Optimize Inkjet Printing Adhesion for Wire & Cable Marking

Digital inkjet printing wire & cable provides manufacturers with productivity advantages including variable data, fast changeover & indelible printing at top line speeds.

However, material properties, contamination, ink/material compatibility & durability requirements create challenges. Fortunately, a trilogy of suppliers have worked together to develop repeatable solutions for printing on a variety of substrates.

In this paper Gem Gravure, Excelitas and Enercon cover:

- Benefits of Continuous Inkjet (CIJ) Printing Technology
- Keys to substrate & ink interfacial adhesion
- Why ink formulation matters
- How plasma & flame treatment enable adhesion
- Benefits of UV LED Ink Curing Technology

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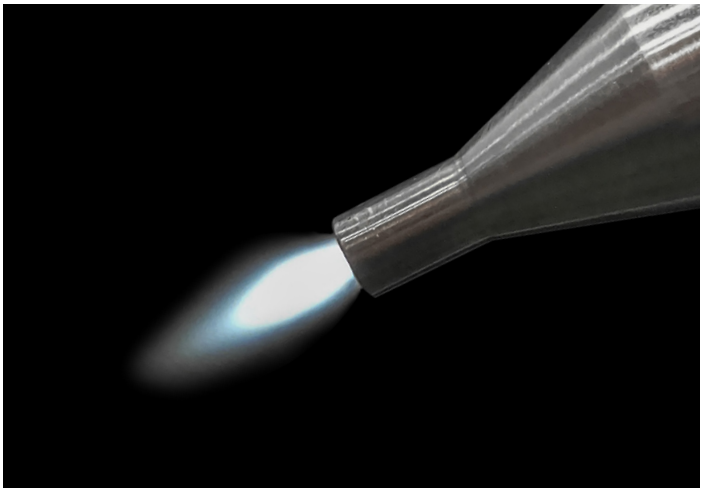
Benefits of Continuous Ink Jet Printing

A common solution for marking wire & cable, continuous inkjet printing (CIJ), has been around since 1979. Though it was initially created as a complement to gravure contact style printing, continuous inkjet has improved to the point where it is the preferred method of printing. Some of the benefits of inkjet printing are variable data – things like sequential footage, serial numbering and more. Printable data can be changed an instant.

Another huge advantage is that the printing is non-contact; the ink is simply sprayed onto the surface. That means you can print on curved, hot surfaces straight out of extruders and even soft surfaces that you can't touch because it would deform the jacket or do something odd.



Speeds are impressive – you can print up to 1,800 feet per minute. You also have the flexibility to move a printer from line to line while being able to recall the same data/message for each print. Ease of use is critical as well. If you can operate a mobile phone cell phone, you can operate a printer. Intelligent use, or the ability to scan a barcode and download a print message directly to your printer from an existing database makes it that much easier to streamline your operations.

You also have less chance of mistakes on the line. Total cost of ownership is much lower than other marking solutions such as laser or other heavy-duty contact style printers. And you can use CIJ in many other industrial applications, if you have more than wire & cable that needs a code.

Aside from UL compliance (which tells people how and why to use your product), CIJ also allows for placement of logos and barcodes. Other tracing data in a code allows for inventory management and quality control. If you need a bright, durable code that can withstand harsh manufacturing environments, inkjet could be a perfect solution for you.

Optimizing Surfaces for Printing

Key to successful wire and cable printing is ensuring the jacket surface is receptive to wetting out and bonding with inks. Most materials used for wire and cable jacketing have low surface energy and low surface energy can lead to poor adhesion. In addition, surface contamination and additives rising to the surface of jackets can interfere with proper adhesion. Fortunately there are plasma and flame surface treatment technologies which can enable successful bonding with these materials by cleaning, etching and functionalizing them.

