Abstract
Production equipment for vacuum web coating is designed for >90% availability and this must include scheduled and unscheduled maintenance. As the next generation of vacuum web coaters is designed for increased profitability, it is important to implement changes that assist operators with minimizing downtime and increasing the productivity of the machine. This can be done by the incorporation of more operator friendly devices, giving easier access to areas that require maintenance and providing tools that would allow ease in maintenance. Ergonomics and reliable components increasingly play a role in the uptime and availability of equipment since this is the focus of today’s production facilities.

INTRODUCTION.
As we become a more global marketplace, the challenges of maintaining good quality, profitability and investment continue to dominate the decisions of manufacturing facilities. The choice for an equipment supplier is often affected by indirect management that makes decision purely based on initial investment or delivery time. The focus of producing the best quality and long term profitability is often overlooked for short term returns. For example, cheaper equipment, minimized options, more intensive maintenance requirements, and less reliable components are often the outcome. The role of the equipment supplier has increasingly become one of minimizing costs but still adding value for productivity and minimizing downtime while maintaining or even improving the quality of the output.

For the past few decades, there have been minimal changes in the overall technology of the deposition of Al in vacuum roll coating equipment. The burden has been on machine design, electrical and mechanical improvements and overall productivity for competitors to differentiate themselves. Recently, there appear to be some new technologies that can change the output of the final product and/or improve efficiencies and productivity of vacuum coating equipment. The next generation of equipment needs to consider these tools and implement more ergonomically friendly tools to increase customers’ profitability and competitive edge on the market. The machine has to be more flexible to incorporate potential new processes.
Higher productivity

Prices for metallized products have greatly decreased during the last few years and the rising requirements from the market are becoming more and more demanding. In order to remain competitive, it is critical to maintain high uptimes and increase the productivity of all production equipment.

One primary method of improving yields is to increase line speed while maintaining quality. The ability to increase line speeds by 15-20% and increase the quality level of the end product has been achieved. For a 2450mm wide metallizer, by increasing the line speeds alone, the output of the machine can be improved by greater than 900 tons/year. To increase line speed, it is necessary to increase the evaporation rate which is determined by the evaporation capacity of the evaporation boat itself. To achieve a higher collection rate of aluminum with existing evaporation source, the evaporator surroundings and coating window must be improved. Higher collection means also less cleaning, shorter turn-around time, less consumables and higher overall efficiencies.

Over the years, the boat suppliers have improved their products but in order to meet the demands of higher line speeds, it was necessary to consider a more innovative approach. Based on the impact of a boat control system, that minimizes the fatigue for
the ceramic boat, it was determined that the evaporation boats are being run at a much more controlled and lower temperature, thereby allowing a higher uniformity of evaporation. This control not only improved quality but also extended the life of the evaporation boats. With the ability to control the evaporation boats much better, the amount of Aluminum wasted is minimized and a tighter control of the Optical Density can be achieved. This not only allows for higher evaporation rates and therefore, line speeds but also can improve the uniformity of the overall deposited layer. This improvement alone gives an increased value to the metallizer equal to additionally more than $340,000 (relative to base material and optical density deposited).

**Process Flexibility**

The ability to handle a wide variety of film substrates, a wide range of substrate thicknesses (7 µm to 100 µm for films and 40 g/m² to 250 g/m² for papers, widths from 1250 to 4000 mm) while depositing at high quality and high speeds is increasingly becoming a demand on metallizing equipment. Metallizers are now looking at the ability to be more flexible within a single machine by adding more processes or the possibility to deposit different materials. The primary focus has been on alternative metals (e.g. Cu), clear materials for holographics (ZnS), clear materials for barrier applications (oxides) and striping or patterning of the deposits.

**Copper**

Copper can be evaporated by using a newly developed evaporation boat. Together with boat suppliers, an evaporation boat has been created using a special mixture of components to achieve a higher temperature range for proper melting of the copper wire. These metallized films are mainly used for functional applications, such as anti-static packing for electronics or roof insulations.

**ZnS and Oxides**

High refractive index ZnS layers are used for decorative/security applications coatings on a holographic embossed film. ZnS has been of interest for a long time but the market has not grown to a critical mass to justify dedicated equipment, therefore the ability to evaporate ZnS must be a quick and easy option for the a current metallizer. A modular evaporation source has been developed for thermal evaporation of ZnS which can be installed directly into the existing evaporation system. This modular design accommodates a theoretically unlimited coating width. In addition, this concept features a temperature controlled evaporation utilizing specific evaporation boats, a staggered boat design and a standard boat controllers which allow for very uniform heat control and deposition uniformity.

This evaporator is designed with a nozzle system that allows a very uniform deposition of the material. This modification is done by adding this evaporator directly onto a staggered boat design. In less then 60 minutes a metallizer can be transformed into a holographic evaporator. A web speed of 3 m/sec has been achieved to reach a
thickness of 50 nm, which is sufficient production speed. The thickness distribution of 10% meets the current product requirements and request from the market.

The optical properties show a high refractive index of $n=2.4$ and low adsorption which is required for holographic films.

ZnS evaporation has technical and economical requirements and therefore a collection efficiency of $>75\%$ proves this concept as a highly productive and cost effective solution for high refractive evaporation layers on flexible film.

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**Fig. 2: Holographic film**
Vacuum deposition of SiO\textsubscript{x} is used for transparent layers for high barrier against moisture and oxygen on standard films. PET and BOPP base film do not fulfil the necessary barrier and technical requirements for food packaging and therefore require additional layers to achieve these values and maintain their transparency. Therefore the evaporation of metals and the ability to deposit alternative barrier materials has always been a focus of metallizers.

