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From Packaging to Functional Applications

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Recent Technological Advances in Vacuum Web Metallizing: From Packaging to Functional applications

Introduction

At present, there is a growing demand for vacuum web metallizers with higher speed and performance to metallize films with various grades, types and thickness for flexible packaging and functional applications. This includes heat sensitive films. For example, the new generation of equipment for packaging applications requires a line speed of more than 10m/s with coating thickness uniformity below ± 5% . For solar window film application the uniformity requirement is below ±2%. The increase in machine efficiency has focused the attention on improving the adhesion, thickness, uniformity, barrier, visual appearance and durability of the deposited layer across the width and down the length of a moving film web. Adhesion and uniformity are the most important characteristics reflecting machine performance. Poor adhesion or uniformity often leads to splitting and banding effect on metallized film as well as poor barrier against oxygen and water vapour. The various properties of the metallized film are influenced by many parameters including film type, film quality, surface wettability (i.e surface energy), level of vacuum in the evaporation zone, design of evaporation source, inline optical monitoring and control of evaporation and deposition rates .Therefore, there are so many challenges for technical innovations in both equipment and processes to meet the increasing demands for added value functional products.

This article will discuss some recent additions to the technology of vacuum web metallizing and will outline some new processes that can be produced inside standard vacuum web metallizers.

Fundamentals of vacuum web metallizing

Over the past many decades, there has been a tremendous growth in the use of vacuum web metallizers for many applications. The early applications concentrated mainly on the capacitor industry to supply metallized zinc and aluminium on paper, polyester and then polypropylene films. Then the stamping foil industry became a large user of aluminium metallized polyester. After that, new developments and applications have accelerated throughout the 80’s and 90’s with continuous growth. This technology has been marked with continuous evolution of development between machine design and process requirements as shown in Figure 1.

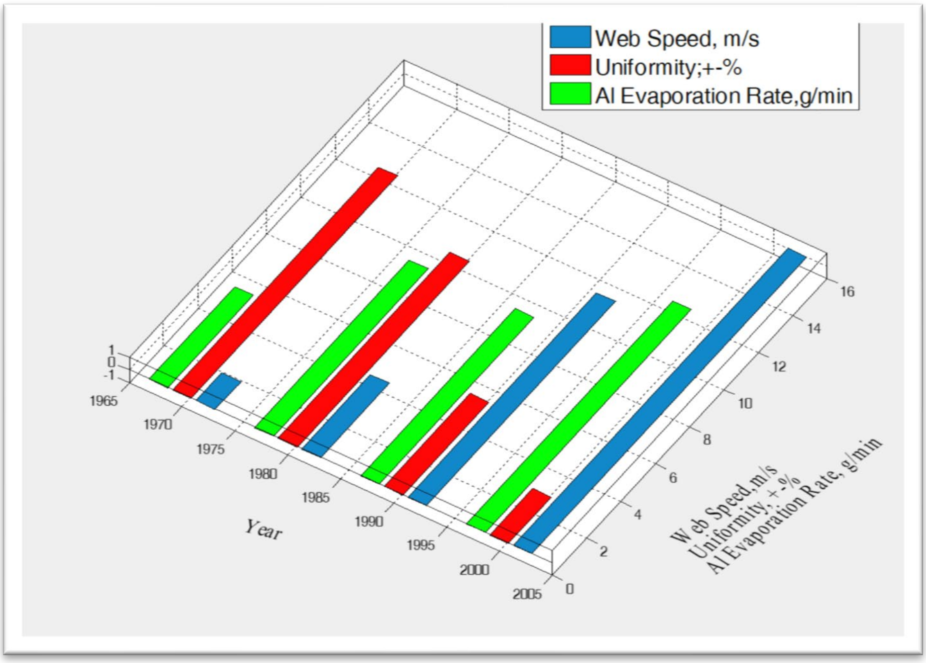

Figure 1. Development of vacuum web metallizers over the last couple of decades.

The concept of aluminium web metallizing is shown in Figure 2. The process involves the use of unwind/rewind zones and a deposition zone. The vacuum chamber is evacuated using a combination of mechanical and oil diffusion pumps. The film moves from the unwind zone onto a process cooled drum to the deposition zone where the film is coated with aluminium (or other materials) then moves to the rewind zone. The evaporation source is mounted underneath the cooled drum. The process chamber is optimised for each individual deposition technology. This includes, size and cooled deposition drum, pre and post lead-in rollers, nip rollers, number and placement of load cells, pre and post chill drums, vacuum pumping and gas flow requirements.