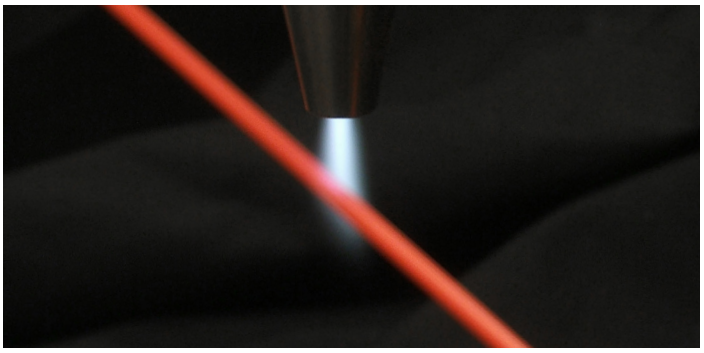
When you observe an ink or liquid beading up on a surface you are witnessing **the forces of cohesion** (the property of the liquid's like molecules to remain attracted) being stronger than the **forces of adhesion** (the property of unlike molecules to attract.) When you plasma or flame treat the surface, you are enabling the adhesive forces to be greater than the cohesive forces to promote bonding.

What is plasma?

Plasma is the fourth state of matter -- simply stated it is an ionized gas. It has positive & negative electrons, UV light, and free electrons. When you bombard the surface with plasma, three things happen. Plasma cleans the surface by removing organic and some inorganic impurities. Organics usually take the form of a hydrocarbon chain, so when you bombard them with oxygen or hydrogen ions, you create CO2 and water vapor.

When plasma etches a smooth manufactured surface you create more surface area for bonding with inks. The etching is only in the range of 5 to 30 nanometers, but any increase in surface gives you more area for bonding.

Last and most important, you're functionalizing the surface. Functionalizing the surface means adding oxygen groups, hydrogen groups, and hydroxyl groups to the outer most molecular layers of the surface. In the case of flame surface treating, carboxyl groups are being added. These additions increase the overall surface energy promoting indelible ink adhesion.



WIRE JACKET MATERIAL	IN-LINE PLASMA TECHNOLOGY	PRE-TREATMENT DYNES/CM	POST-TREATMENT DYNES/CM
XLPE	Blown-ion™ Plasma	32-40	46
XLPE	Flame Plasma	32-40	60+
PVC	Flame Plasma	35	46
PVC	Blown-ion™ Plasma	35	60+
Silicone	Blown-ion™ Plasma	20-25	50+
HDPE	Blown-ion™ Plasma	35	60
HDPE	Flame Plasma	35	66

Table 1

Materials and changes in surface energy

Surface energy is commonly measured in Dynes. Higher dyne levels mean higher surface energy which is better for promoting adhesion. **Table 1** includes common materials with before and after surface energy measurements:

Integrating plasma treaters

Plasma treaters are easily integrated into existing lines. The treatment discharge head is mounted prior to the inkjet printing head. Depending on your line speed, jacket material, ink chemistry and area to be printed on either a blown-ion or flame plasma treatment technology will be recommended.

Determining which technology is best for your application can be determined either by lab testing or field lab trials. If you have a CSA standard or some other standard that you're trying to meet trials can be run in your facility with a demo system. Enercon also offer free laboratory trials as well.

Also, prior to the jacket going on the wire, many times, we're cleaning the conductor with plasma and/or flame. This is another common application we clean the conductor before the jacket comes on. Then after the jacket is on the wire, we will help with the printing.

Ink Jet Printing Technology

One of the main reasons CIJ works so well in industrial applications is the way the technology works. The printer itself has a printhead which maintains a constant stream of ink. The ink itself is broken up into thousands of droplets and the droplets are then charged by the printer so they can be controlled. The printer knows which ink droplets to charge to create the desired message. When the printer sends the message to the printhead, the charged droplets travel through an electromagnetic field that dictates size, shape and spacing before finally exiting the printhead onto your substrate. Any ink not used is deflected back into the system and recirculated for future use. The messages are designed and printed in a simple dot matrix format allowing this technology to work seamlessly. Any text, logo, batch code, QR code or barcode can be created with this simple technology.

Ink Technology

Another important component of CIJ technology is the ink itself. There are three main categories of ink: dye-based, soft-pigmented and hard-pigmented. Dye-based inks are like sugar in hot water; the components dissolve easily and are easy to run in the printer. These are generally black inks for standard applications. Soft-pigmented inks are like sugar in cold water; the components take a fair amount of agitation to solubilize, however there is better adhesion and contrast and can be a few different colors. Heavy-pigmented inks are like sand in water; the components need to be constantly stirred to maintain proper ink properties. While the printer operation of these inks may require some extra attention, these inks can provide every color of the rainbow for nearly every application.

