lamination cycles. This enables new applications and complex structures in design without the manufacturing complexity of multiple laminations. In the designs, NextGIn sees this process as contributing to lower board fabrication costs and higher data rates thanks to better-tuned impedance in the vertical connections (impedance will be discussed in detail later in this series).

Figure 5 shows an example of the density to which components can be placed on two sides of the circuit without interference between the

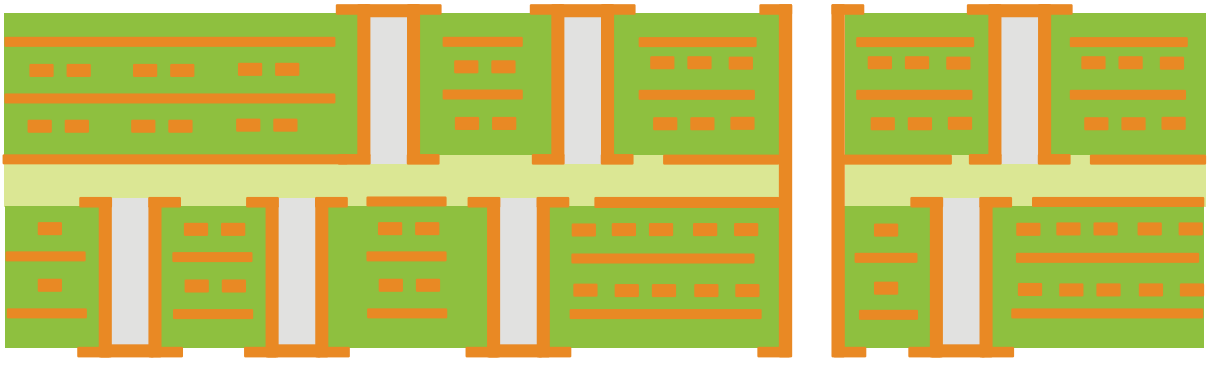


Figure 5: Practical examples of plating deep blind structures with VeCS.

top and bottom sides. Again, this is without the need for sequential lamination.

Note that the traditional double-blind via construction uses three lamination cycles: two for the half product and the third to laminate both half products together. In contrast, NextGIn's process at this point in fabrication has used only a single lamination cycle.

Building the Vias

Next in the process is buried via construction, using microvias on both sides of the buried via. The microvia can be placed on top or next to the buried via. Placing it on top requires an additional plating cycle.

The microvia constructions in Figures 5 and 6 can be replaced by a single lamination cycle using VeCS-2 (blind slot) as shown in Figure 7. The routing and power plane density can be increased using VeCS-2. This will yield a lower cost price for the same product as the layer count can be decreased as well.

Using VeCS-2 delivers two-side component placement capabilities similar to conventional

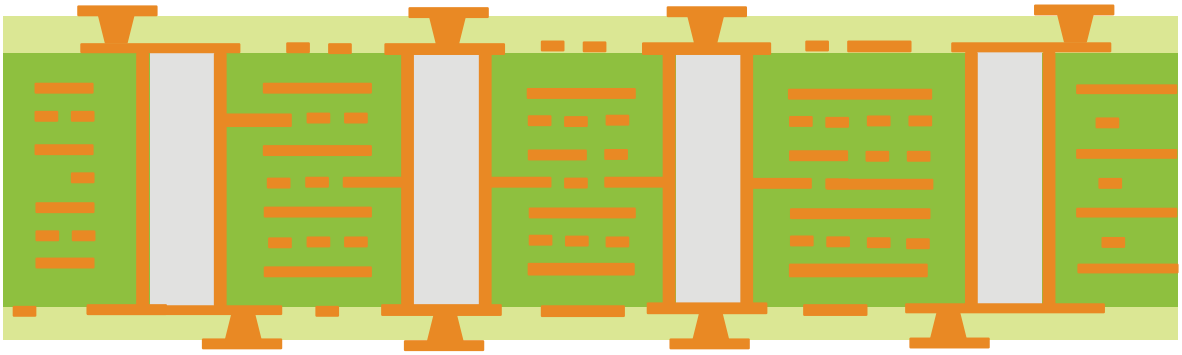


Figure 6: Traditional microvia constructions that can be replaced by VeCS.

