Pattern De-Metallizing of Flexible Films: From concept to Applications

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Abstract

Pattern de-metallizing is a process of a selective elimination of metal layer (such as aluminium) from the surface of metallized film prior to converting. Pattern de-metallizing is mainly used to create a see-through window for packaged products or as a security feature of the first level on holographic film, which means that it can be detected with unaided or aided eye. Different patterns can be selectively de-metallized from a fully metallized film using different processes depending on the final application.
This article outline the various process technologies used for Pattern de-metallizing of metallized films and their applications.

1- Introduction

Pattern de-metallizing is a process of removing metal, or a dielectric, coating from a coated flexible film to produce see-through packages that stands out on the shelf. This makes the product visible to the naked eye to enable consumers to see the product inside the package. In converting, the de-metallized package can then be printed with inks on the metallized side for visual appearance. De-metallization is also used to add extra security features to holograms as a first level of security that can be detected with unaided or aided eye.
At present, pattern de-metallization is receiving increasing interest for a variety of applications since its original development for capacitor films. Capacitor films are made either with aluminium or mixtures of aluminium with zinc and/or silver. Originally, these films only required a clear de-metallized stripes in the machine direction and that was produced using an in-contact mechanical mask. The contact mask was in the shape of a belt of either metal or heat resistant polymer in the form of a loop that was brought into contact with the film just before the deposition zone and then was peeled off after the deposition zone. Although the mechanical mask was providing the required stripes, yet there were many problems of using it due to coating build up and the degree of edge sharpness of the stripes. Also, falling debris from the mask onto the film create defects in the deposited metal leading to the failure of the capacitor.
Since then the technology of stripe metallization and pattern printing has moved forward and now there are different processes that can be employed to produce the required pattern de-metallizing onto the metallized film. These processes will be discussed in some details.

2- De-metallizing Processes

At present there are different pattern de-metallizing processes that can be employed to produce simple or complex patterns on the metallized film depending on the final application. The de-metallization processes includes:

a- *Chemical Etching*
b- Oil Pattern printing in Vacuum
c- Laser de-metallizing
There are other methods to remove metal from the metallized surface but they are used on a smaller scale in the market.
These processes will be discussed in more details.

a- *Chemical Etching (de-metallizing*)

In this process, the metallized side of the film is initially selectively protected with etchant resistant lacquer or varnish in those areas where aluminium layer is to be remained. The varnish is printed on the metallized side using gravure, flexo or other printing machines. The film is then immersed into a PVC tank containing an alkaline aqueous solution, such as sodium hydroxide (NaOH) for a time at least sufficient to completely remove the etched metal [Aluminium] from non-protected areas of the film as shown in the following simple equation:

$$2\ Al + 2\ NaOH + 6\ H_2O \rightarrow 2\ Na^+ + 2[Al(OH)_4]^- + 3\ H_2\ (gas)$$

The de-metallized film is then washed and dried to remove the metal from the unprotected areas. The sodium hydroxide material is usually diluted with 50% water to prepare the aqueous solution to remove about 300-400 angstrom of aluminium. The etching solution is kept hot at a temperature from 50-90°C to accelerate the etching of the exposed metal. Line speed of the de-metallizing process could be from 50-80 m/min depending on many factors including aluminium coating thickness.
In some processes a flexographic press with a rubber roller is used to print the aqueous sodium hydroxide solution onto the metallized (aluminium) side of the flexible film. The film then moves to a washing tank followed by drying before rewinding the material onto a roller.
In another process for the partial de-metallization an acrylic based lacquer mixed with at least one metal dissolving etchant is applied on the metallized side to locally reacts with the aluminium layer. The dissolved metal remains within the multilayer structure and the dissolution of the metal allows the creation of a window in the metallic layer without the necessity of a washing step. This selective de-metallization is carried out using a standard gravure or flexo printing presses. The chemical de-metallizing process usually use a PVC chemical reaction tank and stainless steel guide roller to provide strong corrosion resistance and good durability. The chemical etching technology is notable for its good productivity. However, the precision of the image is about 1mm with a small resolution of about 300 dpi. Structures and lines are up to 0.5mm (Figure 1).