These inks all have four main components – carrier solvents, colorants, resin and additives. Carrier solvents disperse solid components (pigments) and support electrical conductivity. They evaporate at stable rates, keeping the ink shelf stable for long period of time. Colorants can be dye-based or pigmented and mainly affect color, opacity, shelf-life, appearance of print and transfer properties. Resin provides adhesion, durability and chemical resistance to the ink. Additives aid conductivity, modify the surface tension of the substrate and stabilize the dispersion. The composition of these four components are important in choosing the right ink for your application, as different substrates have different surface tensions. For some challenging applications, not even a perfectly engineered ink may work which is why GEM partners with companies

like Enercon and Excelitas – to use their applications and our technology to create the perfect marking solution for you.

UV Printing and LED Based Solutions

While there are different technologies for wire and cable printing, ultra-violet (UV) curing provides fast, durable, and legible inkjet marking with exceptional adhesion, for fiber-optic and electrical cables. UV LEDs provide even further benefit over traditional lamp systems as the low temperature curing does not induce stress into the cables, thereby improving the yields. UV inks differ from water or solvent-based inks, whereby exposure to UV light triggers the polymerization of the ink to "dry". Present in those inks are photoinitiators with specific absorption spectra and dose requirements to enable the cure. Other parameters impacting UV curing include:

1. Irradiance (W/cm2) – the minimum peak energy required to initiate polymerization
2. Dosage/Energy density (J/cm2) – measured as the time integration of irradiance, where sufficient energy is needed to enable adequate cure
3. Exposure time(s) – duration of exposure time to UV energy, and is a function of print speed and size of UV emitting window
4. Spectral content – responsiveness, as determined by match of photoinitiator to peak wavelengths of UV output

Traditional mercury based UV lamps emit a very broad spectral output, with contributors from the UVC (200 – 280nm), UVB (280 – 320nm) and UVA (320 – 400nm) bands. Consequently, with exposure of UV inks to these broad band sources, there is typically spectral content reactive to photoinitatiors in the ink to ensure a successful cure.

UV LEDs, however, differ from UV lamps, in that they are essentially monochromatic. Only a narrow band of light is emitted, and is centered on a peak wavelength. As such, a match between the LED output spectrum and photoinitiators in the ink chemistry is crucial.

Figure A illustrates the spectral output of a mercury based UV lamp in comparison to the emission of four common UVA LED wavelengths – 365nm, 385nm, 395nm, and 405nm. On the left is a depiction of early UV LED solutions, where the relative output intensity is quite low. With the introduction of LEDs, not only were there limitations in performance, but also in the availability of compatible ink formulations. As a result, initial adoption of LED based systems for print applications was slow. However, as performance and costs of UV LEDs improved, and a wider range of inks became accessible, UV LEDs become a favorable choice for printing. The image on the right shows the tremendous output improvement of where LEDs are today.

