Flexible Substrate

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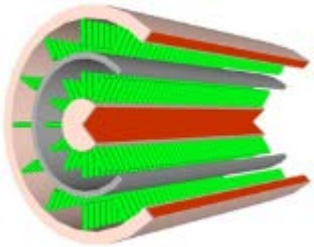

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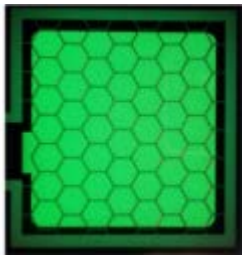

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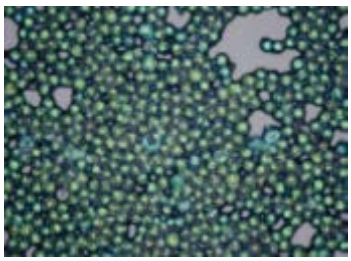

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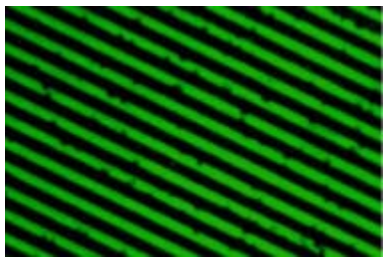

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Interview with Lou Panico, CEO and President, XENON Corporation

Lou Panico is president and CEO of Xenon Corporation. One of the founding principals of the company, he has authored numerous technical papers on Pulsed Light Technology and its application in various industries. He holds a degree in Electronic Engineering from Northeastern University and is a veteran of the U.S. Marine Corps.

Please give us some background information about XENON. XENON Corporation manufactures high energy pulsed light systems for Industry. This includes the design and manufacture of High Energy xenon Flash Lamps and all associated electronics for customer specific requirements. The company has been established for 50 years with specialization in a number of markets including Optical Disk (Blu-ray and DVD), Surface Sanitization, Food Enhancement, Printed Electronics, OLED and Displays. Applications of our core technology include: UV Curing, Photonic Sintering, UV Sanitization and Surface Annealing. Advantages of Pulsed Light Technology are high peak power, Low Substrate Temperature, and Instant On-Off lamp flashing with controlled energy delivery. Pulsed Light systems offer a non-contact process requiring no additional chemicals or special environments. It is a versatile tool that can be configured to meet demanding continuous or batch process requirements and has been proven to operate 24/7 in industrial environments. XENON is a privately owned manufacturing operation with headquarters based in Wilmington, MA in the USA. All XENON products, including lamps, are manufactured at their main facility in USA. Website: www.xenoncorp.com

The phrase "Printed Electronics" covers a huge array of product concepts. Do you have a definition of "printed electronics" as it pertains to your solutions? Printed Electronics is an additive process of depositing ink onto a often Low Temperature flexible substrate and then Sintering the ink to form conductive traces. These inks are typically based on nano or micro metal particles that achieve low resistivity after exposure to Pulsed Light. The process of Sintering inks can also be done with the use of Low Temperature ovens, however, as process times for oven based Sintering are in the order of minutes in most cases, this form of Sintering is not ideal for roll to roll or high speed production. An alternative is to use Pulsed Light or Photonic sintering. This can achieve similar results to oven based sintering but in fractions of a second. It can be retrofitted to a production process and is a Low Temperature alternative. This technology is currently used in the high-speed manufacture of printed circuits on paper, PET and other thin film substrates. A number of different inks have been proven to work with this technology including silver, copper, gold and ITO. This allows the technology to be used in touch screen, display, RFID and other printed circuit applications.

