LIA TODAY

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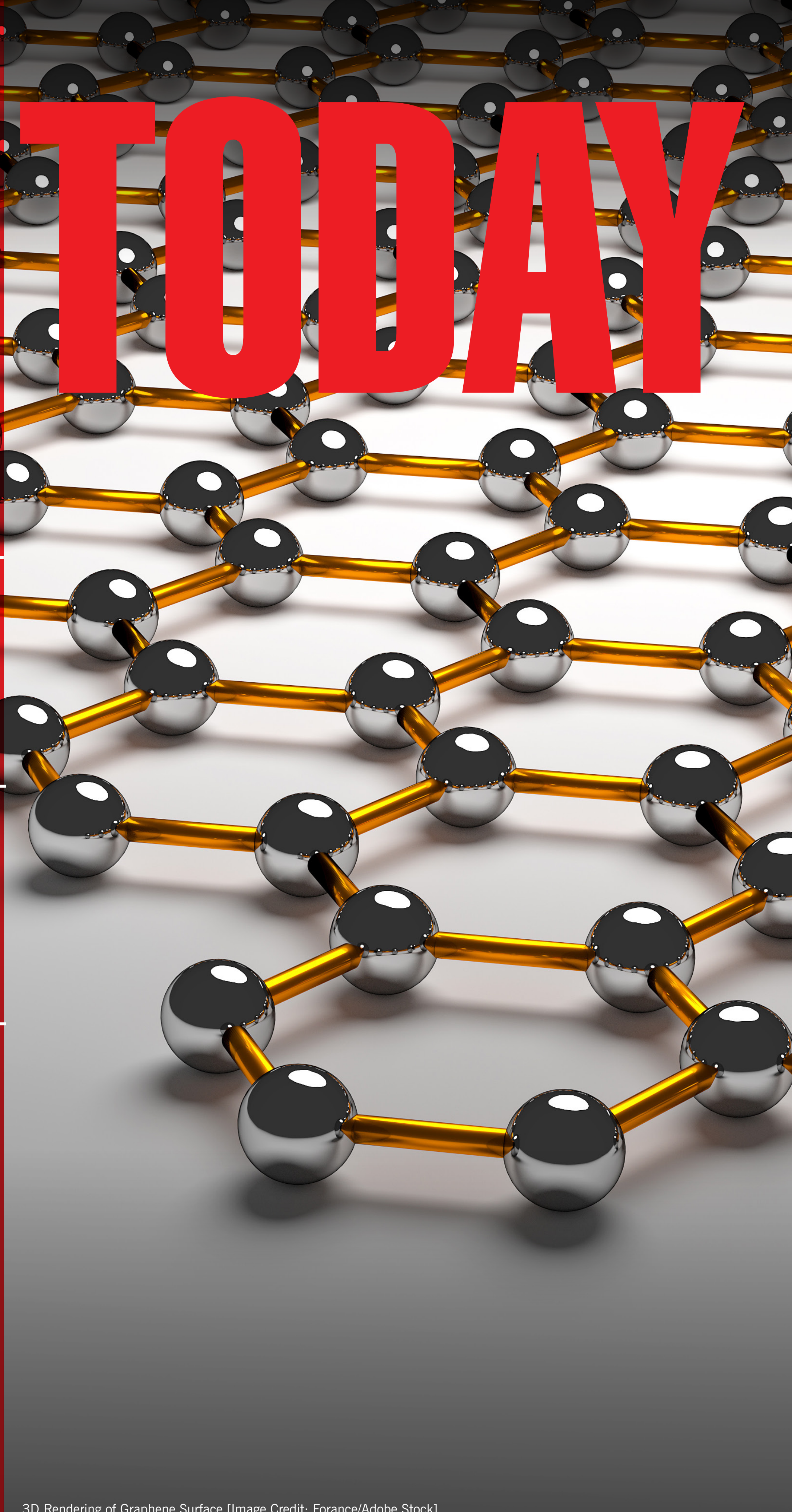
LIA 50 YEARS



3D Rendering of Graphene Surface [Image Credit: Forance/Adobe Stock]

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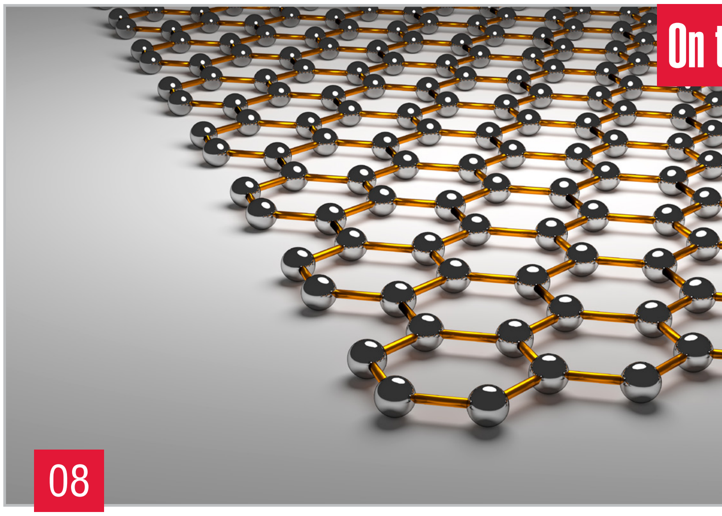
LIA TODAY is published bimonthly to educate and inform students and professionals of challenges and innovations in the field of photonic materials processing.



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3D Rendering of Graphene Surface, Orange Bond [Image Credit: Forance/ Adobe Stock]

On the Cover:

INVENTORS MAKE GRAPHENE WITH LASERS

Graphene caused quite a stir in 2004 and expectations were high; however, the lack of scalable manufacturing methods stunted its progress. Lasers could be the solution to industrializing graphene production.

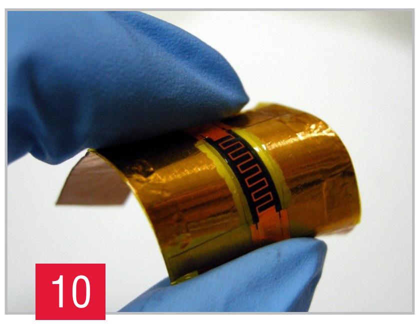

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Image of a carbon microsupercapacitor prepared by laser direct writing [Image Courtesy of Jinguang Cai]

A LASER DIRECT WRITING APPROACH TO FLEXIBLE HYBRID ELECTRONICS

As we become more dependent on technology, we can expect to see wearable, flexible devices, such as folding smartphones, become more mainstream. Jinguang Cai and Akira Watanabe weigh in on using a laser direct writing approach to manufacture this next generation of technology.

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Metal powder is poured into the chamber of a laser sintering machine [Image Credit: mari1408/ Adobe Stock]

LASER ADDITIVE MANUFACTURING'S JOURNEY TO COMMERCIALIZATION

Laser Additive Manufacturing (LAM) has obvious advantages over the competition, but why aren't more companies adopting it? Discover what barriers still stand in the way of LAM being more widely utilized, and what can be done about it.

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COURSE HIGHLIGHT

LSO FOR R&D | AUG. 14-16, 2018

Hosted in Orlando, FL, this course is tailored for individuals newly appointed as Laser Safety Officers and placed in charge of laser safety at corporate research laboratories, universities and colleges that are using lasers in graduate-level programs in physics, chemistry and electro-optics laboratories, as well as Department of Energy research laboratories. In addition, current Laser Safety Officers at R & D laboratories and testing labs who would like a review or refresher course are encouraged to attend.