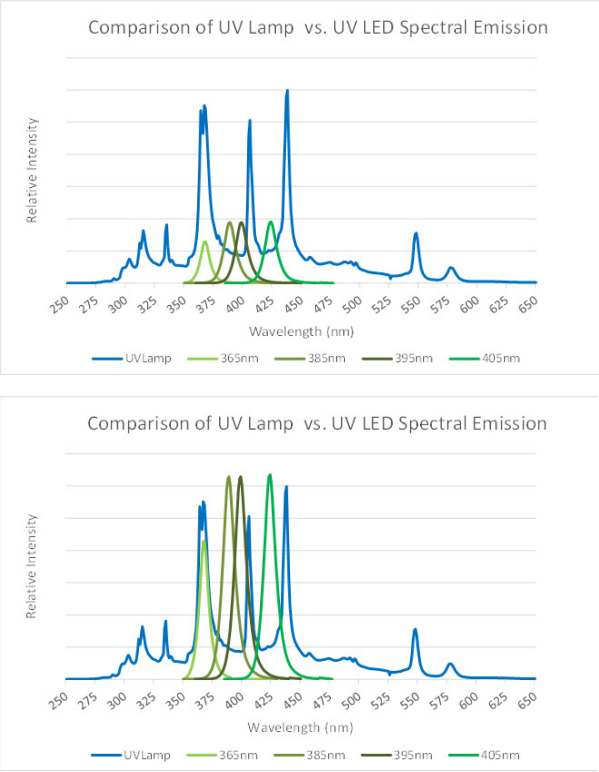


Figure A

Traditional mercury based UV lamp sources were commonly used in print applications, but have since been replaced by UV LED systems for a number of reasons. LED enabled print solutions bring performance and productivity enhancements. Lower temperature curing from LEDs ensures no heat damage to jacketing materials; the result is more consistent and reliable curing leading to higher yields. LEDs can also support a wider variety of substrates including those that would be damaged from the heat coming from an Hg lamp. Being that LEDs have low power consumption and long operational lifetimes (>30,000hrs vs. the couple thousand hours with lamps) with limited maintenance required, significant cost savings can also be realized from minimal down time and reduced energy usage. Support for a wider range of substrates due to the lower temperature curing from LEDs ensures no heat damage to jacketing materials.

Besides performance and productivity enhancements, UV LEDs also offer environmental benefits. As many companies adopt green technology initiatives, LED curing is an ideal solution with no VOC emissions and low energy consumption. These solutions are also scalable to support increased speeds and expanded cure areas. In wire and cable applications, multiple curing units can be used serially to increase print speeds.

Differentiating UV LED Curing Systems

UV LED curing systems are complex devices that are not all created equally. Comprised of 4 main components – LED module/array, thermals, electronics and optics – the architecture and design of each play a significant role in the system level performance and lifetime/reliability of the solution.

LED lifetime is typically rated by the number of operating hours until it emits at 70% of its initial output (L70). While UV LEDs have a long lifetime in comparison to traditional UV lamps, they still degrade over time (albeit at a much slower rate). Depreciation is dependent on LED temperature; the more effectively thermals are managed, the longer the useable life. That said, thermal design and adequate cooling of the LEDs have a profound impact on performance, and are one of the differentiating characteristics of a high quality system. Electronics and power drivers are also very important because they monitor and control the unit.

As an example, OmniCure® UV LED systems from Excelitas Technologies® have a number of protection mechanisms such as safety shut-offs and module temperature checks to safeguard the operation under optimal conditions. Proprietary technology to enable control of each output segment is also available, so not only is the uniformity managed, but the cure width can also be adjusted to suit each application need. Tight uniformity across the illumination area is crucial in print applications, as large variations will impact the consistency of cure and result in some regions that are not adequately cured while others are.

Selecting the right LED curing solution

LED systems have a wide range of performance, cure size, and cooling options, and choosing the appropriate one can seem like a daunting task. Included are some tips to help determine your application requirements:

1. Ink compatibility: Is it a UV LED formulation, and what is the irradiance or dose needed?
2. Process parameters: What is the size of area to be cured? What are the intended speeds, working distances, and range of substrates to be supported? Will there be pre/post treatment?
3. Integration needs: Is this to be installed into an existing printer with space constraints? Can air (or water) cooled form factor be supported? Are there any specific mounting requirements?
4. Applications support: Do the equipment suppliers have personnel to assist in finding the right solution and for integration support? Have similar applications been successfully implemented, and if so, how?

Remember that promoted performance metrics and start of life benchmarks are generally not indicative of long term reliability, and the specifications of each supplier may not be equivalent, as quoted values may vary depending on measurement techniques and radiometry. The most accurate method of determining the efficacy of a solution is to conduct trials with the equipment being considered, and under the intended operating conditions. Look beyond the specs, as testing is the best validation.

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Company profiles:

Excelitas Technologies Corp. is a photonics technology leader focused on delivering innovative, high-performance, market-driven solutions. Through its industry-recognized OmniCure® product line, the company offers innovative lamp and LED UV curing solutions with faster, more consistent curing results to ensure the highest product quality and production efficiency; www.excelitas.com. Gem Gravure is a family owned and operated company since 1952, GEM is your total solution for product identification; www.gemgravure.com. Enercon Industries provides in-line blown-arc plasma, blown-ion plasma & flame surface treating solutions to improve bonding of inks, adhesives & coatings; www.enerconind.com.