How atmospheric plasma surface treating enables ink jet printing on wire and cable

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Abstract

Creating indelible markings on wires and cables for military, aerospace, automotive, telecom and datacom applications can be a challenge for many manufacturers. Ink jet printing offers numerous production advantages for these companies, however not all materials used in the wire and cable industry are receptive to ink jet formulations. Implementing in-line atmospheric plasma pretreatment systems prior to printing is enabling ink jet printing success by increasing surface energy for proper ink adhesion. This paper will look at the impact of atmospheric plasma surface treating on a wide variety of materials used in the industry to enable successful ink jet printing. Lab data will be provided along with recommendations for successfully implementing pretreatment in the field.

Keywords: wire; cable; ink jet: printing; surface treatment; plasma; surface energy; dyne level; ink; adhesion

1. Introduction

Traditional printing on wire and cable is accomplished with contact printing technologies such as print wheels and hot stamp systems. Ink jet printing offers numerous advantages over traditional marking technologies. It is economical, efficient and offers greater operational control and flexibility. However, ink jet chemistry alone is not always enough to achieve bonding success.

Many of the materials used in the wire and cable industry, such as PE, PVC, PP, PTFE, XLPE, ETFE, FEP, EPDM and silicone, have very low surface energy making it difficult for ink bonding. Additional factors such as surface contamination and additive migration can also undermine adhesion success.

In-line atmospheric plasma technology has emerged as an enabling partner technology for many wire and cable ink jet printing applications. Plasma cleans, etches and functionalizes surfaces which increase free surface energy to improve wettability and bonding. The bonds created between the ink and the surface on pretreated substrates is strong enough to pass the demanding durability tests required by wire and cable manufacturers.

Pretreatment prior to printing allows wire and cable manufacturers to take advantage of many ink jet printing benefits. First, it expands the possible locations on the line where you can print since ink jet is a non contact process it is effective on both soft surfaces and hot surfaces. Secondly, inks can be printed at extremely high speeds and changing over between products is very rapid. And lastly, as a digital technology ink jet is highly desirable as it supports variable data, and adds more message control by managing messaging from a database rather than the shop floor.

2. Surface Energy and Wettability

Substrates such as plastics are generally composed of non-polar, long-chain molecules. Polymeric surfaces have a small amount of free energy. Fluorocarbons, silicones and vinyls have particularly low free-surface energies.

As such, these materials have relatively few available bonding sites due to low levels of charged ions on the surface. In addition to low surface energies, plastics may be composites in structure, may be blended with processing additives, and may have surface contamination. All of these variables can have a negative impact on molecular attraction, causing liquids to fail to wet the surface.

2.1 Measuring Surface Energy

Surface energy is a key component for successful adhesion. Dyne solutions are used to determine the surface energy of substrates. Dyne solutions are calibrated so that One Dyne equals 1 $g \cdot cm/s^2$ or 0.00001 Newton.

Distilled water has a surface tension of 72.8 mN/m. This means that a surface which allows water to wet it has a surface energy of 72.8 mN/m or higher.

Ink suppliers will generally provide a target dyne level for successful adhesion.

3. Plasma Surface Treatment Technology

For the purposes of this paper tests were conducted with three types of plasma surface treating technologies blown ion, flame, and variable chemistry. Generally speaking, these technologies have an increase in cost factor beginning with blown ion plasma, followed by flame and then variable chemistry plasma.

3.1 Blown Ion Plasma

Blown Ion Plasma treaters generate a concentrated discharge that bombards a material surface with a high-speed discharge of ions. Positive ion bombardment facilitates a micro-etching or scrubbing (ablation) effect which can remove (desorb) organic and inorganic contaminants from the surface of an object.

Blown ion air plasma systems push pressurized air past a single electrode which discharges inside the treater head. The electrode creates positively charged ions in the surrounding air particles. The air pressure forces the air particles to accelerate of the tip of the head as a high velocity stream of charged ions directed toward the substrate surface. Through direct contact, these particles positively charge the object's surface increasing its surface energy and making it more receptive to inks and coatings.

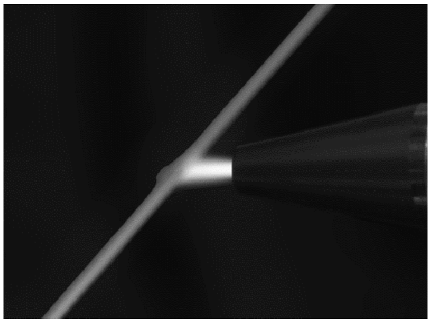

Figure 1. Blown Ion Plasma Discharge

3.2 Flame Plasma

Flame is also considered a plasma. Flame plasma is formed when a flammable gas and atmospheric air are combined and combusted to form an intense blue flame. The surface of materials are made polar as species in the flame plasma affect the electron distribution and density on the surface. This polarization is made through oxidation. In addition, functional groups are deposited on the surface.