President's Message

I would like to report that we had a very successful LAM/LME event at the end of March in Schaumburg. The event attracted some 400+ visitors and attendees. The LAM conference continues to attract several hundred core participants ranging from users, researchers to technology providers. Again the quality of the presentations and their relevance to additive manufacturing in general was high with the feedback from attendees quite positive. The keynote sessions delivered by Rob Gorham, CEO of America Makes, Prof. Ehsan Toyserkani, University of Waterloo, Canada and Prof. Xiaoyan Zeng, Huazhong University of Science and Technology, Wuhan, China on the networking through industry/ government/researcher partnerships in additive manufacturing and the benefits to industry attracted many questions and stimulated discussion. The panel session which I chaired at the end of LAM was engaging in particular on the topic of AM standards and part certification. The questions and discussion on this topic took most of the allocated panel time. This is obviously a hot topic as companies start to move into their product manufacturing phase, especially for semi-critical and critical applications.

Walking through the LME floor gave LAM attendees an opportunity to discuss with vendors their products and services. I wandered through LME on both Wednesday and Thursday and observed continuous attendances and engagement with vendors. Talking with some of the vendors the comments were that Schaumburg was a much better venue than Atlanta in 2017 and that they got more time with potential customers.

I would like to thank LIA staff and my two co-chairs Minlin Zhong from Tsinghua University, China and John Hunter, from LPW Technology for all the effort they put into organising this event.

No doubt you would have read and or heard by now that LIA is transitioning and that we need to respond to local and global challenges and pressures that are impacting us in order to keep providing value to you our members. The executive and Board of LIA have discussed some of these issues at their meetings in Schaumburg and are now starting to implement these changes to place the organisation on a more sustainable path. I'll report more on these changes in the future but would like to reassure all members that the changes are carried out in the best interest of the association.

Finally, I strongly encourage you to engage with LIA and attend ICALEO which will be held on October 14-18 in Orlando, Florida.

Milan Brandt
President, LIA

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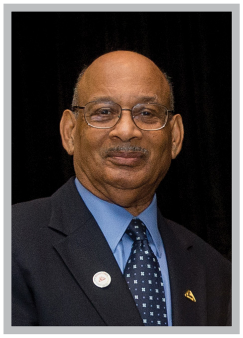
Executive Director's
Message



LIA has embarked on a transformational journey. Over the past few months, the institute has been redefining its vision, mission, as well as core values and exploring exciting new growth opportunities. Through the process of completing a preliminary market analysis and drafting a new strategic plan, LIA has concluded that in order to deliver greater value to our members we must evolve, as all great innovators do, to help solve challenging problems. Fifty years ago, LIA grew out of a need for safety standards in the use of a then new technology we called LASER. Today, we continue to serve that need, while we also look to deliver more value and help to solve the new challenges that our members face.

We are listening closely to our members as we make changes, and it is from this feedback that we have developed a new organizational vision.

Vision: "Helping to make the world a better place through safe, optimal and novel use of lasers, optics and photonics, including quantum science and technology, and their application to advanced materials."

LIA has begun taking steps to implement this vision. The cultural change is already very tangible as we are evolve into a leaner and healthier organization.

Your feedback has also prompted us to develop a new organization mission:

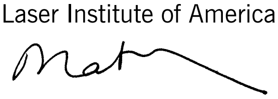
Mission: "Delivering value to our members by developing and sharing knowledge, catalyzing innovation, stimulating access to capital, facilitating networking and professional development, and helping to integrate all the above across lasers, optics and photonics to advanced materials."

Our hope for the future is that LIA grows to become the most respected, premier institute for cutting edge photonic materials processing innovation worldwide. Only through your valued support and involvement will we be able to reach that goal.

LIA's membership can expect to see changes rolling out over the next year, including: an array of new member benefits, improved online registration and payment processing, and products and services that reflect the institute's new vision and mission for LIA. Attendees of ICALEO 2018 will be the first to preview and experience the new LIA.

At the same time, *LIA TODAY* is also changing. Articles will focus on industry challenges and the novel technological innovations that are being developed to solve them, as well as safe and optimal use of devices, systems and applications in the space of photonic materials processing. A member-based editorial board will be established this year to curate content that is engaging and timely. We hope you enjoy the new *LIA TODAY* and encourage you to share your feedback and help us to develop future content.

Nat Quick, Executive Director
Laser Institute of America



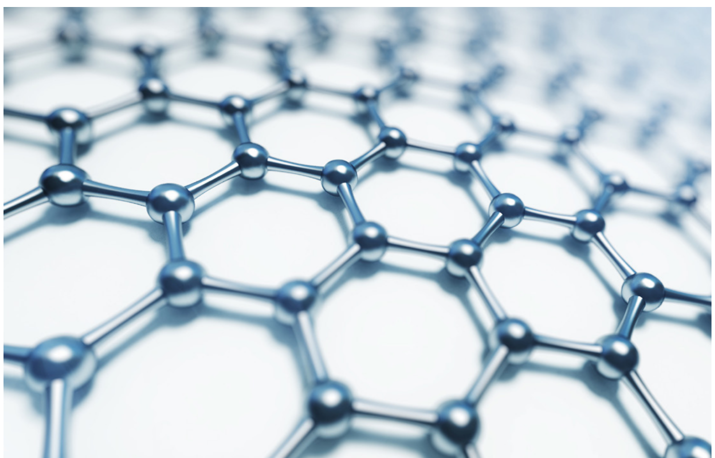
FEATURED ARTICLE

Inventors Make Graphene With Lasers

And They Say You Should, Too

BY LILIANA CALDERO

Graphene – it's the two-dimensional (2D) allotrope of carbon atoms that ignited the imaginations of researchers across the globe. Heralded as a 'miracle material', its potential seemed limitless and it was predicted to usher in the next generation of technology. Flexible, stronger than steel, transparent, lightweight, and an amazing conductor of heat and electricity, it was going to revolutionize everything from household electronics to biomedical nanotechnology.



3D illustration of graphene organized in a hexagonal lattice structure [Image Credit: artemegorov/ Adobe Stock]

THE PROBLEM

Yet, nearly eight years after Dr. Andre Geim and Dr. Konstantin Novoselov earned the Nobel Prize in Physics for first isolating graphene and identifying its properties, graphene has encountered barriers to moving out of the lab and into the marketplace. According to Prof. Dr. Aravinda Kar of the University of Central Florida's Center for Research and Education in Optics and Lasers (CREOL), one of the most prominent barriers has been finding scalable manufacturing processes that can produce graphene of a quality and quantity ready for consumers and businesses.

Graphene is notoriously difficult to synthesize in large quantities at a consistent quality. Early methods of isolating graphene involved a slow and tedious mechanical exfoliation technique; the researchers would extract a thin layer of graphite from a graphite crystal using regular adhesive tape, continually reducing the graphite sample by sticking the tape together and pulling it apart until only a small, 2D section of carbon atoms with a honeycomb lattice remained. Graphene's unique characteristics are only present when it is one, two, or three layers of atoms thick – any thicker and it becomes graphite, losing all of the exceptional properties of graphene. The tape exfoliation method, although useful for the lab, was not going to translate very well to an industrialized process.

