SCRATCHING THE SURFACE

Corinna Little explains how atmospheric plasma systems can improve the print quality and adhesion of markings and codes on challenging substrates with low surface energy

Printing codes on low energy materials like polyolefins (lightweight, flexible, thermoplastic materials) can be a challenge. Due to high throughput in production, the marking process typically needs to be fast while still being reliable.

Atmospheric pressure plasma can increase the wettability on a wide variety of materials. This results in improved adhesion and print quality by preventing smudging, ghosting, etc. The plasma systems can be easily retrofitted to pre-existing lines and require only compressed dry air and electricity.

CHALLENGES

As consumers, some product markings are more apparent to us than others. While we are very aware of 'best before dates' and QR Codes we can scan with our phones, the markings on ducts for fibre optic cables are buried deep under our pavements. Nonetheless, these hidden codes are just as vital for the processing of the QR Code we just scanned as the code itself. Overall markings on or within the products we use directly or indirectly every day each serve an important purpose. Thus, these prints need to adhere reliably to their respective counterparts and require sufficient resolution to be processed correctly. The methods of choice are inkjet or continuous inkjet systems that are flexible and allow for high-speed printing. However, the substrates they are faced with can be challenging, especially

Figure 1: High power system piezobrushPB3 treating plastics

Relyon plasma's piezobrush PZ2-i automated plasma device. Piezobrush technology can be retrofitted, while the compact design allows for flexible use not only with inkjet but also for pad and digital printing

polyolefin-based materials like polyethylene (PE) or polypropylene (PP) but also others like Polyvinyl chloride (PVC) or even metals. Their surface energy can be very low, resulting in poor print quality and insufficient adhesion.

STATE OF THE ART SOLUTION

Atmospheric pressure plasma has the ability to increase the surface energy of almost any material and requires only electricity and a plasma gas such as compressed dry air or nitrogen. State of the art plasma jet systems like relyon plasma's plasmabrush PB3 use an electrical arc between two electrodes to produce a highly effective plasma plume (see **Figure 1**). Due to elevated temperatures in the plasma plume of 200–700°C, this system is suitable for the surface activation of plastics as well as the fine cleaning of metals at high speeds.

While the surface activation is based on the functionalisation of the topmost layers of the polymers, plasma cleaning involves removing sub microscopic layers of organic contaminants from the surface (see **figures 2** and **3** respectively).

These layers are usually remnants of earlier processes, i.e. residues from lubricants or release agents, that inhibit the ink from reaching the substrate. The plasma plume

> *"Markings on or within the products we use every day serve an important purpose"*

of the high-power plasmabrush PB3 system can remove these separation layers not only from metals but also from composites and plastics. The latter group typically shows poor wettability even if there is no residue on the surface. Here, the plasma helps to functionalise the surface, where molecular anchor groups establish bonds between the plastic surface and the ink.

