Electrostatic Printing of Metal Traces on PET and PEN Films for Flexible Display and Flex Circuit Applications

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Introduction

Electrostatic printing of functional materials configured as liquid toner was presented at NIP 14 &15. Previous experience with solid silver particle, resin-less toners required heating to chemical sinter them into a solid silver trace at 230° C for about 2 minutes in air at atmospheric pressure. With these processing conditions, PET and PEN films cannot be used. Polymides can be used but they are expensive (typically $80/lb.) and are a deep amber in color. Since that time we have discovered certain coatings that can be applied to PET or PEN, the coating materials have a synergistic affect on the silver toner giving useful conductivity after sintering as low as 125° Celsius.

A Brief Review of Electrostatic Printing

Electrostatic printing is essentially a non-contact or pressure less printing operation which is massively parallel in that an entire web of material up to 36 inches wide can be imaged at a rate up to 1 meter per second.

While traditional electrophotography prints resin toners containing 5% to 10 % by weight pigment on paper or film, electrostatic printing as a manufacturing process requires the imaging of toners of high density, like metals, glasses, phosphors, ceramics and ferroelectric materials like barium titanate. Material densities range to 10 or 12, and in many cases one does not want any resin to be present. If one wants to print metallic conductor pattern, high K dielectric, or high permeability magnetic materials any amount of resin defeats the final goal. In cases of subsequent high temperature processing, like glasses or phosphor, some resin can be tolerated because it will burn off. But if one wants to print on PET or PEN films (low cost and optically clear they have a maximum working temperature of 125° C and 150° C respectively) no resin burn off is possible so resin less toners are needed.

Working together with scientists at Parclec LLC of Rocky Hill, NJ, a resin-less solid silver toner was developed which is 96% silver, no resins and the organics contained decompose nominally at 230° C in about 2 minutes. (The decomposition products are carbon dioxide and water). The toner consists of a solid silver metal particle coated with a metal organic decomposition (MOD) layer which upon gentle heating decomposes yielding "atomic" silver which sinters the silver particles together into a compact mass. US Patent # 5,882,722 describes some earlier work in this area.

While the melting point of silver is 979° C, the gentle heating referred to above of 230° C is still beyond the range of most useful films, 125° C for PET and 150° C for PEN. While polymide has a range to 400° C its price ($80/lb.) and deep amber color make it unsuitable for many circuiting and display applications.

We have found that certain coatings applied to the PET and PEN films to act as anti-static or bonding layers have a synergistic effect in promoting the sintering of the silver toner at a temperature within the working temperature limits of PET and PEN (125° C and 150° C respectively). Not only do these coatings facilitate electrostatic transfer of the toner to the films but also provide superior adhesion of the sintered silver toner to the films. The most vigorous tape test removes the coating before it removes silver metal.

Experiments in Printing Silver Metals Toner on PET and PEN Film

Small electrostatic printing plates are made by laminating the printing plate material to ITO coated glass. These are imaged by UV radiation through a photo-tool. The plate is now finished, ready to be imaged and re-used many times.

It is sensitized by charging with a corona device to, after a few seconds, the background areas discharge yielding a high quality latent image of patterned electrical charges. These are developed with the silver toner and the plate cleaned with clear Isopar diluent. Excess liquid is scavenged from the plate.

The coated PET film to be imaged is placed over the almost dry liquid toner image and a back electrode behind the receiving films is raised to a voltage of +2.0 to +2.5 kv. Excellent toner images are found on the receiving film. The film is allowed to dry, then placed in the oven for a suitable period of time. If the film is PET the temperature of the oven is 125° C; for PEN, 150° C.

No	Substrate/Thickness	Coating/Thickness	Processing conditions	Results (micro-ohm-cm)
1	PET/75 micron	CTC/5 micron	125°C/30 minutes	15
2	PEN/125 micron	CTC/5 micron	150°C/30 minutes	10
3	PET/25 micron	DSC/1 micron	125°C/2 minutes	10
4	PET/75 micron	CT-DSC/5 micron	125°C/1 minutes	15
5	PET/75 micron	CT-DSC/5 micron	125°C/30 minutes	8

Results

The table shows some of the bulk resistivities that were achieved with three types of proprietary coating and processing conditions.

Longer processing times and higher temperatures obviously lower the resulting resistivity of the silver traces. This can be seen by comparing items 1 & 2 and items 4 & 5. Optimum processing conditions and ultimate lower resistivity limits have to be determined but our position is that times longer than 30 minutes are not of commercial interest.

The best resistivities achieved with silver filled resins, the competition, are typically 50 to 100 micro-ohm-cm, 3 to 12 times our best and worst results.

Conclusions

Improvements in silver toner processing conditions have dropped the max temperatures into the range of PET and Pen films thereby achieving huge cost advantages. Bulk resistivities of the order of 8 to 15 micro ohm cm are still 3 to 12 times better than the best metal particle filled composite inks. These resistivities are of commercial interest in producing inexpensive electronic products. The new silver toner on PET film technology is an important manufacturing tool for flexible displays, and flex circuits, an innovative new electronic products.

Addendum

Recent work on the electrostatic printing of organic semiconducting materials for the manufacture of field effect transistors (FETs) will be reviewed. Success in this area will open up new markets and products for this technology.

Biography

Robert H. Detig founded Electrox Corp. in 1992 to apply electrographic imaging technology as a manufacturing tool for various industries. He has some of the basic patents relating to the polymeric electrostatic printing plate. He has extensive experience in all aspects of the electrographic imaging process going back to his early years at Xerox. He pioneered the concept of functional toners made of high density materials like metals and glasses to be used in a manufacturing process

He was awarded a PhD in Electrical Engineering from Carnegie Mellon University in Pittsbugh, PA.