SOLVENT-AIDED EXFOLIATION AND CVD

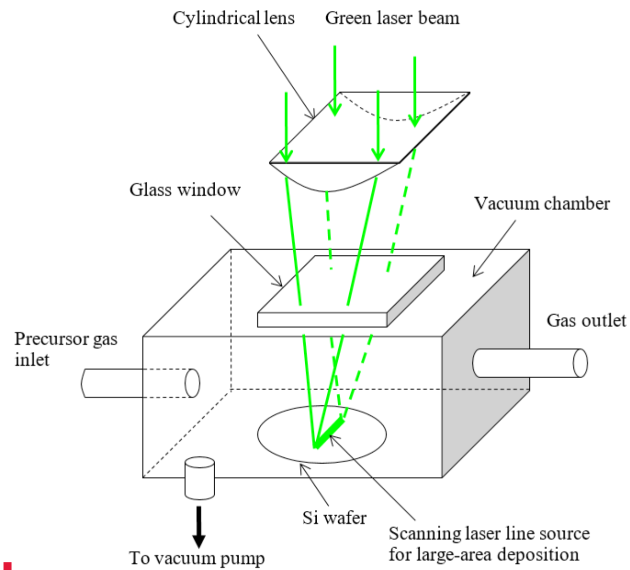
Two of the more promising and potentially scalable methods of producing graphene are solvent-aided exfoliation and chemical vapor deposition (CVD). In solvent-aided exfoliation, sonication is used to exfoliate graphene crystals which are then further separated in a solvent and later gathered into graphene monolayers. Scientists at the National University of Singapore have identified a flocculation method that reduces the amount of solvent needed for their exfoliation process, which could yield graphene using far less solvent than was previously needed. Another method experiencing innovation is CVD, which uses thermal chemical reactions to 'grow' graphene on substrates of specific materials, typically copper or silicon. Recently, engineers at MIT developed a CVD process for producing graphene filtration membrane sheets at 5 cm per minute. One of the biggest issues with traditional CVD and exfoliation methods is the need to transfer graphene from its fabrication platform to a substrate. Lasers are going to change that.

"Picture this: a template is placed over a substrate and a line-shaped laser beam sweeps over it briefly... when the template is removed, an intricate graphene design has been printed onto a circuit board."

THE MISSING PIECE – LASERS

Lasers may provide yet another avenue to the elusive mass production of graphene, with an eye toward innovating the semiconductor industry. In 2003, Kar, along with Dr. Islam Salama and Dr. Nathaniel Quick, realized that laser-direct writing could be used to fabricate carbon-rich nanoribbons on a silicon carbide (SiC) wafer in a nitrogen rich environment. Although these ribbons were too thick to be considered graphene, Kar believed that with a few changes, this process could be reworked to synthesize graphene in situ on a large scale, very quickly. In 2013, Kar and Quick were issued a patent for a Laser Chemical Vapor Deposition (LCVD) method that could be scaled for mass production.

Their method involved a few simple components: a frequency doubled Nd:YAG (green) laser of 532 nm wavelength, methane (CH4) gas, a silicon substrate, and a vacuum chamber.



An experimental set up for multiphoton photolytic laser chemical vapor deposition (LCVD) of graphene from methane precursor. Image courtesy of Dr. Kar and Dr. Quick.

The 532 nm wavelength corresponds to a photon of energy 2.33 eV, so the energy of two photons is 4.66 eV, just within the range of the C-H bond energy (4.3-4.85 eV) in CH4. Focusing the laser beam to a high intensity can induce two-photon absorption at the focal plane, causing the decomposition of CH4 to release the hydrogen atoms and deposit carbon atoms only on the substrate. The laser heating of the silicon substrate is just low enough to avoid melting the silicon, while providing sufficient thermal and electromagnetic energies to assist the carbon-carbon bonds rearrange into graphene's trademark hexagonal pattern.

LASER DIRECT WRITING OF GRAPHENE

Kar believes this process could be adapted to add graphene directly onto any substrate. Using laser direct-writing, a company could easily draw graphene circuits onto a board. For companies using a hybrid approach, the graphene could be deposited at precise points as interconnects. "You would have all the CAD/CAM capability you could want," says Quick. Currently, green lasers are available at high output powers, 100 W in continuous wave mode from most large laser manufacturers, so adding this additional step to the manufacturing pipeline for semiconductors would be easy and inexpensive compared to other methods.

At 1.9 cm per second, or 45 inches per minute, this method of graphene production is fast and efficient. This LCVD method offers control over the number of graphene layers, whether one, two, or three are required. This process also removes the need to manually place graphene onto its intended location, as it is synthesized precisely where it should be. It's also worth mentioning that this process is conducive to minimal environmental impact, as the unreacted methane and hydrogen byproducts can be captured to be recycled and reused.

A LOOK AT THE FUTURE

Picture this: a template is placed over a substrate and a line-shaped laser beam sweeps over it briefly or a beam of large cross-sectional area illuminates the entire template in one shot; when the template is removed, an intricate graphene design has been printed onto a circuit board. That is the future that Kar says is possible, with the right equipment. He suggests that we need manufacturers to develop lasers producing line-shaped beams or large area beams with spatially uniform intensity profile to realize this vision cost-effectively. He emphasizes that a true line-shaped beam produced by a slab laser system or an array of optical fiber laser would be necessary, as shaping the beam synthetically by changing the shape of an aperture would result in too much lost energy. With this technology, graphene could easily be printed onto circuit boards immediately, only where it's needed, saving in material costs and time.

Nearly 14 years after the excitement first began, researchers are still exploring the potential uses of graphene; from applications in microsupercapacitors to Organic LEDs in flexible displays to ultra-sensitive optical sensors, and even lightweight body armor, the possibilities are still as exciting as ever.

ACKNOWLEDGEMENTS

Prof. Dr. Aravinda Kar, University of Central Florida, CREOL

Dr. Nathaniel Quick, Executive Director of LIA

LEARN MORE

Laser Formation of Graphene: Patent
N. Quick, A. Kar
http://www.freepatentsonline.com/8617669.html

NUS-led research team develops cost effective technique for mass production of high-quality graphene - http://news.nus.edu.sg/press-releases/mass-production-graphene-slurry

MIT researchers develop scalable manufacturing process for graphene sheets - https://newatlas.com/mit-manufacturing-graphene-filtration-membranes/54274/

A Laser Direct Writing Approach

To Flexible Hybrid Technology

Originally Presented at: ICALEO INTERNATIONAL CONGRESS ON APPLICATIONS OF LASERS & ELECTRO-OPTICS

BY JINGUANG CAI, AKIRA WATANABE

The development of miniaturized portable and wearable electronic devices has attracted worldwide research attention, due to their increasing integration with day-to-day life. Different from traditional electronic devices on "hard" boards, such devices should be soft and flexible. A concept called "flexible hybrid electronics", which is a hybrid of soft and hard parts, has been proposed to address the fabrication issue of flexible devices.