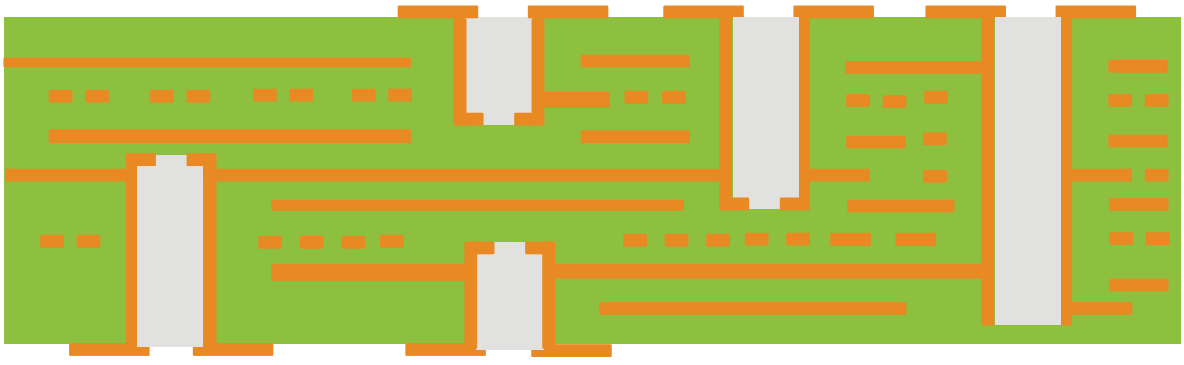


Figure 7: Single-lamination VeCS with a blind slot.

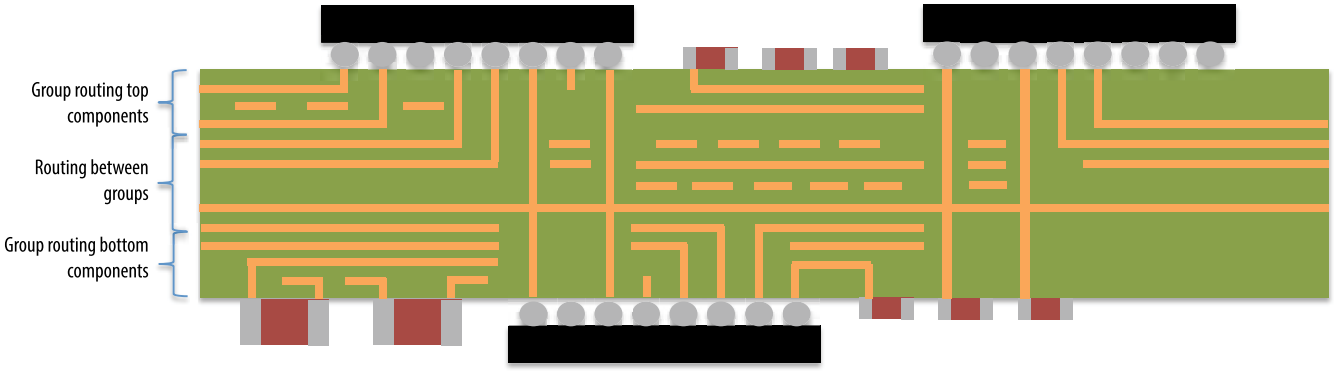


Figure 8: Two-sided component placement using VeCS.

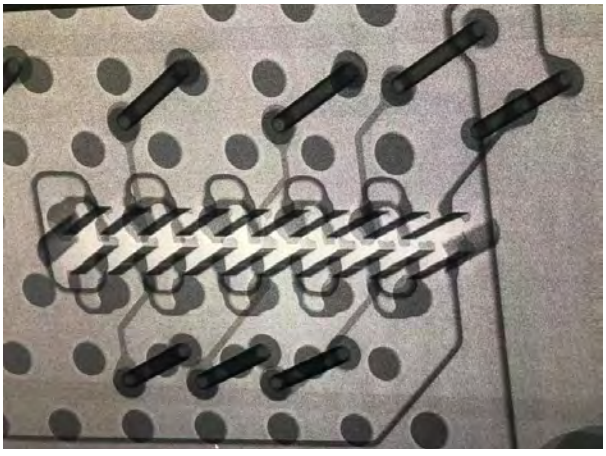


Figure 9: VeCS slot under magnification.

double-blind and buried via with microvia cap technology (Figure 8). The advantage is that we can do this using VeCS at a lower cost than the traditional sequential constructions as used today.

