Development of high index optical coating for security holograms

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ABSTRACT

Over the past few years security holograms have grown into a complex business to prevent counterfeiting of security cards, banknotes and the like. Rapid advances in holographic technology have led to a growing requirement for optical materials and coating methods to produce such holograms at reasonable costs. These materials have specific refractive indices and are used to fabricate semi-transparent holograms.
The present paper describes a coating process to deposit optical coating on flexible films inside a vacuum web metallizer for the production of high quality semi-transparent holograms.

Keywords: Holograms, Security Holograms, ZnS Coating, Vacuum Metallizing, Web Coating, Plasma Treatment, Vacuum Coating, High Index Coating

1. INTRODUCTION

Security holograms are now widely used on passports, ID cards and driver licenses for authentication and protection against counterfeiting and tampering[1,2]. Security holograms have become now increasingly complex, artistically impressive and difficult to duplicate. The fine structure in holographic image can contain up to 2000 lines per millimeter and this usually requires a top coat with high index coating to produce iridescence with the 2D/3D image[3]. The rapid advances in holographic technology require the utilization of advanced optical coatings and further development of coating methods to reduce production costs. Consequently, there has been an increasing interest in zinc sulphide (ZnS) for its high refractive index and wide wavelength passbands[4]. When applied to embossed flexible films such as polyester it produces a semi-transparent coating that splits and reflects light with different colours when viewed at selected orientation. This material is inexpensive as compared to others such as titanium dioxide and zirconia (ZrO_2)and can be encapsulated and used in I.D. cards, credit cards and other products. This coating has to fulfil certain requirements such as easy to detect colour shift, high transparency for see through applications, repeatability and consistency, compatibility to document structure, durability, stability and low cost[5]. PET is mainly used as a substrate because of its stability and availability. For holographic applications the substrate is usually coated with a basecoat before embossing to give a smooth appearance and a soft surface. Basecoat also promotes adhesion of optical coating on substrate. Basecoat of this kind mainly contain solvents and resins. Well dried basecoat has no or minimum retention of solvent. The solvent is the primary mechanism for controlling surface tension to ensure wettability and thus adhesion to the substrate[6]. However, it could also affect the adhesion of the optical coating to basecoat. By carefully selecting the basecoat and by using plasma treatment the overall productivity of the coating process would increase.

2. PROCESSING EQUIPMENT

The work was carried out inside a 2m diameter, two zone vacuum roll coater. The winding system composed of independently driven unwind, rewind and water cooled process drum. Figure 1 shows a schematic diagram for the roll coater. The chamber was pumped directly by rotary and diffusion pumps to a base pressure of $5x10^{-5}$ mb, although during evaporation the pressure rose to $1.2x\ 10^{-4}$mb. By using this coater a wide variety of substrates such as PET, BOPP and paper were coated with ZnS at an average line speed of 200m/min. In order to improve the adhesion of ZnS onto some base lacquers, a plasma treatment source was used. The source consisted of a medium frequency AC powered, magnetically enhanced dual electrodes with one racetrack per electrode. The source was enclosed in a pressure controlled

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zone to maintain a stable plasma. Zone sealed rollers were used for web control in the plasma zone. The gas flow to the plasma source was controlled by a closed loop circuit. The source was operating at 5kW power and used a gas mixture of 80% argon, 20% oxygen for the treatment. The base lacquered film was treated in the unwind zone before it enters the coating zone. During operation the pressure in the plasma unit was $5x10^{-2}$mb. However, plasma treatment did not affect the pressure in the coating zone.

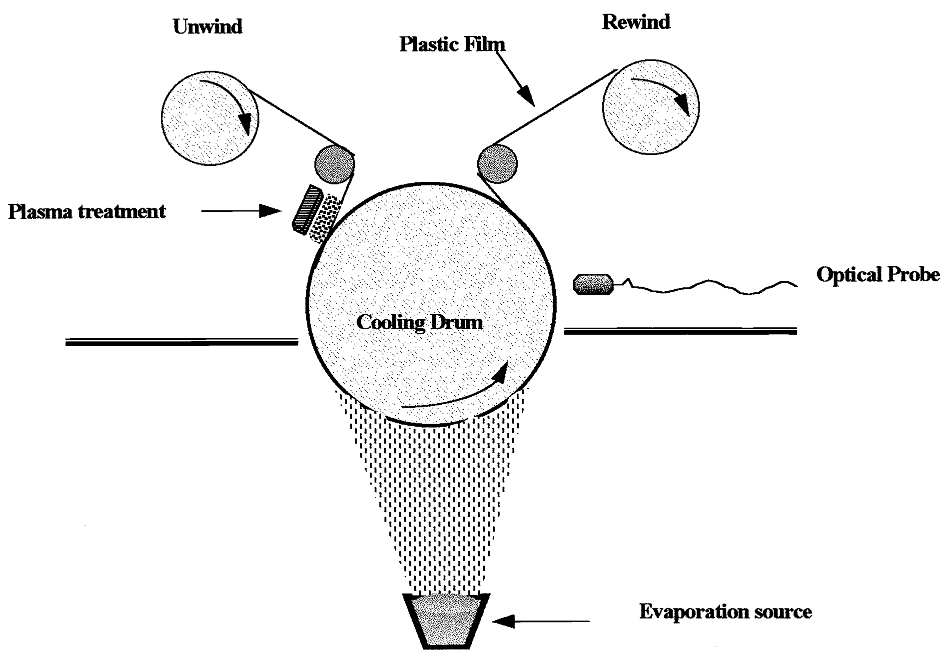

Figure 1. Schematic diagram of the roll coater

Zinc Sulphide coating was achieved using ZnS granules from Merck. On-line monitoring of coating reflectivity was carried out using an optical spectrometer in the visible region. The optical monitor consisted of a white light source, fibre optics and a diode detector array. Three on-line optical probes were placed close to the moving web in the rewind zone. One was used in the centre and the other two were located on each side of the film. Coating uniformity was mainly controlled by source power and line speed. The final spectral transmittance and reflectance was confirmed using a Perkin-Elmer Lambda 9 spectrophotometer. Coating thickness was chosen to give a high reflectance in the visible region as monitored by the on-line optical spectrometer. Table 1 summarises the evaporation conditions used in this work.