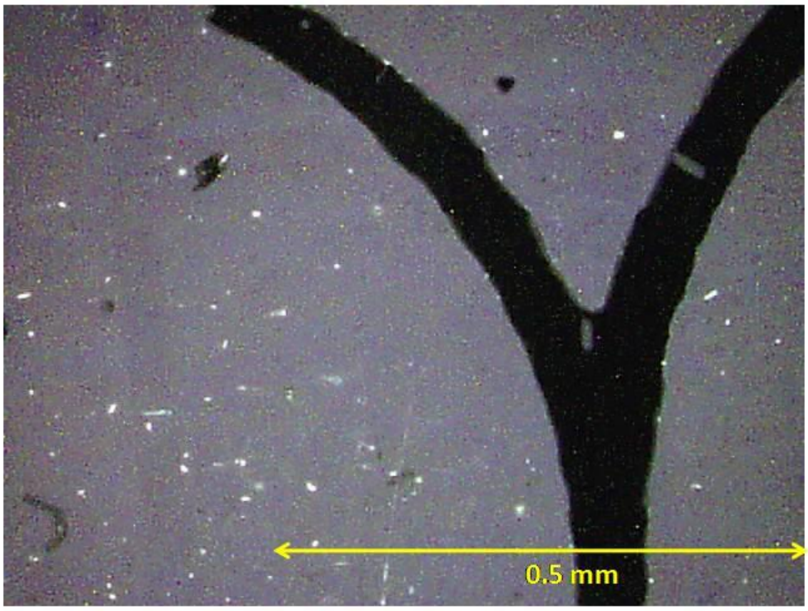

Figure 1. Chemical de-Metallized Product

2- *Oil Pattern Printing in Vacuum*

This technology has been around for many years but recently been developed further to improve the process and final product. Oil de-metallizing (or Pattern printing) is an in line process that is carried out in vacuum prior to the metallization process. It was initially developed for making simple clear stripes in the metallized film for capacitor applications. However, the demand for more complex patterns for different packaging applications has resulted in the development and utilization of printing heads inside the vacuum web metallizer.

Oil masking process involves the application of a vacuum compatible oil such as Fomblin using a special boiler with well defined slots having defined widths and spacing onto the film in the machine direction prior to entering the metallizing zone (Figure 2).

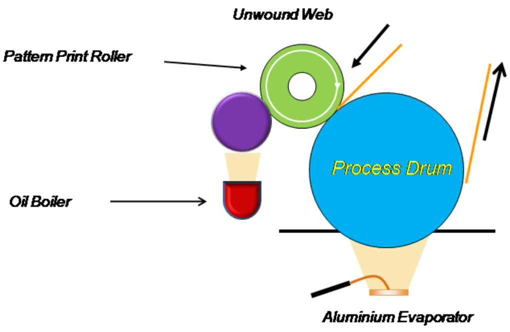

Figure 2. Schematic Diagram of Oil de-Metallizing Process

When the oil printed film enter the metallizing zone, the oil is flash evaporated by the heat generated from the aluminium vapour and the heat of the metallizing process. The flash evaporated oil removes the metal in that printed area resulting in a see-through window. The film areas without printed oil remain metallized. This process can give stripes with reasonable edge definition between the metallized and de-metallized areas (Figure 3).

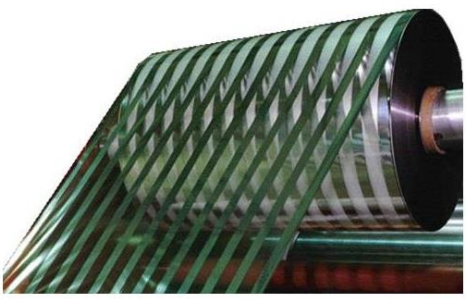

Figure 3. Stripe Metallization using Oil in Vacuum

During flash evaporation, a very small amount of oil may remain on the de-metallized areas resulting in poor printing of ink on top of the film as well as problems with lamination process during converting. Also, there is a resolution limit in terms of the minimum stripes width that can be formed on the film. In this process the deposited aluminium thickness has to be balanced with the oil thickness to allow for full or partial flash evaporation of oil from the printed areas.