Give us some history about the use of pulsed light solutions for use in electronics surface applications and solutions. XENON started looking into the use of Pulsed Light to sinter nano-metallic inks around four years ago. These inks were silver and copper based. Early success suggested the development of low cost R&D tools for emerging Sintering applications. The first R&D equipment was sold to ink formulators to identify ways to optimize their inks for Photonic Sintering. Over the years R&D Sintering equipment was primarily sold to government institutes, academic organizations, ink formulators, print manufacturers and process developers. To bring all these diverse technologies together, XENON established PE Test Center Network sites with 27 worldwide locations to provide new Printed Electronic players a means to quickly evaluate Photonic Sintering technology. These commercial, government and academic sites allow access to their facility and resources to validate the efficacy of the technology and identify ways to optimize the system for a given customer process requirement. The success

generated from these R&D offerings has evolved into the creation of high-speed, continuous, Photonic Sintering products such as the Sinteron 5000, which has been deployed in production.

Are all of your pulsed light solutions based on xenon lamps? Yes they are all xenon lamps, designed and manufactured by XENON. What XENON is able to offer our customers is years of experience in the development of xenon lamps that are application specific in terms of key performance needs such as output spectrum, length and optical profile. XENON is today the only supplier of lamps and power systems to Sony for their Blu-ray manufacturing systems. These systems operate 24/7 under the highest standards of reliability.

Xenon recently introduced a 60 inch (1.5 meter) Pulsed UV Linear Lamp system for industrial applications. The LH-8150 was developed for large area UV curing and sintering in roll-to-roll or web based processes and designed specifically for the display and printed electronics markets.

Do xenon lamps provide any particular advantages over other light sources? XENON flash lamps offer a broad-spectrum light source ideally suited to Sintering nano-inks. This is because light absorption of various inks will vary based on their base metal, formulation, substrate and particle size. A broader spectrum means that these parameters need not be tightly controlled. Additionally as flash lamps generate high intensity pulses which only last, at most, a few milliseconds, where peak powers can be in the megawatt region, there is sufficient energy to instantly sinter the ink without significantly raising the temperature of the substrate. The process is instantaneous and with high peak power, light is capable of penetrating into the ink and, though attenuated, still have enough energy to effectively sinter the inks. Customization of the lamp and optical parameters allow flexibility in deployment for customer specific requirements. Our flash lamps are air cooled, requiring no special handling or processing.

Please give us an overview of your sintering system-level offerings. XENON offers both R&D and production systems falling under our Sinteron family of products. For R&D this includes the Sinteron 500 and the Sinteron 2010. The Sinteron 2010 allows higher energy pulse generation and better control of the pulse energy in terms of pulse width and amplitude. The Sinteron 2010 also includes an option for a conveyor or linear stage facilitating dynamic testing in roll-to-roll (R2R) applications. The conveyor system can be used for small-scale production runs. Moving to full production, the Sinteron 5000 is an example of a system incorporating up to 10 flash lamps to accommodate a web width of 12in. This system is capable of throughputs of 75 ft./min. It includes a touch screen user interface for setting up and controlling the lamp sequencing. This product is currently available and being used in commercial production today.

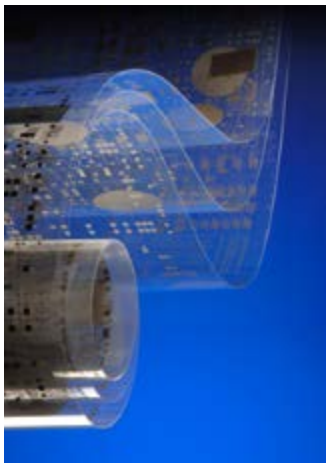
It seems that most any material can be put into solution. XENON's focus is on the sintering of metallic inks. Are there specific materials that are optimal candidates for your solution and are there some materials that don't work well with your technology? When we talk about Printed Electronics we refer to functional inks. In this regard resistivity is only one functional parameter. There may be others such as adhesion, transparency, stitching (the interplay between two adjacent sintered regions). To have one function, say resistivity, work and the others not work is the same as not having the overall process work. All these requirements are features of the complete process and all its components. This includes ink formulation, substrate choice, print technology used, and drying, pretreatment, web width and process speeds. So even if a solution exists for Sintering silver as an example, the final solution which requires a specific substrate and print technology may not have acceptable results in terms of the required functional parameters.