Figure 9 shows a VeCS-2 slot taken from the bottom side of the slot showing the vertical traces. Plated through-hole vias surround the slot via holes.

Acknowledgments

NextGIn wants to thank WUS PCB China for performing the work in fabrication the sample and making the cross-section results available. WUS has been a VeCS development partner over the last few years, demonstrating the capabilities of this new approach.

About NextGIn Technology

NextGIn Technology is a fabless company that develops and engineers solutions for the interconnect industry. It works with designers and fabricators in solving industry problems and will sell or license the technology to the industry. **PCB007**

Joan Tourné is CEO of NextGIn Technology BV.

Atomic-scale Binary Logic Could Power Faster, More Energy-efficient Electronics

Researchers at the University of Alberta have designed atomic-scale versions of the binary logic components that allow computer processors to perform complex operations—the latest in a series of advances that lay the groundwork for faster electronics that use far less power.

"The atom-scale devices we are developing create a new basis for computer electronics that will be able to run at least 100 times faster or operate at the same speed as today but using 100 times less energy," said atomic physicist Robert Wolkow.

The proof-of-concept devices Wolkow's team designed work much like logic gates in current microprocessors. But rather than using metal-oxide transistors mounted on silicon wafers, the atomic-scale logic gates use individual electrons confined in "quantum dots" directly on the silicon surface, dramatically reducing the space needed to pack millions of them into a microprocessor and the electricity needed to run them.

"Because our components are made of silicon, we make a straightforward marriage of the new atomic-scale technology with the standard CMOS technology that powers today's electronics, providing an easy entryway to market," said Wolkow.

This year alone, Wolkow and his team–supported by his graduate students and research associates at the U of A, the National Research Council of Canada, and the spinoff company Quantum Silicon Inc.–published research demonstrating an atomic-scale simulated computer circuit. This technique boosts the storage capacity of solid-state memory by 1,000 times, and they also developed a method for automated manufacturing of atomic-scale circuitry.

"Today's electronics have reached a point of maturation and can't be made any better," said Wolkow. "We have to stop using so much electricity to run our computers, and that means we need a drastic change in the kind of computers we use."

The research was published in *Nature Electronics*. Wolkow's work was supported by Western Economic Diversification Canada. (Source: University of Alberta)

Editor Picks from PCB007

1 Punching Out! Why Sell to a Private Equity Group? ▶


Tom Kastner

One category of buyers that is often overlooked is private equity groups. PCB/PCBA owners either think that their company would not be of interest to a non-strategic buyer, or they have a negative impression of financial buyers. Here are six reasons why companies should consider selling to a private equity group.

2 It's Only Common Sense: Eight Great Tips to Teach a New Salesperson—Listen! ▶


Dan Beaulieu

Today, all of us are working diligently on getting more young people involved in our industry. And many of those people are going to be involved in sales. To help you with developing that training, here are eight great tips to teach a new salesperson.

3 Gene Weiner on the IPC APEX EXPO 2019 Automotive Executive Forum ▶


Gene Weiner

Dan Feinberg spoke with Gene Weiner, president and CEO of Weiner International Associates, about IPC's history of forums, his thoughts on the Executive Forum on Advancing Automotive Electronics at IPC APEX EXPO 2019, and how the IPC Hall of Famers and the industry can help improve forum success.

4 Flex/MSTC Joint Conference: A Collaborative Week in Monterey ▶


Nolan Johnson

Collaboration filled the air at the Hyatt Regency in Monterey, California, as the 18th annual Flex/MEMS & Sensors technical conference brought flex technology and sensor experts and 550+ attendees together to network and share their ideas.

5 Institute of Circuit Technology Evening Seminar ▶

The Institute of Circuit Technology hosted its first 2019 seminar at the Woodland Grange Hotel in Royal Leamington Spa in the Midlands of England.


Martin Goosey

6 IPC Issues Warning on Microvia Reliability for High-performance Products ▶

The proliferation of tighter microvia densities and signal integrity requirements in printed boards within the electronics industry has revealed reliability concerns with microvia structures in high-performance products.