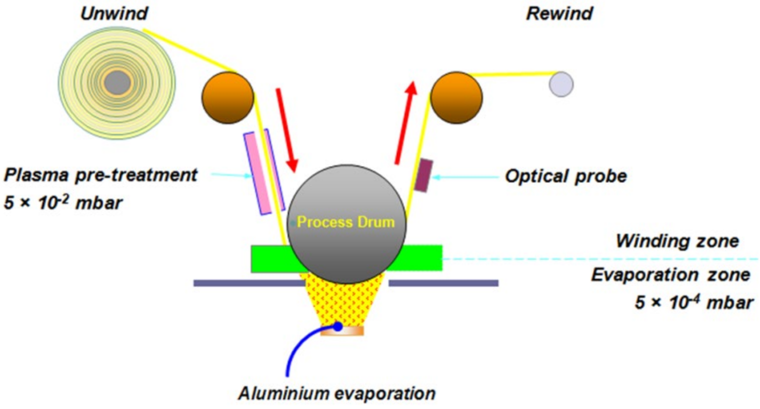

Figure 2. Schematic of vacuum web metallizer

Recent Advances in vacuum web metallizers

Over the past couple of years the design and performance of modern metallizers has undergone major changes to cover all aspects and to add new features. This includes the followings:

a- ***Vacuum level***

In modern metallizers the vacuum diffusion pumps are located underneath the chamber rather than connecting at the end of the chamber. In this case, diffusion pumps are close to the evaporation source to provide uniform pumping gradient across the web. The pumps are protected from debris to ensure consistent pumping. Variable speed motors are used for mechanical pumps for soft starting and power savings. Also, better vacuum zoning are designed to enhance pumping speed. More efficient Cryogenic systems with higher condensation capacity are used to improve pumping performance.

b- ***Cooling***

Cooling of the deposition drum is a significant factor particularly when metallizing heat sensitive films such as CPP and LDPE. Typically the drum is cooled by a chilled liquid that is fed into one end of the drum where it is directed to the drum outer walls, then returns and drains out at the other end. The increased temperature of the returning liquid can be reduced by increasing the throughput of the cooling liquid coupled with a larger capacity chiller to remove the extra heat from the liquid. In order to improve film cooling efficiency the cooling capacity chilled drum has to achieve a temperature of -20 deg C. Also, a gas injection is used behind the film to improve heat exchange between film and drum. Larger coating drums are used to increase metal collection efficiency as well as providing better film cooling.

c- ***Tension control/Film winding system***

In order to achieve efficient tension control particularly for thin films (<5 microns) the film path has been redesigned to provide steady film support and guide during winding. Recent design includes the use of high modulus rollers materials for firm web path control at high rotation speed. Advanced winding control with multiple differential tension zone is designed to include smooth roller surface finishing to handle different properties materials such as thermally sensitive films or stretchable films. This reduces wrinkles during metallization.

d- ***Plasma pre-treatment***

Increasing demand for enhanced coating properties led to the utilization of advanced in-line plasma sources in vacuum to treat polymer films on a moving web. The interaction of plasma with the polymer surface removes contaminants and increases surface activation by cross-linking native film polymers and incorporating onto the surface species from the plasma gas. This depends on type of gas mixture used, plasma energy and the nature of surface. Consequently, this promotes the interaction between depositing atoms and substrate surface, thus increasing surface energy and improving wettability, adhesion and uniformity.

Plasma sources use Pulsed DC, medium frequency AC or RF generators to strike the discharge. Medium frequency AC excitation sources may have either planar or tubular electrodes or electrode arrays to allow higher treatment powers with no arcing problems, that can sometimes plague DC discharges. Plasma sources use magnetic fields or hollow cathode discharges to produce intense and directed plasma at low gas pressure. Figure 3 illustrates the typical arrangement of a plasma source.

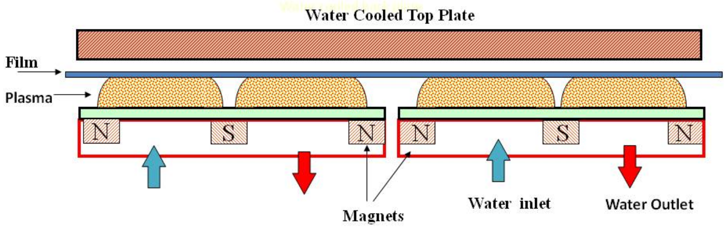

Figure 3. The Basic Design of Dual Magnetron Plasma Treater

New plasma treatment sources include hollow cathode design concept. In this design, the treater has magnets located on the opposite (untreated) side of the substrate. In this case, the plasma field is more directed toward the film surface. Plasma is generated from both the hollow cathodes and the magnetic field, to remove adsorbed moisture, low molecular weight polymer (and additives) and to functionalize the film surface. Medium frequency power is used to strike the plasma and the electrode system is designed to reduce film charge build up (Figure 4).