Oil masking technique was further improved by employing an engraved roller inside the metallizer to print the oil onto the moving film. The oil is deposited on the engraved roller from an oil boiler or oil tank. The roller then prints the oil in different patterns onto the film prior to metallizing (Figure 2).

Oil de-metallizing (or Pattern Printing) technique is used now for food packaging by replacing the Fomblin with Food approved oils. It is also used on a smaller scale to produce electronic circuits including simple RFID. One of the critical limitations in using this process for more complex electronic circuit is the thickness limitation of the metal. For example, if copper is metallized instead of a standard aluminium the thickness has to be small for useful Pattern printing applications, unless the thickness is increased by using other processes such as electroplationg. This is because the amount of printed oil is designed to match the time and the temperature in the deposition zone to flash evaporate. If the metal is too thick then all the oil will evaporate before metallizing is complete resulting in poor de-metallization. In practice, oil de-metallizing technique is good for coating thickness of less than 80nm. For thicker coatings extra processes such as electroplating have to be employed to add extra thickness on top of the coating achieved with oil masking technique. Typical line speed of oil de-metallizing is about 10m/sec with structures and lines up to 0.3mm (Figure 4).

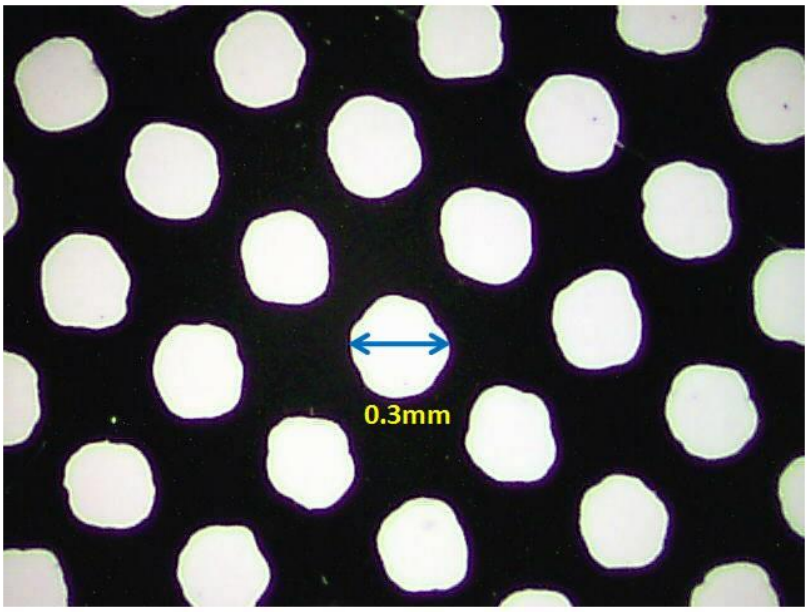

Figure 4. Pattern Printing using Oil Masking in Vacuum

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3- Laser De-metallization

Laser de-metallizing is a new technique to produce high definition, complex patterns on flexible films at a resolution <0.1mm. This process may present an ideal production solution for the ablation of metalized layers for specialised applications such as special packaging, security and electronic.
The laser process imparts no physical force on the metal (or dielectric) during the process, so coated materials with different thicknesses can be ablated. The material is typically removed by directing a focused laser beam. This enables highly tailored removal, so parts of the metal can be removed as needed. Changes to the size and location of the removed ablated parts can be made on the fly by calling up pre-programmed recipes.

This process is dry, non-contact, digital, single step and can be employed for roll-to-roll applications. Fibre and Ultraviolet (UV) lasers are particularly ideal for ablation because metallized materials can effectively be removed with minimal damage to the carrier substrate. The selection of laser source type and wavelength depends upon the coating to be removed and the durability of the carrier film. The selection also depends on the production speed, i.e if the de-metallization is done on a stationary substrate or in roll-to-roll form. The selection of the proper laser wavelength depends on the required ablation width and quality.
A number of different lasers can be employed for metal ablation, depending upon the particular metal type, thickness and the type of the flexible substrate. Table 1 shows the lasers most commonly used for material ablation:

Table 1: Type of Laser Wavelengths for the Ablation of Different Coatings

Coating Thickness	Type of Coating	Type of Laser Wavelength
Thin < 1μ	Conductive	YAG, UV; Green (532nm) and FAYb; short pulses
Thin	Non-conductive (transparent)	UV
Thick	Conductive	Fibre FAYb or YAG

In practical situation it is difficult to use CO_2 lasers to de-metallize conductive coatings from flexible polymeric films. This is because polymers tend to absorb CO_2 laser wavelengths, causing damage to the substrate layer under the conductive coating due to the amount of heat generated during the conductive coating's vaporization.
However, CO_2 lasers can be used in conjunction with Fibre, YAG, and UV lasers to cut or score a material to create registration marks, eliminating the need for pre-processing the material. Also, there is a new generation of enhanced YAG technology called, FAYb(Fibre Amplified Ytterbium). These fibre lasers provide several advantages over traditional Nd:YAG systems., such as better beam quality, smaller housing dimensions, a significantly longer lifetime and lower fixed costs because FAYb consumes much less power and get by with simple air cooling.
Laser ablation is the most efficient method for developing complex prototypes and shortening a product's time to market as a result of fast and easy changeover from development stage to

full-scale production. However, for roll-to-roll production the process is slow and can only be used for high added value products. The advantage of this process is that very small line of <0.1mm can be de-metallised with good tolerance (Figure 5).

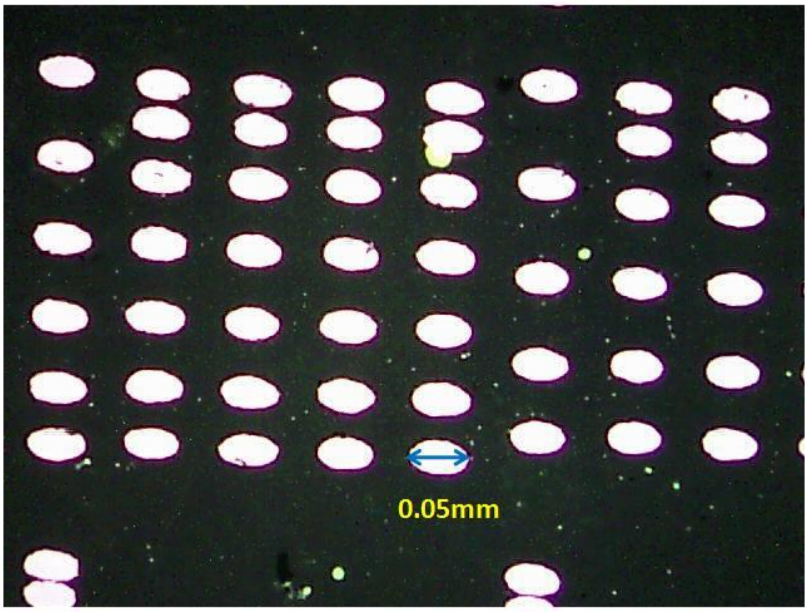

Figure 5. Laser De-Metallised Film

Laser ablation or de-metallizing offer high precision of <1mm as compared to other de-metallizing techniques. The whole process is carried out in open air and there is no need of solvent or any other wet chemicals. The important issue in the laser de-metallizing technique is that the metallic layer must be removed precisely from the polymer substrate, without transferring heat to the substrate and to the surroundings of the laser irradiated area, thus leaving sharp edges and flat undistorted base.

Conclusions

There are various de-metallizing techniques that can be used to print simple or complex patterns on metallized flexible polymeric films. The selection of a process depends on the final product and market. So far, chemical de-metallizing technique has been the most popular due to its simplicity and the availability of the equipment in the open market. Oil masking technique requires special setup inside the vacuum web coater. Laser ablation technique is receiving continuous interest due to the development of new generation of laser equipment with smaller size, less requirement of cooling and more reduction in price. Small, portable laser ablation equipment are available now in the market. Various materials such as Al, Cu, Ni, etc can be ablated with laser. Logos, characters and bar codes of size <0.1mm can be laser ablated. The laser equipment can be installed on a web converting machine.

References For Further Reading

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