7 American Standard Circuits Acquires Lenz Router ▶

PCB fabricator American Standard Circuits (ASC) recently acquired the RLG 550-2 routing machine from Lenz.

8 Taiwan PCB Firms Gear Up Mass Production for iPads, AirPods ▶

Flexible PCB firms Flexium Interconnect and Zhen Ding Technology are gearing up for mass production for Apple Inc.'s next-generation iPad devices while Compeq Manufacturing and Unitech PCB supply rigid-flex boards for the forthcoming AirPods.

9 ALBA PCB Acquires Q-Print electronic ▶

ALBA PCB Group acquired majority shareholding of Q-Print electronic Gmbh.

10 TTM Technologies to Sell Viasource Service ▶

TTM Technologies Inc. and Linkage Technologies Inc. announced the sale of TTM's "Viasource" PCB broker service to Linkage for an undisclosed amount. TTM does not expect any material impact on its financials as a result of this transaction.

For the Latest PCB News and Information, Visit: PCB007.com

Career Opportunities

Pssst! Are You Looking for Someone?

Place your notice in our Help Wanted section.

For just $500, your 200 word, full-column—or, for $250, your 100 word, half-column—ad will appear in the Help Wanted section of all three of our monthly magazines, reaching circuit board designers, fabricators, assemblers, OEMs and suppliers.

Potential candidates can click on your ad and submit a résumé directly to the email address you've provided. If you wish to continue beyond the first month, the price is the same per month. No contract required. We even include your logo in the ad, which is great branding!

To get your ad into the next issue, contact:
Barb Hockaday at barb@iconnect007.com or +1.916.608.0660 (-7 GMT)

I-Connect007
GOOD FOR THE INDUSTRY

smt007 pcb007 pcb design007

Career Opportunities

APCT
Passion | Commitment | Trust

APCT, Printed Circuit Board Solutions: Opportunities Await

APCT, a leading manufacturer of printed circuit boards, has experienced rapid growth over the past year and has multiple opportunities for highly skilled individuals looking to join a progressive and growing company. APCT is always eager to speak with professionals who understand the value of hard work, quality craftsmanship, and being part of a culture that not only serves the customer but one another.

APCT currently has opportunities in Santa Clara, CA; Orange County, CA; Anaheim, CA; Wallingford, CT; and Austin, TX. Positions available range from manufacturing to quality control, sales, and finance.

We invite you to read about APCT at APCT.com and encourage you to understand our core values of passion, commitment, and trust. If you can embrace these principles and what they entail, then you may be a great match to join our team! Peruse the opportunities by clicking the link below.

Thank you, and we look forward to hearing from you soon.

apply now

TAIYO AMERICA

Technical Service Engineer (PCB Process Engineer)

Plano, Texas

PRIMARY FUNCTION:
To provide expert technical advice on production and engineering issues in the application of solder mask and other Taiyo products.

ESSENTIAL DUTIES:
- Troubleshoot customer problems
- Conduct technical audits
- Advise and consult on product evaluations
- Conduct technical presentations
- Frequent travel to customer facilities (travel required, up to 50% of the time)
- Write trip/audit reports
- Coordinate travel arrangements to realize significant transportation savings
- Respond to and write email messages
- Write monthly reports
- Prepare agendas for customers, detailing goals and objectives
- Must comply with all OSHA and company workplace safety requirements at all times

OTHER DUTIES:
- Other duties as assigned from time to time

REQUIRED EDUCATION/EXPERIENCE:
- College degree preferred with solid knowledge of chemistry
- 10 years of technical work experience in the printed circuit board (PCB) industry
- Computer knowledge
- Good interpersonal relationship skills

WORKING CONDITIONS:
- Occasional weekend or overtime work

apply now

Career Opportunities

Multiple Positions Available

The Indium Corporation believes that materials science changes the world. As leaders in the electronics assembly industry we are seeking thought leaders that are well-qualified to join our dynamic global team.

Indium Corporation offers a diverse range of career opportunities, including:

- Maintenance and skilled trades
- Engineering
- Marketing and sales
- Finance and accounting
- Machine operators and production
- Research and development
- Operations

For full job description and other immediate openings in a number of departments:

www.indium.com/jobs

apply now

Field Service Engineer: Multiple U.S. Locations

Reporting to a regional service manager, these customer-focused engineers will uphold the Koh Young culture while delivering professional technical services for our award-winning portfolio of inspection solutions. The role will enthusiastically visit our growing list of customers for installations, training, and evaluations, as well as technical support and maintenance.