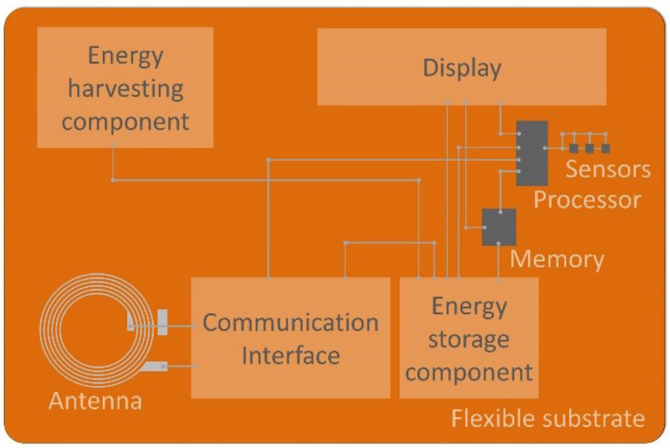


Figure 1. A schematic image of a simple flexible hybrid electronic device

Laser direct writing is a non-contact, fast single-step fabrication technique without requirements for masks, post-processing, and complex clean environments. Meanwhile, various kinds of lasers have been rapidly developed with relatively low costs and broad available wavelengths and powers, and widely used in industry for materials welding, cutting, and polishing. Besides, laser processing can be focused into a micrometer-sized or submicrometer-sized area to realize on-demand fabrication of functional micro-patterns, showing the potential to be integrated into current product lines for commercial use. Laser direct writing has been demonstrated to prepare energy harvesting and energy storage components, electronic circuits, sensors, communication interface, and antennae.

The concept of a flexible hybrid electronic device is illustrated in Fig.1, in which "soft parts", such as electronic interconnection, energy harvesting and energy storage components, antennae, and even displays, sensors, and communication interfaces, can be prepared via printing methods. "hard parts", such as processor and memory, can be provided by the commercial small-size silicon components, which are small enough, and can be integrated into the device without influencing the flexibility. However, printing methods have some issues such as limitation of materials, high cost of inks, and complicated post-processing.

ENERGY HARVESTING AND STORAGE COMPONENTS

Generally, a flexible device employs a thin film battery as the energy storage and supply unit, in combination with a flexible energy harvesting device such as a polymer solar cell. Recently, as a new type of energy storage device, micro-supercapacitors (MSCs), has been developed and recognized as potential power supply units for on-chip micro-devices, because they possess not only the advantages of supercapacitors such as high power density, excellent cycling stability, pollution-free operation, maintenance-free feature, and flexibility, but also simplified packaging processes and compatibility with integrated circuits. Among various materials for supercapacitors, carbon materials possess the properties which can satisfy the requirements of MSCs in the flexible devices, such as high specific surface area, high electrical conductivity, high electrochemical stability, and high mechanical tolerance.

Laser-induced carbonization of polymers such as polyimide has been demonstrated to prepare flexible all-solid-state carbon-based MSCs with high performance by laser direct writing on a polyimide

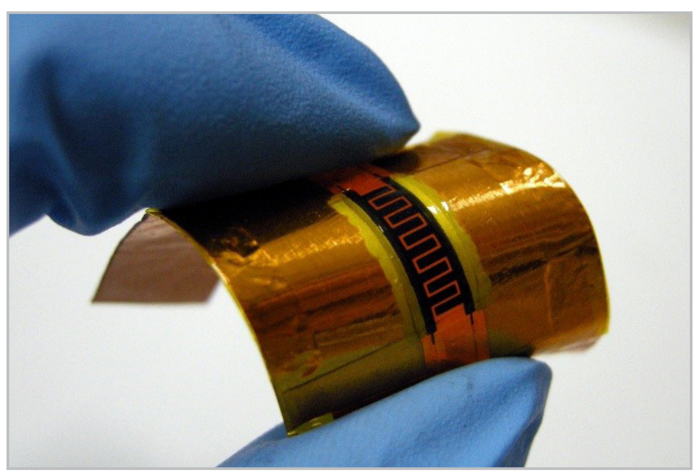


Figure 2. A carbon micro-supercapacitor prepared by laser direct writing

(PI) film in air (Fig. 2). In order to suppress the oxidation process and thus, increase the conductivity of the laser-induced carbon structures, the laser direct writing was conducted on PI films in an inert gas such as Ar, resulting in carbon MSCs with improved volumetric energy density and power density. Furthermore, high-conductive Au nanoparticles can be incorporated to construct double-layer carbon/Au composite electrodes with improved conductivity by two-step laser direct writing.

It will be beneficial for practical use if energy harvest and storage units can be integrated into the same device. As a demonstration, TiO2 nanoparticles were deposited on one side of the laser-written interdigitated carbon electrodes by an electrophoretic method, forming carbon/TiO2 composite MSC with photo-rechargeable capability under UV irradiation due to the photovoltaic property of TiO2 nanoparticles. Although the charging voltage is not high enough for practical use currently, it is expected that such a strategy can be developed for practical use by optimizing the photo-absorption materials and the combination.

PHOTODETECTORS AND HUMIDITY SENSORS

Sensors are one of the most important interfaces with users in IoT (Internet of Things) technology, thence it is very important to develop various types of sensors for flexible devices. Laser direct writing can play an important role in preparing sensors directly on the flexible substrate with high performance and stability. For example, a photodetector for UV light can be fabricated by laser direct writing and deposition of ZnO nanoparticles, and can be integrated into the PI film with a carbon MSC fabricated by laser-induced carbonization, forming an integrated photodetector for practical use (Fig. 3, Top). Besides, a humidity sensor based on an interdigitated reduced graphene oxide (rGO)/graphene oxide (GO)/rGO structure prepared by laser direct writing was also demonstrated with high and fast response, flexibility, and long-term stability, showing the potential to be used in flexible devices (Fig. 3, Bottom).

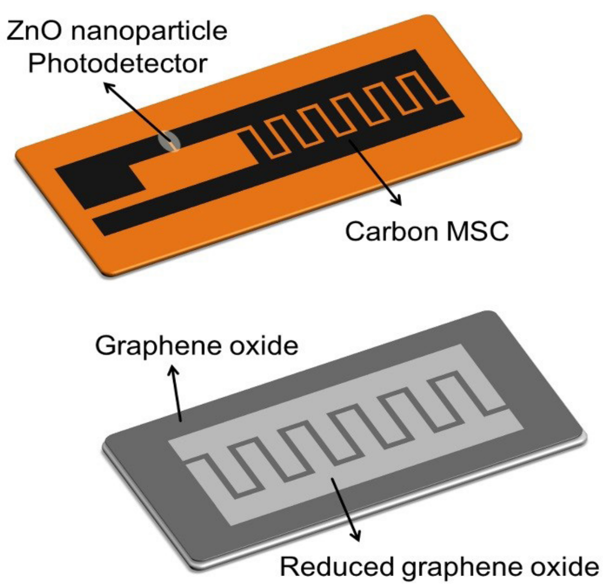


Figure 3. Schematic images of an integrated photodetector (top) and a rGO/GO/rGO humidity sensor (bottom) prepared by laser direct writing.

CIRCUITS, COMMUNICATION INTERFACE, AND ANTENNA

High-conductive metallic circuits with mechanical stability are very important in flexible devices as basic structures, and their preparation should be facile, cost-effective, and easily integrated with other electronic components. Laser direct writing has been demonstrated to pattern metallic Pd on PI films, which can act as catalysts in the electroless Ni plating process, producing high-conductive carbon/Ni composite structures. The carbon/Ni structures exhibited a certain flexibility and excellent anti-scratch performance due to the intimate deposition of Ni layer on carbon surfaces. Such carbon/Ni structures can be used as conductive circuits to construct practical devices. For example, a wireless charging and storage device can be fabricated by integrating an outer rectangle carbon/Ni composite coil for harvesting electromagnetic waves and an inner carbon MSC for energy storage, which can be fast charged by a commercial wireless charger (Fig. 4, Top). In addition, a near-field communication (NFC) antenna was prepared using a carbon/Ni composite coil, and acted as a communication interface with an NFC smartphone for harvesting signals, and an ultra-small commercial IC chip was integrated for data storage (Fig. 4, Bottom). The integrated NFC tag can be used for practical application.