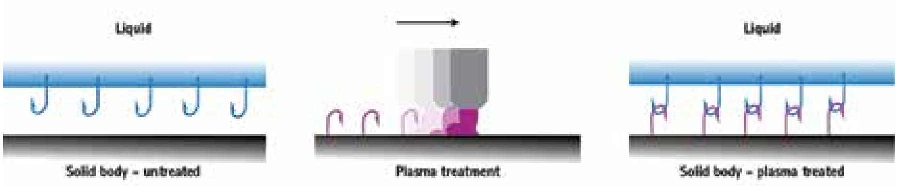

Figure 2: Surface before and after plasma activation

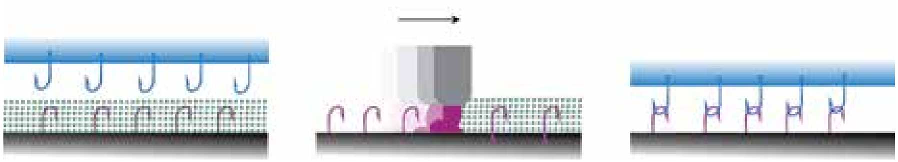

Figure 3: Plasma cleaning – surface before and after

CHARACTERISING SURFACE PROPERTIES

In most cases a strong correlation between wettability and print quality of a material can be established. Therefore, the effectiveness of the plasma treatment can be determined by measuring the surface energy of the substrate. This parameter has the unit of mN/m or dyn/cm and consists of a polar and a dispersive part. These two contributions can be determined by measuring the contact angle of a polar and a non-polar solvent, such as water and diiodomethane. With this method called contact angle measurement, the lower the contact angle, the higher the surface energy. A less precise but more accessible method is the use of test inks with nominal values for the surface energy. After applying the respective test ink to the surface, the wetting behaviour is assessed. If the test ink forms droplets, the surface energy is below the nominal value of the test ink. If, however, the test ink forms a closed liquid film on the surface, the material has at least that nominal surface energy value. These two scenarios can be observed before and after the plasma treatment respectively (see **figures 4** and **5**).

"More users are discovering this highly efficient cold plasma technology for their printing applications"

Fig. 4: IGBT frames before plasma treatment

Figure 5: IGBT frames after plasma treatment

INNOVATIVE COLD PLASMA SYSTEMS

State of the art plasma jet systems like the plasmabrush PB3 have a thermal plasma plume that can damage temperature-sensitive materials if the treatment falls below a minimum process speed (typically 100–200mm/s). The system also requires a suitable extraction unit for its emissions, including nitrous oxides. Power and gas supply are around 1kW and 35–60l/min respectively.

An alternative technology that is already well established in the adhesive industry is called piezo direct discharge or PDD and is used in the piezobrush systems. Here, the plasma is generated by a cold discharge that does not exceed 50°C and requires only a maximum power of 30W. Moreover, it is low on emissions and can run on ambient air as well as on industrial gases like nitrogen or compressed dry air with flow rates of 10–20l/min. Following its successful application in numerous adhesive processes, more and more users are discovering this highly efficient cold plasma technology for their printing applications. Just like its high-power counterpart plasmabrush, the treatment width of the piezobrush systems ranges from 10–25mm, making it ideal for marking and coding applications. Formerly thought to be more suitable for lower process speeds, the piezobrush PZ2-i has recently shown that it can improve continuous inkjet applications for marking PVC tubes at up to 172m/min.

COMPELLING RESULTS

When comparing the effects of the two technologies on different plastics it becomes evident that both the high-power plasmabrush PB3 and the cold plasma handheld piezobrush PZ3 increase the surface energy, especially the polar part. Treatment speeds of 200mm/s were used for the high-power plasmabrush PB3 system and 20mm/s for the cold plasma handheld piezobrush PZ3.

For PTFE, a material known for its liquid-repelling properties, the surface energy could not be improved as significantly as for the other materials. However, during tests with the continuous ink jet system CodeCreator a pre-treatment of a PTFE substrate with the piezobrush led to a notable increase in print quality and adhesion (see **figure 6**).

Another application example is the results after ink jet printing on high density polyethylene ducts with and without plasma pre-treatment with the cold plasma integration version piezobrush PZ2-i system at 90m/min. The microscopy images in **figures 7** and **8** show that the untreated substrate rejects the ink creating distorted dots with insufficient adhesion. The pre-treated sample on the other hand shows a uniform print image which is not impacted by the friction of the following winding process of the duct.

Figure 6: Printing on PTFE (left side untreated and right side plasma-treated)

"Plasma helps to functionalise the surface"

These examples show that atmospheric plasma systems are ideally suited to improve the quality of markings and codes on low energy materials, even with standard ink. ■

Footnote: Piezobrush and plasmabrush are registered trademarks of relyon plasma

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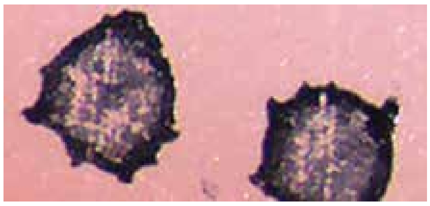

Figure 7: Inkjet printing on high density polyethylene ducts without plasma treatment

Figure 8: Inkjet printing on high density polyethylene ducts after plasma treatment

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