We are looking for candidates with a technical degree or equivalent plus three or more years in a production environment with relevant experience. Given our growing customer base, the position will require extensive travel, including some internationally, as well as a collaborative attitude that drives success.

Koh Young is the leading 3D measurement-based inspection equipment and solutions provider. We perform quality control and process optimization across a growing set of industries including PCBA, machining, final assembly, process manufacturing, and semiconductors. In addition to our corporate office in Seoul, our international sales and support offices help us maintain a close relationship with our customers and provide access to a vast network of inspection experts.

Join the industry's leading provider of true 3D inspection solutions. Forward your resume to Michelle.Hayes@KohYoung.com.

apply now

Career Opportunities

Vision and Machine Learning R&D Engineer

Atlanta, GA or San Diego, CA

At Koh Young, we are focused on developing the future and continue to bolster our newly established R&D center near San Diego, California, with top talent focused on vision engineering and machine learning for electronics and medical applications. Currently, we are collaborating with top medical universities and hospitals across the U.S., Korea, and Japan to develop innovative neurosurgical robotic systems. With core technologies developed in-house, we expect to deliver neurosurgical breakthroughs.

The role will develop practical, scalable 3D machine learning solutions to solve complex challenges that detect, recognize, classify, and track medical imagery. Additional focus on the design, implementation, and deployment of full-stack computer vision and machine learning solutions.

The ideal candidates will hold a master's (doctorate preferred) in computer science or electrical engineering with at least three years of relevant experience. We desire a strong understanding of machine learning and computer vision algorithm application within embedded systems, plus significant vision expertise in multi-view geometry, 3D vision, SFM/SAM, and activity recognition.

Koh Young is the leading 3D measurement-based inspection solutions provider. We perform quality control and process optimization across a growing set of industries including electronics, final assembly, semiconductors, and most recently, medical imagery.

Join the 3D inspection leader as we expand. Forward your resume to Michelle.Hayes@KohYoung.com.

apply now

Service Engineer Reflow Soldering Systems (m/f)

To strengthen our service team at Rehm Thermal Systems llc. in Roswell, Georgia, we are seeking candidates to fill the position of Service Engineer—Reflow Soldering Systems.

Your area of responsibility:

- Installation of Rehm reflow soldering systems at the customers' site
- Maintenance and repair work as well as technical service for our customers in the USA and Mexico
- Execution of machine training

Your profile:

- Completed education studies as an engineer in the field of electrical engineering/mechatronics or comparable education (m/f)
- Basic and specialist knowledge in the field of electronics and electrical engineering/ mechatronics
- High willingness to travel and have flexible employment
- Service-oriented and like to work independently

We offer:

- Performance-oriented, attractive compensation
- Comprehensive training
- A safe workplace in one successful group of companies
- Self-responsibility and leeway

Please send application documents online to Natalie Werner at n.werner@rehm-group.com.

apply now

Career Opportunities

MacDermid Alpha ELECTRONICS SOLUTIONS

Technical Service Rep
Waterbury, CT

Do you have what it takes? MacDermid Alpha Electronics Solutions is a leading supplier of specialty chemicals, providing application-specific solutions and unsurpassed technical support.

The position of the Technical Service Rep will be responsible for day-to-day support for fabricators using MacDermid Alpha's chemical products. The position requires a proactive self-starter that can work closely and independently with customers, the sales group and management to ensure that customer expectations and company interests are served.

- Have a thorough understanding of the overall PCB business, and specifics in wet processing areas.
- Prepare action plans for identification of root cause of customer process issues.
- Provide feedback to management regarding performance.
- Create and conduct customer technical presentations.
- Develop technical strategy for customers.
- Possess the ability to calm difficult situations with customers, initiate a step-by-step plan, and involve other technical help quickly to find resolution.