By far the easiest ink material to sinter is silver in nano, micro or flake form. The best substrates include paper (for its wicking characteristics), PET and PI. Copper is a good example where different formulations work differently. For example, some ink requires high energies to sinter while others sinter readily with low energies. XENON's

Photonic Sintering works best with metallic nanoparticles but also works with a wide variety of inks including micro-particle inks, nanowires, oxides and ceramics. Success with gold, ITO, Platinum has shown that we do have a wide application base. Examples where the technology is less effective is glass and semiconductor wafer substrates, these materials typically show poor adhesion once sintered. Some inks have too small an operating window to be practical.

One thing to bear in mind is that Photonic Sintering is a scalable technology in that as demand for higher throughput is required more systems can be put in line to keep up with the process speeds. However, there may be cases where the energies required for a given process becomes cost prohibitive. In most cases it is not that the process doesn't work well but rather that further optimization is required in the various components to achieve desired functionality.

What substrate materials seem to work best for your process? Photonic Sintering works best with substrates such as PET, PI and other Low Temperature plastic. Paper is another good substrate particularly for adhesion. However XENON can also sinter on a range of surfaces including glass, Fiberglass (such as FR4 used in PCBs), silicone and ceramics. When dealing with any substrate the adhesive properties of the ink on the substrate, the substrates heat sinking ability and absorption characteristics play a role in its applicability.



Example of flexible substrates used in the printed electronics market

How dependent is the relationship between the inks and the print head? Do inks have to be formulated specially depending on the print head? It is important to bear in mind that XENON does not formulate inks or print equipment so we are not the best supplier to answer this question. However, we partner with major ink and printer manufacturers around the world who use our Photonic Sintering systems to optimize solutions based on Pulsed Light. This allows us to have an inclusive approach to use ink formulations from many vendors.

Is your sintering solution optimized for a roll-to-roll process, or is it simpler to operate in a sheet-based production process. XENON has developed systems for both roll-to-roll as well as sheet based processing. For small area applications the XENON spiral lamp housing is used for static full area sintering. For sheet-sized applications a linear stage is available with a linear lamp. An example of such a system would be the Sinteron 2010 with a linear stage. For roll-to-roll the Sinteron 5000 is the ideal choice as it offers 10 lamps with synchronized flashing with the web speed. This system is designed to cope with web widths of 12in but has the flexibility in design to cope with web widths that are more than 1 meter wide. This is the true advantage of XENON in that we can design systems to our customer specifications rather than have limitations set by our equipment.

Popular printing solutions for the PE market include screen, flexo, gravure and inkjet. Does your sintering solution support all of these printing methods or do you have any preferences? Yes, XENON has successfully sintered nano ink samples for all of the above processes on different substrates. We have no preference in this regard.

Identifying how ink interacts with the substrates, curing and printing mechanisms has been a continual bugaboo for PE companies. Which one of these seems to be the biggest challenge? We see ink formulation as the key in the final deployment of Printed Electronics. Ink formulations that require lower photonic energy to sinter, behave well with the print technology selected and the substrate must succeed for PE to advance. Development of low cost copper based inks that are user friendly, require low energies to sinter and have a wide operational window seems like the holy grail of this technology. At XENON we are developing our own list of the best in class processes where we look at success stories with a specific print technology, ink and substrate. This promises to be a useful step in addressing the challenge.

As mentioned earlier we have established the worldwide PE Center Network to look into this multifaceted problem in a cohesive and non-competitive but collaborative manner. To assist the ink developers, we have provided Photonic Sintering equipment for the advancement of the technology.

The third is Xenon's Sinteron 2010

In the next couple of years, what market segments do you expect will comprise the bulk of XENON's PE sales? The PE industry as we see it today includes a variety of unique markets, such as OLED, RFID tags, displays, photovoltaics and battery manufacturing as examples. We anticipate that other Printed Electronics applications will emerge over the next several years as developing markets demonstrate real cost savings when compared to conventional manufacturing technology. For this reason, we are unable to determine which of the existing and future markets that fall under the umbrella of Printed Electronics will comprise the bulk of our future sales. We are excited by the potential increase in our system sales as these markets move to high volume R2R manufacturing. Indeed there are many who feel that Printed Electronics production is still a few years away from mainstream deployment. Based on the large number of XENON's R&D systems that have already been installed by worldwide institutions and with the continuing assistance being given by our partner sites to new companies exploring Printed Electronics for the first time, we forecast that an ever increasing number of new customers will gain sufficient confidence to make the jump to production systems, be it small scale or large.