A modular evaporation sources have been developed for SiO\textsubscript{x} to be deposited by thermal evaporation. Similar to the ZnS module, this modular design accommodates a theoretically unlimited coating width and features a temperature controlled evaporation again utilizing an evaporation control system for very uniform deposition control.

Oxygen and water vapor barrier properties are strongly dependent on stoichiometry of the evaporated layer. A SiO\textsubscript{x} stoichiometry of 1.4 to 1.5 can be maintained throughout a coating length of 20,000 m; this entire length was measured using XPS which proves the ability to maintain the correct stoichiometry over a complete production run.

Oxygen transmission rates (OTR) of 50 ccm/m\textsuperscript{2}/day and water vapor transmission rates (WVTR) of < 3gr/m\textsuperscript{2}/day have been achieved. These values are similar to Al coated polymer film.
Optical properties feature low absorption:

By coating a 20 km long roll, it has been proven that optical properties like transmittance can remain constant throughout the entire run.
While depositing this transparent barrier coating, it was determined that a very high collection efficiency of > 80% can be achieved. Low evaporation material usage is essential for low cost of ownership and high competitiveness.

Stripes

The capacitor industry has been stripe metallizing for decades; the current state of the art is fine line evaporation and pattern metallizing. Striping has been available for packaging applications but requires a specific design for mechanical masking; now using the same technology as the capacitor industry, a metallizer can incorporate an oil evaporation system (with an FDA approved oil) for food or other packaging applications. The coating edge achievable by using this technology is up to a few centimeters per line with accuracy of 0.1 mm. Using this technology, up to 60% of a web width can be “masked” with individual sections of up to 50 mm wide. This system can be retrofit into many existing metallizers and is a proven, dedicated system for high volume production.

Fig. 3: Accuracy of a pattern masking sample on capacitor machines

Measuring Systems

Actual OD measuring range has proven a restriction for OD with values higher than 3.0 OD, sensitivity and accuracy become difficult components to handle in these ranges. Off-line - expensive instruments are available but an in-line solution was needed for 3.0 OD and greater, to enable the coating of opaque and paper substrates with controlled accuracy.
Compared to the previous monitoring systems, a new Extended OD Measurement System uses a transmitted light intensity adjustment control. Quite simply, for opaque materials higher light intensity is required to obtain an OD calculated result. During the calibration procedure for a new substrate, the light intensity of the transmitter is automatically adjusted by the microprocessor to the exact threshold required for the receiver to operate efficiently for that specific base material.

Fig. 4: OD Spectrum for various applications

This measuring system offers the ability to deposit and accurately measure a metallized layer on transparent and opaque substrates using the same measuring tool. This makes the equipment and the production process flexible, allowing the use of a single layer measuring system which is switchable from measuring clear to opaque film depending on the production run. This allows a production facility to measure the complete range of optical densities without using a different type of measuring system and guarantees accurate and repeatable optical density values, as compared to other techniques.
Web Winding

In addition to increased productivity, web quality such as the overall web condition and form, is a critical issue. As more and more film suppliers enter the market, there is a wide variety of roll quality supplied to a metallizer. Getting a perfect edge from the finished roll is constantly the goal. Many films have a “Heavy Edge” which creates difficulties when further processing is required; the ability to oscillate the rewinder eliminates the heavy edge, particularly common in CPP, and produces a perfect roll for further processing.

Monitoring of the edge is important for controlling slip from film with a low coefficient of friction. With such a low coefficient of friction, films tend to slip during unwind and telescope, the edge control monitors the edge of film within ± 30 mm of the outside edge of the film and automatically notifies if film is outside the specified limit, all control is done through the PLC. A worst case example with a 20 mm heavy edge on either side could produce an edge that needs to be slit off which equals 70 t/a or $175,000 from the web’s profit.

![Poor base film quality delivered to the metallizer](image)

Both of these functions reduce scrap, either by having perfect output rolls or by eliminating the need to have wider edges slit off a roll. This allows for higher volume of productive rolls and higher output, both options are available at all film speeds.
A new web winding system is designed with reduced number of rolls touching the substrates coated surface. This improves the surface quality of the film and eliminates “starry effect” and scratches. All web handling improvements are designed to be utilized at current production rates >14 m/s winding and high deposition rates. The reduction of rollers gives higher quality and increased productivity.

An additional process that is now available for metallizers is an in-chamber slitting module. This eliminates the need for additional off-line slitting.
Uptime and Yield

In addition to quality and productivity on a machine, it is important to maintain and even increase the uptime of a metallizer. Currently, the availability of the metallizer is based on maintenance and cleanliness of the machine. Latest improvements are designed to increase the uptime and accessibility for operators and maintenance staff. A high focus on employee safety and accessibility is being further implemented into the new generation of metallizers. Several improvements have been made, including bearings, integrated cleaning tools and, easier access to difficult cleaning areas, including the pre-treatment tool, new boat clamping concept, redesigned evaporator housing and surroundings. The continuation of safety and minimizing downtime is a primary concern and the implementation of these new design tools help reduce down time to achieve highest availability for the machine user.

Summary

Increased profits, productivity, better yields and uptimes are the primary focus for the next generation of equipment for vacuum web coating. Flexibility for alternative processes or combining existing technologies will be implemented into a single metallizer to satisfy the changing markets. As the market for metallized products has become more and more competitive, everyone is forced to show greater variability, higher yields, and increased efficiencies.

This major improvement once again raise the overall level of expectation from metallizing machines and processes worldwide. The ability to evaporate other materials than just pure aluminium give metallizers further flexibility in their overall product offering. The ability to change between evaporated materials quickly and efficiently, gives metallizers more opportunity to fulfil customer requirements and demands. The developed tools support the short time to market and will improve the competitiveness of metallizing companies.
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