Hiring Profile

- Bachelor's Degree or 5-7 years' job related experience.
- Strong understanding of chemistry and chemical interaction within PCB manufacturing.
- Excellent written and oral communication skills.
- Strong track record of navigating technically through complex organizations.
- Extensive experience in all aspects of Customer Relationship Management.
- Willingness to travel.

apply now

LIMATA

Service Engineer USA

Limata GmbH, a provider of direct imaging system solutions for the global PCB manufacturing industry and adjacent markets, is looking for qualified candidates to fulfill the role of service engineer in the United States.

Duties:

- Assemble, install, service, and maintain our products
- Inspect the unit towards operating conditions
- Solve technical problems on-site
- Resolve problems with our customers and technical department
- Ability to support our customers in all technical questions

Qualifications:

- Proven experience in microelectronics is preferred
- Willingness to travel
- Strong verbal and written communication skills

To be part of our team, please click below and send your resume to karriere@limata.de.

apply now

Career Opportunities

Manncorp™

SMT Operator
Huntingdon Valley, PA

Manncorp, a leader in the electronics assembly industry, is looking for a technician to operate our new in-house SMT LED assembly lines.

Duties and Responsibilities:
- Set up and operate automated SMT assembly equipment
- Prepare component kits for manufacturing
- Perform visual inspection of SMT assembly
- Participate in directing the expansion and further development of our SMT capabilities

Requirements and Qualifications:
- Prior experience with SMT equipment, or equivalent technical degree preferred
- Basic computer knowledge
- Proven strong mechanical and electrical troubleshooting skills
- Experience programming machinery or demonstrated willingness to learn
- Positive self-starter attitude with a good work ethic
- Ability to work with minimal supervision

We Offer:
- Paid training period
- Health and dental insurance
- Retirement fund matching
- Continuing training

apply now

Manncorp™

SMT Field Technician
Huntingdon Valley, PA

Manncorp, a leader in the electronics assembly industry, is looking for an additional SMT Field Technician to join our existing East Coast team and install and support our wide array of SMT equipment.

Duties and Responsibilities:
- Manage on-site equipment installation and customer training
- Provide post-installation service and support, including troubleshooting and diagnosing technical problems by phone, email, or on-site visit
- Assist with demonstrations of equipment to potential customers
- Build and maintain positive relationships with customers
- Participate in the ongoing development and improvement of both our machines and the customer experience we offer

Requirements and Qualifications:
- Prior experience with SMT equipment, or equivalent technical degree
- Proven strong mechanical and electrical troubleshooting skills
- Proficiency in reading and verifying electrical, pneumatic, and mechanical schematics/drawings
- Travel and overnight stays
- Ability to arrange and schedule service trips

We Offer:
- Health and dental insurance
- Retirement fund matching
- Continuing training as the industry develops

apply now

Career Opportunities

ventec
INTERNATIONAL GROUP
騰輝電子

Technical Support Engineer, Germany

We are looking for a technical support engineer to join our team at our German facility in Kirchheimbolanden. The successful candidate will assist potential and current customers in appreciating the benefits of using and optimizing the use of Ventec materials in their PCB manufacturing processes, enhance customer loyalty and satisfaction, spread the use of Ventec materials, and grow sales. The technical support engineer will provide a two-way channel of technical communication between Ventec's production facilities and U.K./European customers.

Skills and abilities required for the role:

- Scientific and technical educational background
- Experience in the PCB industry in engineering and/or manufacturing
- Strong communications skills (German and English) with the ability to write full technical reports for group or customer distribution
- Ability to work in an organized, proactive, and enthusiastic way
- Ability to work well both in a team as well as an individual
- Good user knowledge of common Microsoft Office programs
- A full driving license is essential
- Willingness to travel regularly throughout Europe and occasionally to Asia

We offer:

- Excellent salary and benefits commensurate with experience

This is a fantastic opportunity to become part of a successful brand and leading team with excellent benefits.

Please forward your resume to
applytoventec@ventec-europe.com

apply now

GO Gardien

Sales Personnel, Japan

The Gardien Group is looking to expand the sales team in Tokyo, Japan, and seeking highly motivated team players with a positive attitude. Prior experience in the PCB industry is an advantage but not necessary for the right candidate.

The role involves working closely with the customer to identify their needs and deliver the right solution. The candidate should be able to offer a high level of customer satisfaction to ensure ongoing sales.

Training will be provided along with a competitive benefits package, excellent growth opportunities, and periodic bonuses.

Interested candidates, please contact
us at careers.jp@gardien.com
with your resume.