How do displays fit into your long-term plan? We have made excellent progress to date in meeting the needs of a number of application areas for display vendors. First there is curing for bonding glass layers, which use UV Curing. We have built lamps that are 60in long to address the demands for large area displays. This requirement is growing rapidly. Then there are touch screen displays and Films. These are currently based on ITO Films or silver nano-wires again our equipment is currently used in their production. Additionally in the areas of OLED and printed display technologies, our equipment is currently used in production. In this case surface treatment benefits of our technology is used. Overall, the display market illustrates an application that not only has Pulsed Light technology from XENON achieved success in R&D work, but also we have also established success in a production environment where robust hardware systems are demanded. This is fortunate as displays; in particular touch panel displays represent one of the largest growth market sector today.

Please describe what you think XENON will look like three years from now. XENON will be the leader in providing hardware systems for Photonic Sintering of nano inks applied in the manufacturing of Printed Electronics. Our goal is to be the best in class supplier with regard to flexibility, cost, quality and performance. We will have embedded ourselves in a diverse range of markets including Displays, PE, Sanitization and Industrial UV Curing. We will achieve this by our engineering excellence, our expertise and inclusive and open way we work with our customers.

Where do you see the bulk of money will be made in the PE industry? Ink, printers, sintering solutions, materials, end-products? For the Printed Electronics to flourish and grow rapidly in many of the markets we see evolving, end products will have to be the main money earner. This goal can only be achieved if production costs in terms of materials and consumables are low. The initial driving force will be custom high cost, low volumes end products that will allow development and the demand for low cost, high volume products. Without the carrot of the former, the technology will find it hard to overcome the challenges of the later.

Do you have any opinions about whether PE technologies can flourish as North American and European production solutions, or will manufacturing shift to Asia as with other electronics solutions? Interestingly, XENON's first sales of production equipment have been in the USA for the manufacture of custom circuits as well as RFID. Based on these initial success stories, we feel both North American and European manufacturers can compete with the typically more aggressive Asian suppliers. Asian markets may work towards the high volume production but Western nations have invested heavily in the development of PE and there is bound to be significant growth there even if it is on a high cost, low volume, highly custom applications.

Tell us about what motivated you to create your Test Center Network? The PE Test Center Network was created because we believe that working together with experts in all aspects of PE in a non-compete but collaborative fashion is the only way that we can see significant advancement of the technology. As mentioned earlier this is a multi-dimensional problem with an unlimited number of variables. By working with other experts or organizations, we can help in finding optimal solutions for industry.

How many associated organizations are currently participating in your Test Center Network? Currently there are 14 organizations in the USA and 13 organizations distributed outside the US, who are members of the network. This network includes major corporations, academic and government institutes. The success of the network is bringing more and more groups into the network for collaboration and participation.

Are the customers using your Test Center Network primarily from industry, academia, or R&D labs? Main interest for the PE Test Center Network is from end users. Companies that want to develop a custom solution for their custom application.

Describe the "perfect customer" for your Test Center Network. We have the greatest success working with customers who have a good understanding of what they require to sell their end products to their markets, such as cost, features, distribution networks, and is anxious to explore a new manufacturing technology to achieve those goals. Our "perfect customer" will share, under NDA, their material properties to assist XENON in developing the best hardware solution. This may require unique lamp configurations or control configurations to best match our customer application. The network groups can work with our customers to find the optimal solution or, as a minimum, work closely by trying out different parts of the solution to help define the process components and parameters.

The Sinteron 2010C (conveyor system)

How does a company typically connect with one of your Test Center Network partners – through you, or through your partner company? Both ways have been used with success, although the typical process is to contact the test network partner directly, which may be local.