A functional group is a portion of a molecule that is a recognizable/classified group of bound atoms. In organic chemistry it is very common to see molecules comprised mainly of a carbon backbone with functional groups attached to the chain. The functional group gives the molecule its properties, regardless of what molecule contains it; they are centers of chemical reactivity.[1]

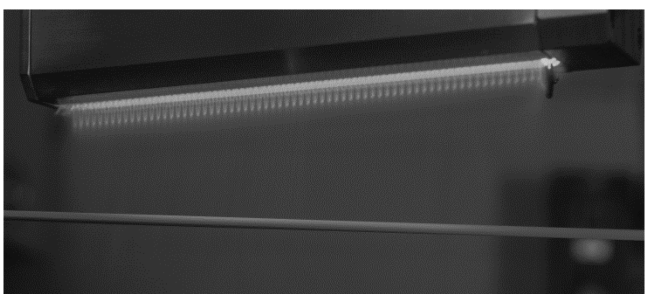

Figure 2. Flame Plasma Discharge

3.3 Variable Chemistry Plasma

Variable chemistry plasma uses gases in addition to atmospheric air to create surface functionality that might otherwise be impossible. Reactive gases are diffused toward the surface under the influence of electrical fields. Low molecular weight materials are knocked off the surface to expose a clean, fresh surface. At the same time a percentage of the reactive components in plasma with sufficient energy bond to the freshly exposed surface, changing the chemistry of the surface and imparting the desired functionalities.

Figure 3. Variable Chemistry Plasma Discharge

4. Plasma Laboratory Dyne Level Trials

Lab trials with each of these plasma technologies were conducted with a variety of substrates.

Blown ion trials were conducted at 200 fpm (60mpm) using a .25” (.64cm) treatment gap.

Flame trials were also conducted at 200fpm (60 mpm), using a 2” (5.08cm) treatment gap.

Variable chemistry plasma trials were conducted at 200fpm (60mpm) at both 20W/inch and 40W/inch power levels using a mixture of Ar, O_2, and C_2H_2.

Table 1. Plasma Lab Trials: Dyne Level Impact of Surface Treatment on Various Materials

Substrate	Initial	VCP 20	VCP 40	Flame	Blown Ion
EPDM	66	70	70	72	72
Silicone	44	70	72	72	72
XLPE	36	48	52	58	50
TPE	35	37	39	40	37
PET	35	70	72	66	70
PVC (black)	34	34	34	34	37
ETFE	33	38	40	36	40
XLETFE	32	36	38	40	36
PTFE	30	31	31	30	30
FEP	30	38	38	30	30

4.1 Lab Trial Data Insights

It should be noted that the materials used for the tests were acquired through commercially available means and therefore may have been affected by heavy surface contamination. As such, some of the results yielded lower changes in surface energy then may have been traditionally expected.

The important takeaway is that in almost all cases plasma surface treatment increased dyne level which leads to improved adhesion.

For those situations where dyne level was not increased enough to provide improved ink adhesion additional trialing should be conducted with changes of the following variables; dwell time, power levels and gas chemistries.

When more than one technology successfully increases the dyne level to enable adhesion, printers should consider the treatment technology which offers the most economic value.

5. Printing Durability with PreTreatment

The data for these printing lab trials is provided for this paper by Gem Gravure.

For plasma treatment a blown ion system was used. A scotch transparent 600 tape was used to conduct the adhesion tests with the following rating system:

0 = complete removal

1= mostly removed

2= significant partial removal

3= consistent partial removal

4= intermittent/slight removal

5= perfect not removed

Table 2. Print adhesion results with plasma treatment

Wire	Ink	Without Plasma Treatment	With Plasma Treatment
Blue SXL AWG18	WTG1860	1	5
Green GXL AWG16	WTG1860	2	5
Red SXL AWG 18R	WTG1860	3	5
Green TXL AWG 20Dg	WTG1860	2	5

In this test blown ion plasma treatment improved the ink jet print adhesion to a perfect score of 5 in the tape test.

6. Considerations When Implementing Plasma Treatment

The data shared in this paper demonstrates that plasma treatment is capable of enabling and improving print adhesion on many surfaces. When implementing plasma technologies in the field there are a number of considerations to keep in mind.

- Put your application to the test with multiple treatment technologies to see which technology provides you with the best printing results at an investment level consistent with the benefit provided.
- It is a best practice to print immediately after treatment, so consider this in determining the location of your in-line treatment system.
- Pretreatment immediately after extrusion can increase treatment results
- Dwell time or the amount of time the surface is exposed to surface treatment can improve treatment results, however there is a point in which each technology could damage the surface if exposure is too long

7. Conclusions

Ink jet printing offers numerous production benefits. As a non contact printing process it can be positioned in various locations on production lines. As a digital printing technology ink jet offers more control, variable data and faster changeovers. Plasma treating technologies including, blown ion, flame and variable chemistry plasma enable ink jet printing when ink chemistries alone are ineffective. These atmospheric plasma surface treaters increase surface energy to enable adhesion and improve print durability. They are most effective when installed immediately prior to printing.

8. Acknowledgments

Special thanks to the Rick Elmer Ph.D., Director of Ink Technology of Gem Gravure for sharing print adhesion durability trial data.

9. References

[1] Definition taken from *Lecture Supplement*, First Edition by Steven Hardinger, Copyright 2008 by Steven Hardinger, Hayden-McNeil Publishing, Inc