(Continued on page 12)

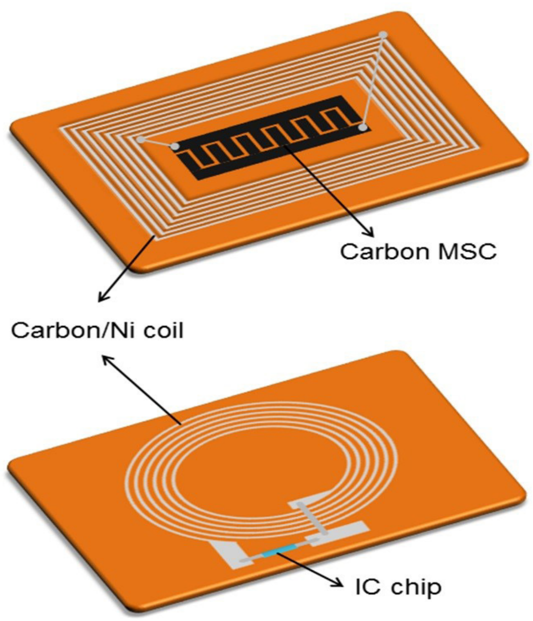


Figure 4. Schematic images of an integrated wireless charging and storage device (top) and an NFC tag (bottom) prepared by laser direct writing in combination with electroless Ni plating.

SUMMARY & OUTLOOK

While laser direct writing has been demonstrated to be an effective approach to preparing most of the components in flexible devices, such as carbon MSCs as energy storage unit, carbon/TiO2 MSCs for energy harvesting and storage unit, photodetectors and humidity sensors, high-conductive carbon/Ni structures for electronic circuits, and even integrated wireless devices, many efforts are still required to promote the laser direct writing technique applied in the development of flexible hybrid electronics for practical applications in IoT in the future.

Affiliations

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LEARN MORE

Laser direct writing of carbon-based micro-supercapacitors and electronic devices.

J. Cai, A. Watanabe, and C. Lv

Journal of Laser Applications 30, 032603 (2018); https://doi.org/10.2351/1.5040648

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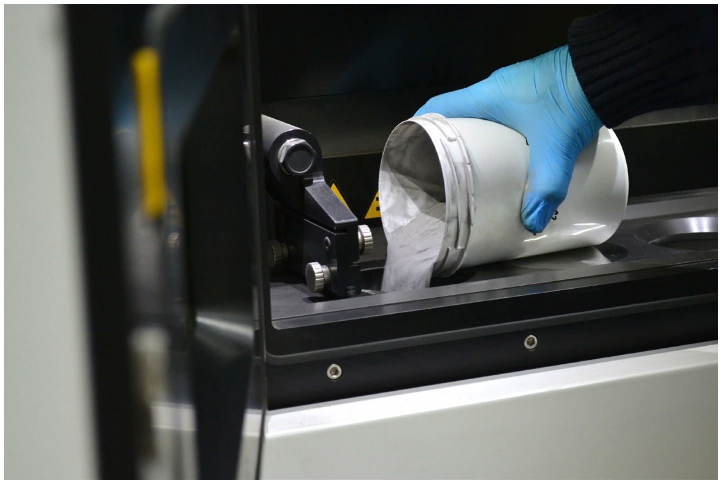
FEATURED ARTICLE

Laser Additive Manufacturing's

Journey to Commercialization

BY ANDREW ALBRITTON



Metal powder is poured into the chamber of a laser sintering machine [Image credit: mari1408/ Adobe Stock]

Laser Additive Manufacturing (LAM), as it pertains to powder based manufacturing, is a technique that utilizes the interaction of lasers and base materials to construct a product, rather than removing material from a pre-constructed block of material. LAM is quickly approaching the critical point of being more than a method to produce prototypes and small runs of one-off parts – it is poised to turn everything we know about mass production on its head. Professor Dr. Minlin Zhong, President-Elect of LIA and Director of the Laser Materials Processing Research Center at Tsinghua University, believes it surpasses all available alternative methods. Zhong says, "LAM shows obvious advantages on freeform manufacturing, including free geometry, free structures, free strengthening mechanism, free microstructures, free performance and even free scale (from macro, to meso, to micro, to nano)." Manufacturers who use LAM are able to reduce the waste of materials commonly associated with traditional subtractive manufacturing methods; decrease the weight of parts by cutting out filler materials; and have more control over material properties resulting in stronger, more complex, lighter, and more efficient parts. With such exceptional technology currently at our disposal, why hasn't LAM been more widely adopted?

IT'S EXPENSIVE

One of the most commonly cited reasons is that the costs to produce parts through LAM are prohibitive. The key driver of these high costs is that the supply chain for metal powders is not yet optimized for LAM technology. Materials are expensive, custom made, or not readily available. The Metal Powder Industries Federation (MPIF) states in its 2017 PM Industry Roadmap that, "A better understanding of the precursor materials impact on the metal AM process is required. Traditionally, precursor materials have been existing thermal spray powders that have not been refined/tuned to the AM process limiting optimization." LAM parts producers are often using metal powders that have not been designed for use in LAM processes, which frequently results in suboptimal products.

According to MPIF, as of 2017, there are approximately 12 suppliers of metals for Additive Manufacturing (AM) for the international market, most produce stainless steel, cobalt-chrome, and titanium, with a few supplying aluminum alloys, copper, super alloys, platinum, Inconel, tungsten, molybdenum, and tool steels. With so few suppliers and a sparse number of common material types, there is a bottleneck for providing quality affordable metal powders to the LAM industry. With companies expanding the selection of materials that can be laser processed, it is vital that the problem of material availability be resolved. For example, Nuburu has produced a "blue" laser which operates at the 450 nm wavelength, and is capable of processing gold, aluminum, brass, and copper.

SUPPLY AND DEMAND

What can be done to improve the supply chain and reduce the cost of LAM part production? The metal powder industry does not supply enough quality powder to support widespread adoption of LAM, while early adopters of LAM applications do not create enough demand to drive competition into the metal powder market to reduce prices. A first step to get these industries operating in unison will be the creation and mass adoption of standards, specifications, and best practices in regards to metal powders. By standardizing metal powder properties for best final product properties, metal powder suppliers would be able to build up an inventory without relying on custom special orders. Specifications on how surplus powder from a project can be reused could also help introduce addition cost savings to manufacturers.

STANDARDS FOR QUALITY CONTROL

Another hurdle for LAM is microstructural quality, uniformity, and repeatability. To become a replacement for more legacy manufacturing methods, LAM needs to produce parts consistently and continuously that are to specifications. With traditional subtractive manufacturing methods, there are several quality control points where product is inspected and defects are addressed prior to the next step, resulting in no wasted effort past the point of failure. With LAM, the part in question is created from the ground up; this determines the final product's quality, microstructure, and mechanical properties simultaneously. The process is completed with either a perfect or defective final product. Paul Denney, Director of Advanced Process Development with IPG Photonics, states, "Unlike machining where you start with a 'block' of material with known quality and properties, additive production of parts requires a combination of motion with the prediction of the microstructures, mechanical properties, and stresses. Because the properties are closely connected to how the material is deposited, this greatly complicates the development of processing procedures and parameters."

