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Vacuum Web (Roll) Coating

Vacuum web (or roll) coating is the coating of a thin, flexible material (web) in the form of a roll that is unwound, coated and rewound in a continuous operation. The roll is typically placed in the vacuum system where the process is completed. The roll of material can vary from a width of a few inches to 10 ft, a length of tens of thousands of ft, and weigh thousands of pounds. The coating speed can be as high as 2000–3000 ft/min. The figure shows a typical roll coating system using thermal evaporation for the deposition process.

How it Started

Vacuum web coating had its beginning in the 1940s for metallizing paper with zinc for producing capacitors, and metallizing paper and cloth with aluminum for decorative applications. Metallizing polyester webs began in the early 1950s for decorative purposes. Metallizing polymer webs to provide permeation barriers for moisture, oxygen and organic vapors for packaging applications became important in the 1980s. Coating polymer webs for energy conservation became important in the late 1980s and early 1900s. Today, the deposition of optically transparent materials, such as oxides for packaging (permeation barriers), and heat-reflecting coatings, such as indium-tin-oxide for energy conservation, are important developing markets for web coating. The thickness of the polymer web that is being coated has also decreased over the years. Typical thickness of polymer web is 12–25 microns (0.5–1 mil). Metallized paper is often used for labeling applications. Specialty applications for coated web material include folding solar reflectors for space applications and flexible amorphous silicon solar cell arrays. The estimated market for metallized polymer film and paper in the U.S. for 1995 was in excess of $250 million.

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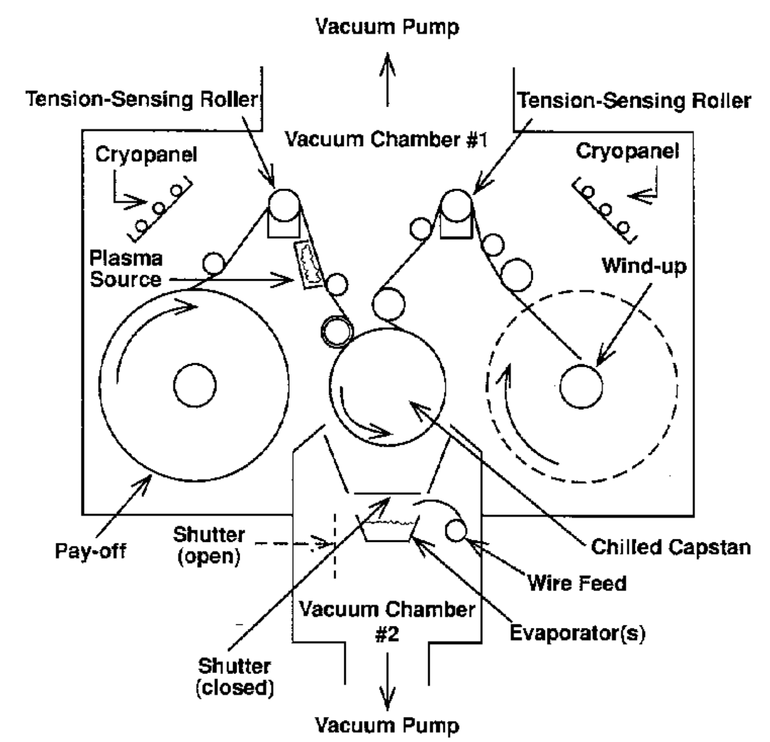

Typical dual-chamber web coating system using vacuum evaporation as the deposition process.

In many applications, the metallized web is subsequently laminated with other web material to form the final web structure. In many cases, ink printing is applied before the lamination process. The metallized rolls of web material are often sent to "converters" for processing the material into the end product, such as packaging or labels. There are, however, many in-house producers who metallize the web and produce the end product.

Film Deposition

Most film deposition in web coating is by high-rate thermal evaporation of aluminum. The evaporation sources are placed close to the substrate requiring high-rate travel of the web and a chilled roller to remove the process-generated heat. Typically, a linear or staggered-linear array of wire-fed evaporator crucibles are used. Sometimes, however, a single long-narrow crucible ("hog-trough") is used. Usually, electrically conductive ceramic boats of TiB_2 containing BN and/or AlN are used to contain the molten aluminum and are resistively heated. The molten material in the crucible is replenished by feeding wire into the molten pool during the process. Electron beam evaporation is sometimes used, particularly in the reactive deposition processes, such as the evaporation of SiO in oxygen to form SiO_{2-x} transparent permeation barrier films.

Sputtering

Sputtering has become an important vaporization technique for reactive and quasi-reactive film deposition of compound materials on webs. In reactive sputter deposition, the elemental material, such as an indium-tin alloy, is sputtered in a plasma having an appreciable partial pressure of oxygen so it will deposit the transparent, electrically conductive, heat-reflecting compound indium-tin-oxide (ITO). Obtaining adequate uniformity of the activated reactive gas over the whole surface being coated is often a problem with reactive sputter deposition. In depositing ITO, this problem can be alleviated by quasi-reactive sputter deposition where the sputtering target is of the electrically-conductive compound material (ITO). Only a relatively small amount of oxygen is needed to replace the oxygen lost in the transport of material from the sputtering source to the substrate.

Usually, web coaters using sputter deposition have several sputtering targets located around the capstan, rather than the one linear source array used in thermal evaporation. This is because the sputter deposition rate from a single source is generally much less than the evaporative deposition rate. The multiple sputtering sources also allow deposition of layered film structures.

Other Considerations

The web coating system has some critical vacuum technology considerations. When unwinding the web, gas is released in large amounts. Often, the machine design is such that there are two vacuum chambers as shown in the figure. The unwinding chamber and the vaporization chamber are pumped independently. By having limited gas flow conductance between the two chambers, the pumping load on the vaporization chamber is lowered. Paper and nylon are particularly troublesome, because they can contain large amounts of water that is released during processing. The unwinding chamber often contains cryopanels to provide a high pumping speed for water vapor. Often, there is a plasma source in the unwinding chamber to allow oxygen plasma treatment of the polymer web surface to improve film adhesion. Important "machine variables" that need to be controlled in web coating include web speed, web tension and the contact between the moving web and the capstan surface.

Web Materials

Important parameters of the web material that must be controlled by the web supplier are the various defects in the material, contaminants released during unwinding, and mobile species that can contaminate the surface of the coated material and interfere with subsequent processing. There are metallization grades of many web materials. In these materials, the additives have been controlled to obtain adhesion, without contaminating the resulting metallization. Orientation by heating and stretching during manufacturing improves many of the optical and mechanical properties of many web materials. Properties of the web material should be carefully specified.

The most common polymer web materials that are metallized are oriented polypropylene (OPP) and polyester (polyethylene terephthalate (PET). Many other polymers are metallized for special applications. The OPP is heat-sealable, giving it an advantage in many packaging applications. The PET has oxygen in its structure, which aids in adhesion without using the oxygen plasma treatment that is typically used with OPP. Nylon is often metallized when tear-resistance is desired.

Coating webs with a transparent film as a permeation barrier has many packaging applications. As yet, the oxygen transmission rate (OTR) and water vapor transmission rate (WVTR) of transparent barrier layers has not been as low as those obtained by aluminum metallizing. This is probably because of cracks and pinholes in the rather brittle transparent film. The incorporation of plasma deposition and plasma polymerization processes into web coating machines may improve this situation. **P&SF**