Kindly note only shortlisted candidates will be notified.

apply now

Career Opportunities

U.S. CIRCUIT

Sales Representatives (Specific Territories)

Escondido-based printed circuit fabricator U.S. Circuit is looking to hire sales representatives in the following territories:

- Florida
- Denver
- Washington
- Los Angeles

Experience:

- Candidates must have previous PCB sales experience.

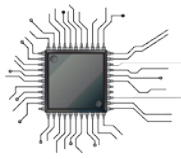
Compensation:

- 7% commission

Contact Mike Fariba for more information.

mfariba@uscircuit.com

apply now



MivaTek Global

Multiple Positions Available

Want to work for a fast-growing company? MivaTek Global may be the place for your next career move. 2018 has brought significant growth, increasing sales and revenue. And, we are just getting started! To support the current customer base and fuel further expansion, we are looking for bright and talented people who are energized by hard work in a supportive and flexible environment.

Open Positions:

- Technical Service Technicians
- Regional Sales Representatives
- Regional Leader for Asia Sales and Support

Proven experience in either PCB or Microelectronics and willingness to travel required for all positions.

More About Us

MivaTek Global is a distributor of manufacturing equipment with an emphasis of Miva Technologies' Direct Imager, Mask Writer, Flatbed Photoplotter imaging systems and Mach3 Labs X-Ray Drills. We currently have 45 installations in the Americas. Expansion into Asia during 2018 has led to machine installations in China, Singapore, Korea, and India.

To be part of our team, send your resume to n.hogan@kupertek.com for consideration of current and future opportunities.

apply now

Career Opportunities

ELECTROLUBE
THE SOLUTIONS PEOPLE

We Are Recruiting!

A fantastic opportunity has arisen within Electrolube, a progressive global electrochemicals manufacturer. This prestigious new role is for a sales development manager with a strong technical sales background (electro-chemicals industry desirable) and great commercial awareness. The key focus of this role is to increase profitable sales of the Electrolube brand within the Midwest area of the United States; this is to be achieved via a strategic program of major account development and progression of new accounts/projects. Monitoring of competitor activity and recognition of new opportunities are also integral to this challenging role. Full product training to be provided.

The successful candidate will benefit from a generous package and report directly to the U.S. general manager.

Applicants should apply with their CV to
melanie.latham@hkw.co.uk
(agencies welcome)

apply now

ZENTECH

Zentech Manufacturing: Hiring Multiple Positions

Are you looking to excel in your career and grow professionally in a thriving business? Zentech, established in Baltimore, Maryland, in 1998, has proven to be one of the premier electronics contract manufacturers in the U.S.

Zentech is rapidly growing and seeking to add Manufacturing Engineers, Program Managers, and Sr. Test Technicians. Offering an excellent benefit package including health/dental insurance and an employer-matched 401k program, Zentech holds the ultimate set of certifications relating to the manufacture of mission-critical printed circuit card assemblies, including: ISO:9001, AS9100, DD2345, and ISO 13485.

Zentech is an IPC Trusted Source QML and ITAR registered. U.S. citizens only need apply.

Please email resume below.

apply now

Career Opportunities

BLACKFOX
Premier Training & Certification

IPC Master Instructor

This position is responsible for IPC and skill-based instruction and certification at the training center as well as training events as assigned by company's sales/operations VP. This position may be part-time, full-time, and/or an independent contractor, depending upon the demand and the individual's situation. Must have the ability to work with little or no supervision and make appropriate and professional decisions. Candidate must have the ability to collaborate with the client managers to continually enhance the training program. Position is responsible for validating the program value and its overall success. Candidate will be trained/certified and recognized by IPC as a Master Instructor. Position requires the input and management of the training records. Will require some travel to client's facilities and other training centers.