Are customers within your Test Center Network assigned to specific partners depending upon their needs or is the network designed more to enable regional test support? There is a mixture here. Some partners are experts in their own specific area. This could be an ink manufacturer or a process developer. Others are government agencies or academics who have a range of different equipment and processes for people to try out. A few are distributors with equipment available for doing experimentation. In this way we are able to deal with groups who require different degrees of assistance. Some may have fixed on the ink and substrate but needs help with the lay down and sintering. It would make more sense for them to visit print equipment manufacturers within our network. The network provides the tools and expertise that the customer needs.

How do your Test Center Network partners make money from their relationship with XENON? XENON does not charge or receive any monies from our PE Test Center Network partners for their participation in the program. Most network partners offer their support at no charge to participants seeking data to verify how Pulsed Light technology works on their inks and substrates and thus do not make money directly from the program. A limited number of our Test Center Network partners will offer their services, equipment, time and expertise for a nominal charge. Some partner sites can showcase their solutions and this may lead to sales say for inks, printers and so on. Some government institutes get government funding for R&D.

Is XENON's goal to sell sintering tools and lamps to the customer using the Test Center Network or is your intent to support the partner company as they expand their use of XENON systems to mass production solutions? Yes, XENON and our distributors will sell Sintering systems to customers who decide they need to establish their own in-house capability for continuous long term R&D work. This will typically occur, for example, with ink formulators. However our key objective is to provide ultimate production hardware solutions that use not only our technology but also those that are offered by our partners. We consider our test sites to be a platform to showcase the best in class technologies and facilitate a dialogue between XENON and end users to make it easier for XENON to match the specific needs of each market regarding lamp configurations, power levels, substrate transport and operator control interface. As these discussions take place, using the data achieved using XENON's R&D systems; new hardware system solutions can be rapidly developed. This approach has been the hallmark of how XENON has worked for 50 years in disparate markets such as the manufacturing of Medical Devices, semiconductors and Optical Discs – Blu-ray and DVD. Additionally we seek to advance PE technology as a whole and we do this by bringing experts and researchers together for a common objective.

Xenon's Sinteron 5000

Do you have any worries that your partners in the PE Test Center Network may end up competing against one another, or is the market potential adequate to avoid such potential conflicts? No we have a strict no-compete strategy where the best technology is offered and our prospects obtain the optimum solution for their specific needs. We also see an overall market with a potential for accelerating growth over the next 5 to 10 years as end-users experience their success in achieving low cost high volume manufacturing using Pulsed Light technology for Sintering.

Please share a couple of favorite examples of customer success stories. A major printing company based in the US, with a business model focused on selling both printing equipment and their inks, decided to enter into the PE domain. Their analysis showed they could compete directly with low cost Asian manufacturers of RFID tags if they could achieve high-speed, low cost, production. They approached XENON to learn how to sinter their inks on PET substrate material. They found the results to be exceptional. They initially purchased our R&D equipment to do their own optimization of the sintering process using their proprietary inks. We worked with them in developing a new hardware system for their initial production requirements. The final system was delivered meeting their schedule based on the close working relationship between the engineering staffs of both organizations. It is important to mention that XENON agrees to enter into a confidential relationship with all our customers so our engineering staff can work closely on all aspects of our customer requirements. The close working relationship that evolves is almost a custom designed system matching exactly what each customer requires to achieve low-cost

large scale manufacturing of his product. In the example discussed here, the XENON system is currently in production use and we anticipate future additional orders as our customer achieves their forecasted growth in sales of their products.

What value do you see in attending trade shows targeted to the PE markets? XENON both exhibits and delivers conference papers at major shows such as the upcoming Printed Electronics USA2014 show this November in CA. Our main objective is to educate potential users on how our technology works and how it can be adapted to match their specific low-cost manufacturing requirements. We typically showcase our R&D systems so attendees can witness actual room temperature Sintering on heat sensitive materials using examples of available nano inks. For this coming PE show in Santa Clara, we will be bringing our S-2300 Sintering Tool to demonstrate its Thermal Management capability.