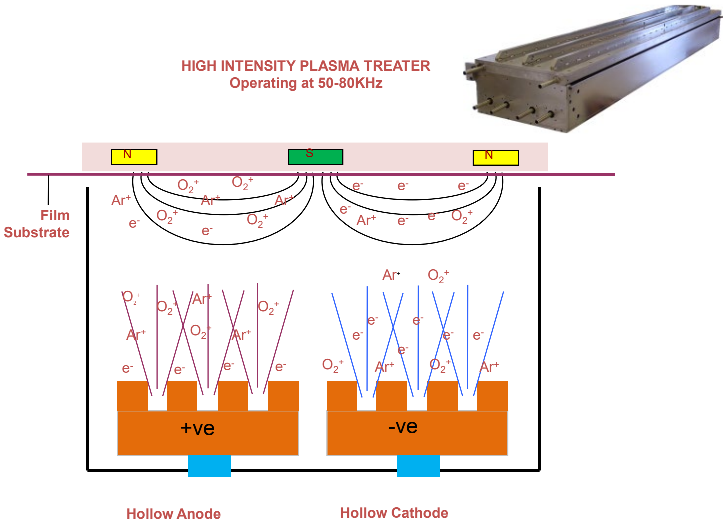

Figure 4. How Cathode Plasma Treater (Reprinted with permission from Sigma Technologies Int.)

Pre plasma treatment can also involve the deposition of a seeding layer to improve adhesion between film and metallised layer. This can be done by injecting special monomer into the pre treatment plasma which is then cured by the plasma to deposit onto the film as a seeding layer. Thickness of the seeding layer is only few nanometer but can improve adhesion and barrier.

e- *Evaporation source/Evaporation control*

Evaporation system is the most critical part in the metallizer. Web metallizing process involves the production of a vapour from a material, such as aluminium, placed in a heated source inside a vacuum chamber. The source is generally heated either by electrically resistance boat, RF induction or electron beam guns. Any fluctuation in boat temperature results in bad uniformity across the web width and length (Figure 5). Because vacuum evaporation is a line -of-sight coating process the evaporation sources are spaced in certain geometry to obtain uniform coating. For efficient evaporation the boats are equally spaced for intense vapour density to provide a coating uniformity of <±5%. This can be in the shape of staggered boats geometry. More work has been done to improve aluminium wire feeders and to isolate them electrically to achieve vibration and spitting free evaporation. The power distribution across each boat, which carries a current of up to 1000A, is improved to avoid electromagnetic interference from the high current flow.

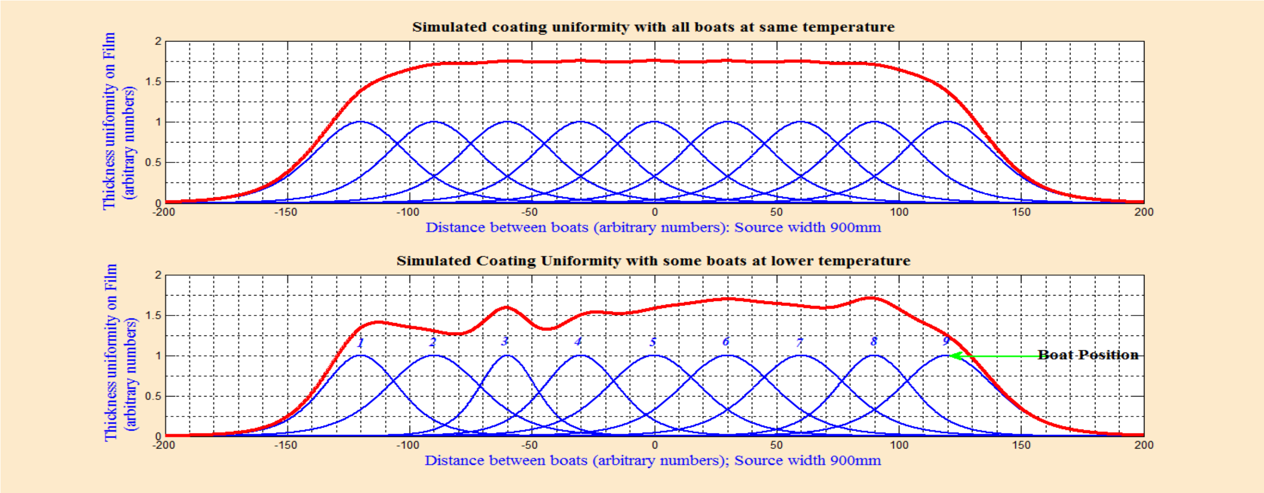

Figure 5. Simulation of thickness uniformity of boats with stable and fluctuated temperature.