For more information, click below.

apply now

YOUR JOB AD HERE

For information, please contact:
BARB HOCKADAY
barb@iconnect007.com
+1 916.365.1727 (PACFIC)

I·Connect007
GOOD FOR THE INDUSTRY

Events Calendar

NEPCON China 2019 ▶
April 24–26, 2019
Shanghai, China

Del Mar Electronics & Manufacturing Show ▶
May 1–2, 2019
San Diego, California, USA

SMTconnect ▶
May 7–9, 2019
Nuremberg, Germany

Medical Electronics Symposium 2019 ▶
May 21–22, 2019
Elyria, Ohio, USA

Industry 4.0–Smart Factory ▶
May 29, 2019
Tel Aviv-Yafo, Israel

EIPC Summer Conference 2019 ▶
June 13–14, 2019
Leoben, Austria

NEPCON Thailand 2019 ▶
June 19–22, 2019
Bangkok, Thailand

PCB Pavilion @ LCD EXPO Thailand ▶
June 27–29, 2019
Bangkok, Thailand

NEPCON South China 2019 ▶
August 28–30, 2019
Shenzhen, China

productronica India 2019 ▶
September 25–27, 2019
Delhi NCR, India

Additional Event Calendars

IPC SMTA iNEMI pcb007

Coming Soon to *PCB007 Magazine:*

MAY: New Materials
Evolving designs and applications require advanced levels of performance from materials. We look at new materials across the industry.

JUNE: Everything Starts With Design
Designers need more information to estimate their design choices, and fabricators ultimately build what the designers specify. How can we make this conversation more efficient?

PUBLISHER: **BARRY MATTIES**
barry@iconnect007.com

SALES MANAGER: **BARB HOCKADAY**
(916) 608-0660; barb@iconnect007.com

SALES: **ANGELA ALEXANDER**
(408) 489-8389; angela@iconnect007.com

MARKETING SERVICES: **TOBEY MARSICOVETERE**
(916) 266-9160; tobey@iconnect007.com

MANAGING EDITOR: **NOLAN JOHNSON**
(503) 597-8037; nolan@iconnect007.com

CONTRIBUTING EDITOR: **PATRICIA GOLDMAN**
(724) 299-8633; patty@iconnect007.com

CONTRIBUTING TECHNICAL EDITOR: **DAN FEINBERG**
baer@iconnect007.com

TECHNICAL EDITOR: **PETE STARKEY**
+44 (0) 1455 293333; pete@iconnect007.com

ASSOCIATE EDITOR: **KIERSTEN ROHDE**
kiersten@iconnect007.com

CONTRIBUTING TECHNICAL EDITOR: **HAPPY HOLDEN**
(616) 741-9213; happy@iconnect007.com

PRODUCTION MANAGER: **SHELLY STEIN**
shelly@iconnect007.com

MAGAZINE LAYOUT: **RON MEOGROSSI**

AD DESIGN: **SHELLY STEIN, MIKE RADOGNA, TOBEY MARSICOVETERE**

INNOVATIVE TECHNOLOGY: **BRYSON MATTIES**

COVER: **SHELLY STEIN**

COVER IMAGE: **ADOBE STOCK © MACROVECTOR**

PCB007 MAGAZINE®
is published by BR Publishing, Inc.,
942 Windemere Dr. NW, Salem, OR 97304

April 2019, Volume 9, Number 4
PCB007 MAGAZINE is published monthly,
by BR Publishing, Inc.

ADVERTISER INDEX

AGFA..... 7
atg Luther & Maelzer GmbH..... 19
Burkle North America..... 5
DB Management..... 83
Electra Polymers..... 71
Entelechy Global..... 27
ESI..... 31
Excellon..... 85
FLEX007 Magazine..... 79
Gardien..... 57
I-Connect007 eBooks..... 2, 3, 89
IPC..... 43, 61
ITEQ..... 41
MacDermid Electronics Solutions..... 55
Mentor, a Siemens Business..... 23
Meptec..... 17
MivaTek Global..... 11
Nordson March..... 51
Panasonic Electronic Materials..... 35
PCB007 China Magazine..... 33
Pluritec..... 45
Prototron Circuits..... 69
Rogers Corporation..... 15
Taiyo America..... 47
Technica USA..... 63
Ucamco..... 65
Ventec International Group..... 75
Viking Test..... 37

I-Connect007

GOOD FOR THE INDUSTRY

FREE SUBSCRIPTION

myiconnect007.com

mediakit.iconnect007.com

EDITORIAL CONTACT

Nolan Johnson

nolan@iconnect007.com

+1 503 597-8037 GMT-7

SALES CONTACT

Barb Hockaday

barb@iconnect007.com

+1 916 365-1727 GMT-7

www.iconnect007.com