"LAM processes need both a way to detect defects and the ability to react to them immediately."

What methods can be implemented into a given LAM process to help ensure quality of the final product? The first quality control concerns are addressed long before the process begins. Starting materials must be certified as appropriate for the application, the order of operations of the production device should be scrutinized to ensure that the final product will be to spec with minimal waste, and the machine itself must be operating at peak parameters. As the production of a LAM product can take an extended amount of time, any loss of power to the point of interaction can have detrimental effects to the end product and even the products in queue. Loss of power can be caused by an actual power failure, a dirty or damaged optic, or other origins. With the structural integrity of a LAM part resting critically on the success of every step of the process, it is imperative that the process is stringently optimized and the machine is operating at peak performance. Here is what Denney has to say about the subject:

"Because of the additive manufacturing approach in bed based systems, even if defects can be detected and possibly 'corrected', any changes may not be possible. An example of this may be what is done if a 'defect' is flagged in a single part in a batch of parts being produced. One approach would be to stop the processing and 'correct' the defect. However, if this is done then the thermal history for all of the parts may be altered and all parts may now be out of the desired properties. Another approach would be to stop processing on the part with the defect, but this again would alter the heat load on the complete batch or the time between other parts being produced which may again alter the properties. So any monitoring system will need to detect changes prior to the formation of any defects while at the same time any corrections must be made within the acceptable parameter range."

There is a thin line between success and failure: one small interruption can ruin an entire batch of product. What can be done to prevent this?

As Denney explained, this is not a single issue. LAM processes need both a method to detect defects and the ability to immediately respond to them. A starting point is to ensure that redundancies are incorporated into the build process so that if a common defect occurs at a certain stage, there are defined responses the system can take automatically to correct them. In the case of a laser lens issue, it may be beneficial to incorporate additional laser delivery systems to the process as a redundancy to pick up where a suboptimal device has failed in real time.

EVALUATING THE FINAL PRODUCT

In addition to inline defect detection, the industry as a whole will require a standardized best practice for evaluating finalized parts. For traditional manufacturing methods, a sample of the produced part pool is selected for evaluation via destructive and non-destructive tests to certify whether a set of parts are built to specifications. As many LAM-produced parts are complex and costly to produce, it seems wasteful to destroy a set of them to certify them. In the paper "Evaluation of 3D-Printed Parts by Means of High-Performance Computer Tomography" presented at ICALEO 2017, authors Lopez, Felgueiras, Grunert, Brückner, Riede, Seidel, Marquardt, Leyens, and Beyer reviewed the viability of X-ray Computer Tomography (CT) and 3D scanning as methods to detect inferior AM parts. The paper concludes that the CT method best fits the needs of the AM industry. According to Lopez et. al, "Computer tomography can quantify all complex structures in scope of the proposed demonstrator and delivered deviation values of the measured structure, providing a good base for comparison across demonstrators made by different methods, materials and dimensions. Porosity or defects down to 3 µm can be determined by the used CT system." Currently, CT scanning a LAM part is a time consuming process, but with additional focus on improvement it could become an essential quality non-destructive control method for finalized parts to evaluate complex internal structures.

TOO MANY ALTERNATIVES

A third barrier to the spread of LAM is the multitude of alternative methods in the industry. As stated by Zhong, "Some conventional metal deposition technologies such as arc building-up welding, plasma building-up welding and electronic building-up welding can also fabricate metallic components in near shape. Their deposition rate and productivity may be high and the costs may be lower, but normally they are limited in fabricating complex geometry and accuracy." Freeform manufacturing is where LAM excels, but despite its many advantages over alternative methods, it has an Achilles heel.

One advantage of alternative manufacturing methods is the speed at which a product can be produced. However, according to Denney, this speed gap is closing faster every day.

(Continued on page 16)

"While higher laser powers allow for higher deposition rates but at the expense of lower resolution, some researchers are looking to maintain the resolution by combining multiple lasers into an additive deposition system. Research groups and equipment builders are investigating how best to handle multiple lasers in the same processing area. There are other areas that may be investigated including power distribution to improve the interaction between the power and laser beam to improve efficiency of the process and to minimize defects. This could improve the deposition rates while at the same time maintaining quality."

Zhong hopes that soon LAM researchers will, "improve the materials diversity, increase the dimension (to square meters), increase the deposition rate and decrease costs. A hybrid approach to combine LAM with the conventional additive manufacturing methods may be a solution to achieve the above targets." The concept of a hybrid production system that can combine multiple lasers with fast alternative methods where complexity is not a requirement could lend itself to faster build times.

"If AM is supposed to make a big impact, companies are going to have to rethink their parts; they should determine how AM allows for changes in the design and possibly improves the performance.

THE FINAL BARRIER

There is one final barrier to the wide spread success of LAM: industry standards. Current standard offerings from ASTM and ISO cover Design, Materials and Processes, Terminology, and Test Methods. Additionally, new processes are created frequently and new standards are being developed every year in an attempt to keep up. It is unclear how much of the industry has adopted these existing specifications. Until the entire market accepts a set of standards for all steps of the Additive Manufacturing process and supply chain, the evaluation of AM parts will remain a costly endeavor that will limit AM's potential. MPIF expresses a bleak outlook on metal AM in its *State of the PM Industry in North America – 2017* report: "Despite all the fanfare, true commercial long-run production still revolves around only three product classes: titanium medical implants, cobalt-chrome dental copings, and cobalt-chrome aircraft nozzles." The truth of the matter remains that without a set of clearly defined standards, the LAM industry will continue to remain confined to early adopters like the Aerospace and Medical fields. With the benefits in intricacy and weight-saving advantages LAM, should have obvious opportunities in the automotive and electronics industries.

THE NEED FOR INNOVATION

Markets are watching LAM for innovative uses before taking the plunge and embracing the technology. Currently, LAM may appear to have a bad Return on Investment (ROI) if producers only hope to replicate their existing products through LAM rather than innovating their parts to capitalize on its strengths. In the words of Denney, "If AM is supposed to make a big impact, companies are going to have to rethink their parts; they should determine how AM allows for changes in the design and possibly improves the performance. The benefits can come in many forms which could be a weight savings, a production savings, and/or a performance savings." The industry needs to challenge its way of thinking about production to allow the benefits inherent to LAM to propel their production and parts to new levels of performance. Denney provided the following illustration: "With the formation of properties 'locally' instead of in 'bulk,' it is possible to produce 'gradient' materials. The 'gradient' can come by changes to the properties of a given chemistry of material or by using materials with different chemistries. As an example: a bracket could be produced for a jet engine that has high temperature properties near the engine but as the bracket extends to an attachment point, the properties/chemistry can be altered to improve the fatigue properties."

LAM has a bright future and many engineers and scientists are working to unlock its full potential. Once the barriers of the supply chain, dynamic quality control, speed of production, and process standardization have been resolved, it is highly likely the LAM will be a manufacturing method of choice.