f- *Plasma post metallization treatment*

In this geometry plasma is used immediately after metallizing and prior to rewinding to passivate metallized metal. It was reported that this keeps a stable surface energy for the converting stage. It was also found that post plasma treatment can also improve the oxidation and transparency of the AlOx coating.

g- *Optical monitoring of film*

There are two systems available to monitor and control the thickness of the deposited aluminium layer. The first is a non-contact resistance monitoring system. It measures the deposit on the substrate by measuring eddy current fluxes.

The second type of monitors is the optical monitor system. Light transmission is measured at numerous points across the web using light sources or lasers and the data is directly translated into O.D. readings. This system has the ability to measure very low OD, which is required for semi-transparent coatings and solar window films. Modern metallizers have also in line defect monitors to monitor defects formation during metallisation for quality control.

i- *Value added new products*

Standard vacuum web metallizers can be converted to produce added value products without hampering the metallizer capability to metallize aluminium. This includes the following examples:

1- **AlOx**

There is a growing interest in metallized aluminium oxide (AlOx) as transparent barrier coating for packaging. At present, there are two main vacuum deposition processes used for the production of AlO_x clear barrier coating. These are:

a. Reactive thermal evaporation of aluminium with oxygen; where oxygen gas is injected in the metallization zone during aluminium evaporation (Figure 6).

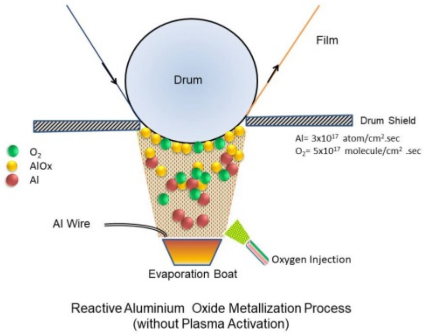

Figure 6. Reactive Aluminium Oxide without Plasma Activation

b. Plasma assisted deposition; where plasma is used in the metallization zone to enhance the oxidation of the aluminium, which is then deposited on the film as transparent AlOx (Figure 7).

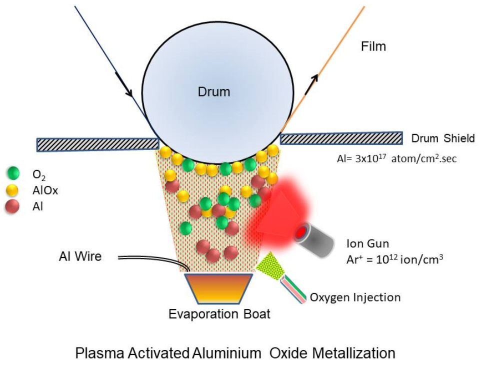

Figure 7. Plasma Activated Aluminium Oxide metallization

The selection of a particular process depends on many factors including barrier level required and the financial budget available to acquire a new generation of plasma assisted metallizer or a retrofit inside a standard aluminium metallizer.

2- **SiOx**

This is another transparent coating which provide barrier against oxygen and water vapour. The starting material is evaporated from special sources in the metallization zone (Figure8).

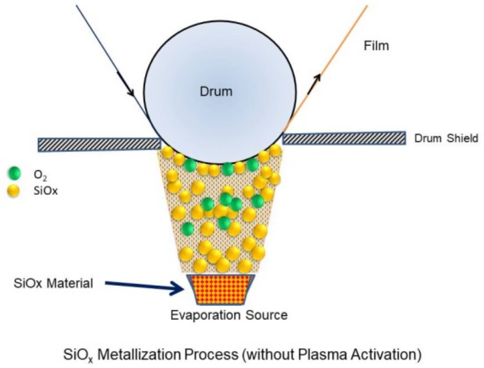

Figure 8. SiOx metallization Process without Plasma Activation

3- **Copper**

Copper metallization is receiving so much interest for many applications including visual appeal, electrical conductivity and anti-bacterial properties. Some applications include security document and RFID (Figure 9).

Figure 9. Copper metallization inside a standard web metallizer

CONCLUSIONS

New modern metallizers have so many advanced features as compared to old generation metallizers. The science and technology of vacuum web metallizers are still advancing to improve performance for both standard aluminium metallizing and added value coatings.

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