ACKNOWLEDGEMENTS

Paul Denney, Director of Advanced Process Development with IPG Photonics, LIA Past President

Prof. Dr. Minlin Zhong, Director of Laser Materials Processing Research Center at Tsinghua University, LIA President-Elect

LEARN MORE

Evaluation of 3D-printed parts by means of high-performance computer tomography
E.Lopez, T. Felgueiras, C. Grunert, F. Brückner, M. Riede, A. Seidel, A. Marquardt, C. Leyens, and E.Beyer

Journal of Laser Applications 30, 032307 (2018); https://doi.org/10.2351/1.5040644

MPIF 2017 PM Industry Roadmap -
https://www.mpif.org/MarketPM/2017-Roadmap.pdf

MPIF State of the PM Industry in North America 2017 -
https://www.mpif.org/News/Press-Releases/pdfs/PR12-2017-State-of-the-PM-Industry-Report.pdf

ASTM Additive Manufacturing Technology Standards -
https://www.astm.org/Standards/additive-manufacturing-technology-standards.html

MEMBER INNOVATIONS

Member innovations is a space for LIA members to share how they are making strides in their respective industries. Submit your innovation news by August 6, 2018 to be considered for the July/August edition of the *LIA TODAY*. Only submissions by active LIA members will be considered.

For full submission guidelines, please email: **lia@lia.org**

MIDWEST ENGINEERED SYSTEMS

INTRODUCES A LASER METAL WIRE PRINTING SYSTEM FOR MANUFACTURING: ADDERE

Faced with the common problem of high material costs and availability, along with low efficiency, in the Aerospace and Defense Manufacturing Industry, Midwest Engineered Systems (MWES) has developed a laser metal wire printing solution. MWES developed the system, known as ADDere, to reduce manufacturing costs and time, while increasing the quality and ROI.

Traditionally, large parts, such as airplane wings, seat structures and rocket engines, are manufactured either out of billets and machining or in small sections which are then welded together.

In lieu of machining parts out of billets, and dealing with a high percentage of scrap material, only material that is needed is deposited and therefore reduces the overall cost of machining the parts. The ADDere system allows 3D parts to be built out of exotic material, such as Aluminum, Titanium, Inconel and other metals, in dimensions that were not feasible in the standard 3D metal printing process.

The ADDere system uses commonly available welding wire as build material, which allows for the elimination of hazardous handling and processing of metal powder. The high deposition rate of up to 20lb/hr by the ADDere system outperforms commonly used 3D metal powder printing systems.

Interested parties can contact MWES through the ADDere website for information or to request a demonstration at: www.addere.com.

By Hans Volkhart

Sr. Sales/Applications Engineer

ADDERE

A DIVISION OF MWES INC.

BLUE LASERS ARE ADVANCING MATERIALS PROCESSING

Image courtesy of Nuburu Inc.

Blue lasers bring significant advantages over traditional infrared lasers, especially for materials processing. "Yellow" metals, for example, absorb only a few percent of incident infrared radiation, so infrared laser welding is possible, but only in an operating regime that requires time-consuming wobbling or spiraling patterns. Even then, infrared welding must be done in keyhole mode, leading to porosity in the weld, reducing both the mechanical strength and the electrical conductivity. Metals absorb ten times (or more) as much energy from blue light. That leads directly to higher quality welds and faster processing speeds.

NUBURU (Centennial, CO) has introduced a new class of high-power, high performance blue lasers ideal for demanding applications. The first product of the new line, the 150 watt, 450 nm AO-150 high-power blue laser is already making its mark with improved performance in a variety of materials processing applications. The AO-150 modular design efficiently combines individual diode beams to produce blue laser output with unprecedented quality and power.

Those qualitative and quantitative advantages are already bringing disruptive capabilities to bear on fabrication challenges for lithium batteries, and also cellphone fabrication, where the blue laser's ability to weld copper and dissimilar metals is essential. In fact, NUBURU's technology is appropriate for almost any application where thin to moderate-thickness copper must be welded. The blue laser is more flexible than ultrasonic welding and faster than infrared laser welding, and the weld quality is unsurpassed by any alternative technological approach. NUBURU is continuing to develop the technology, with higher power lasers coming to market in the near future. In addition, the company continues to expand the application space. For example, the higher absorption of blue wavelengths offers a 3X to 10X improvement in speed for selective laser sintering, a process where laser energy fuses metal powder into arbitrary shapes. Blue light offers a similar advantage for laser metal deposition, an alternate additive manufacturing process.

For more information, visit www.nuburu.net

By Jean-Michel Pelaprat
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NUBURU®

NEW TECHNOLOGY FOR LASER ROOM ENTRY CONTROL

MITIGATES RISK OF HUMAN ERROR

The laser safety community has pointed out the need for a low-cost solution for indicating laser hazards and potential laser exposure. Current room control solutions range from the simple placement of a static sign on the entryway to installing a third-party system control system to interlock a laser. Signs that are manually switched could lead to a potential hazard if personnel neglect to turn them on. Remotely triggered signs often mitigate risk of human error but generally cost more.

Kentek has developed a new technology for laser room entry control to meet this need. The laser draws power from Kentek's Area Warning Device (AWD) which sends low voltage to a lighted warning sign. It's simple: the sign turns on when the laser is on – with no user intervention required.

Kentek's Area Warning Device (AWD). Image courtesy of Kentek.

Designed for 120VAC powered lasers, the minimum ampere draw required to trigger the AWD is 1.5 amps. Kentek has selected the maximum ampere draw to match typical household receptacle rating of 15 amps.

National standards, including ANSI Z136.1, *American National Standard for Safe Use of Lasers*, provide guidelines that keep personnel safe and allow options for different applications and budgets. Choosing to standardize these controls at your facility aids in easy identification of the hazard controls in place and requires less overall complexity in training.

Refer to the national standard and consult with your Laser Safety Officer (LSO) to evaluate risk at your facility and develop possible solutions available for your application.

For more information, visit: **http://www.kenteklaserstore.com/**

By Shane Legere
Laser Safety Officer

KENTEK
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JULY/ AUGUST MEMBER INNOVATION SUBMISSION GUIDELINES:

- Must be an active member of LIA
- Article must be informational and should explain how the innovation solves an industry challenge
- Article must be between 200 - 500 words in length, submitted as a Word document
- Article should include 1 - 3 relevant images, sent as separate attachments
- Article should include company logo, sent as a separate attachment
- Article should include the author's name and job title

Deadline: August 6, 2018 | Email: lia@lia.org

Laser-assisted dry, wet texturing and phase transformation of flexible polyethylene terephthalate substrate revealed by Raman and ultraviolet-visible spectroscopic studies

BY ASHISH K. SHUKLA, I. A. PALANI, AND ANBARASU MANIVANNAN

A systematic understanding of laser-induced texturing and its influence on the local structural change in polyethylene terephthalate (PET) substrate offers enhanced performance characteristics of photovoltaic devices. The formation of multiple phases in flexible PET substrate using selective processing by means of laser-assisted heat input reveals enhanced ultraviolet-visible (UV-Vis) absorption. The authors investigate the characteristics of multiple phases formed during the interaction of the laser pulse on the PET substrate processed under dry and wet environments. It is observed that the laser beam profile is replicated on the substrate during wet environment. Moreover, the heat gradient of laser beam have induced various indexed crystalline phases as revealed by Raman spectroscopy as well as their optical characteristics of replicated profile on PET substrate is quantified using UV-Vis absorption spectroscopy. Furthermore, a redshift in the absorption measured at the center of the projected beam profile is attributed to the higher degree of ordered crystalline phase as compared to other graded phases inside the trench. These findings of phase gradients and their influence on optical properties of laser-induced texturing would be useful for laser-based rapid texturing for flexible photovoltaics.

Journal of Laser Applications 30, 022008 (2018);
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Laser Safety in Health Care

Arriving July 2018!

Remove the guesswork from your medical laser safety program!

Recognized as the industry standard for the safe use of lasers in health care applications, the revised Z136.3 provides the guidance necessary for establishing a medical laser safety program. The document has been extensively revised in every section to reflect current thinking and practice.

New to the 2018 document:

- Updated sections on laser plume (LGAC)
- Expanded sections on third party laser rentals
- Introduction to the newly defined Class 1C
- Clarification of the roles for the LSO, DLSO, LSSC and LSS
- Review of the best practices relevant to a broad spectrum of laser applications in health care

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Coming soon – the latest revision of the Z136.3, *American National Standard for Safe Use of Lasers in Health Care* is on the horizon!

The Z136.3 standard serves as a guideline for medical laser use in health care environments such as hospitals, surgery centers, dental and veterinarian offices, as well as cosmetic facilities such as laser hair removal salons and spas. All personnel who use or are exposed to a laser or laser system used as a medical device for a health care application are advised to follow this standard. It is meant to aid in the establishment of medical laser safety policies, procedures and training programs.

The document has been extensively revised in every section to reflect current thinking and practice. The roles and responsibilities of the Laser Safety Officer (LSO), Deputy LSO, Laser Safety Site Contact, and Laser Safety Specialist have been clarified, with additional information regarding these positions discussed in a new normative appendix. The sections on laser plume, and guidelines for third-party laser rentals have been revised and expanded. This version also introduces the newly defined Class 1C, which includes laser products designed explicitly for contact application to the skin, i.e., intended for hair removal, skin wrinkle reduction and acne reduction.

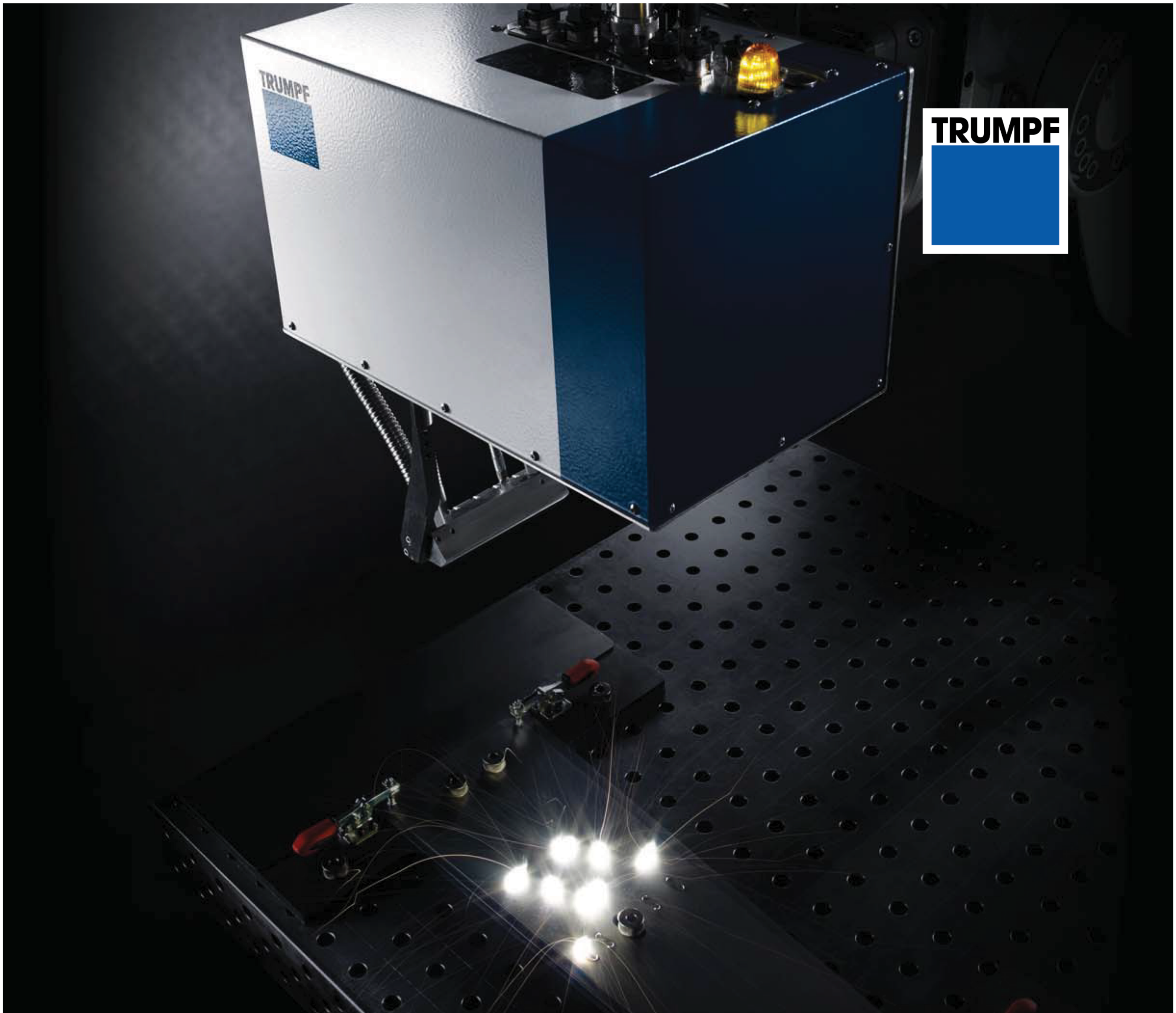
The Z136.3 standard has proven to be the key to successful medical laser safety programs. June Curley, a registered nurse and certified medical laser safety officer at Tampa General Hospital, said, "I highly recommend that the ANSI-approved Z136.3 standard be an integral part of any laser program as an invaluable source of reference. I cannot imagine having the responsibility of being CMLSO without the support of the recommendations it offers."

The document also enables medical laser safety officers like John Sakaris of MD Anderson Cancer Center, Houston, to feel more confident in their position of authority, "The standards are an excellent source to help educate non-clinical personnel on Laser Safety Committees, and some who are but novices. It recently helped me reinforce a laser maintenance issue; John Sakaris was right because of the standards, not because John said so. I am considering doing a presentation on this topic at our next International Laser Safety Conference (ILSC)!" We hope to hear more from John about his experience as a CMLSO at the March event.

From medical/surgical laser education specialist and MLSO instructor Lesley Pollard, "When I am asked to make just one suggestion to a medical/ surgical healthcare professional with a primary goal to ensure the efficacy and appropriate framework at their facility in order to begin the journey of developing or supporting a thorough and compliant health related laser safety program, that initial suggestion will always be to purchase, read, and understand the latest edition of ANSI Z136.3. A proper framework or foundation is imperative to achieve goals. The best foundation for an effective and compliant medical/ surgical laser safety program is a basic understanding of the healthcare laser safety reference document, ANSI-approved Z136.3."

The latest Z136.3 Safe Use of Lasers in Health Care will be available in both print and PDF formats in the Laser Institute of America online store in July/August at:

https://www.lia.org/store/laser-safety-standards.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