Table 1. Deposition parameters of ZnS coating on basecoated Polyester films

Process Parameters	Typical Values
Film	12-50μ PET
Web width	600-1600mm
Coating thickness	500-600Å
Line speed	200m/min
Starting material	ZnS granules
Coating uniformity	± 5%
Refractive index	2.3
Absorption	<2.8%
Reflectance	35-40%
Adhesion	excellent
Hardness	soft
Coating tone	very light yellow/light brown
Roll length	3000-5000m

3. RESULTS AND DISCUSSION

ZnS coatings were deposited onto a variety of substrates at an average line speed of 200m/min. Fig 2 shows the optical reflectance of ZnS coating onto a pre-lacquered 20 μ thick polyester film at a line speed of 200m/min. The coating shows a maximum reflectance of 40% at 550nm. It is clear from this figure that surface reflectance increases from 15% to 40% following the deposition of ZnS onto the pre-lacquered PET film.

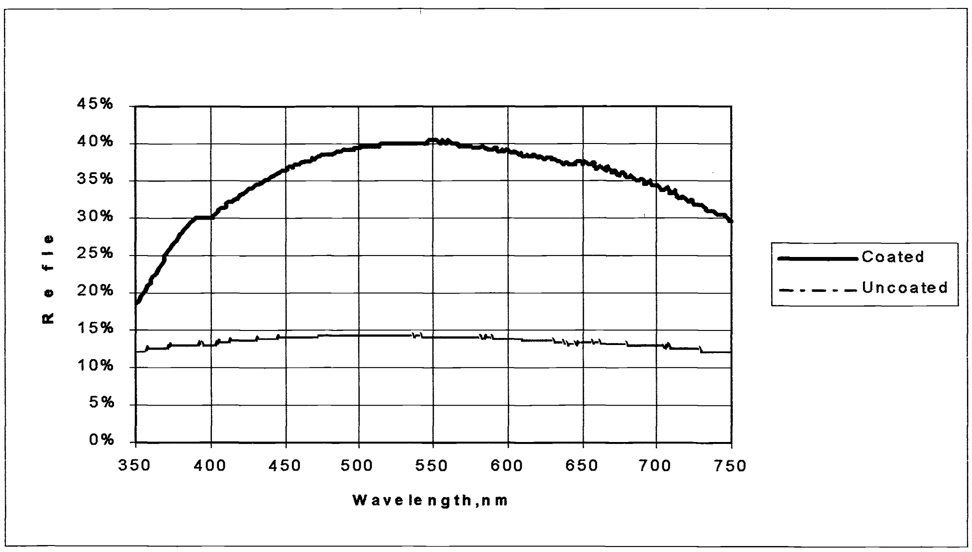

Figure 2. Reflectance of ZnS on 20μ, base lacquered PET Film at a line speed of 200m/min

Fig 3 shows the optical reflectance of ZnS coating onto 80gsm, 1600mm wide embossed paper. The paper was pre-coated with a soft base lacquer. Surface reflectance increases from 6% to 15% at 570nm following coating with ZnS. By controlling line speed and source power a coating uniformity of ± 5% was achieved across the film width.

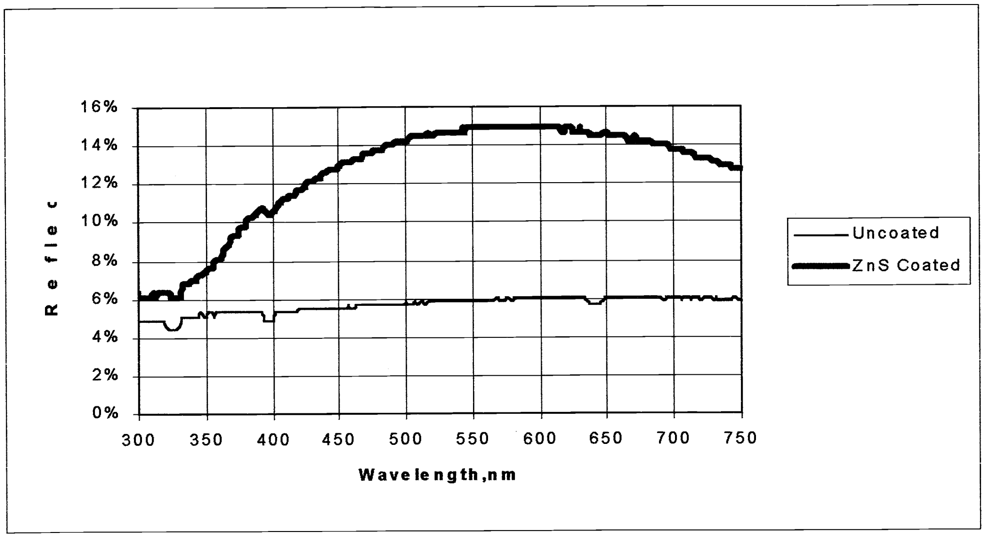

Figure 3. Reflectance of ZnS on 80gsm, base lacquered paper at a line speed of 200m/min

Fig 4 shows the coating uniformity across the width of 1300mm wide, 20µ PET pre-coated with hard lacquer. ZnS coating was deposited at a line speed of 200m/min.

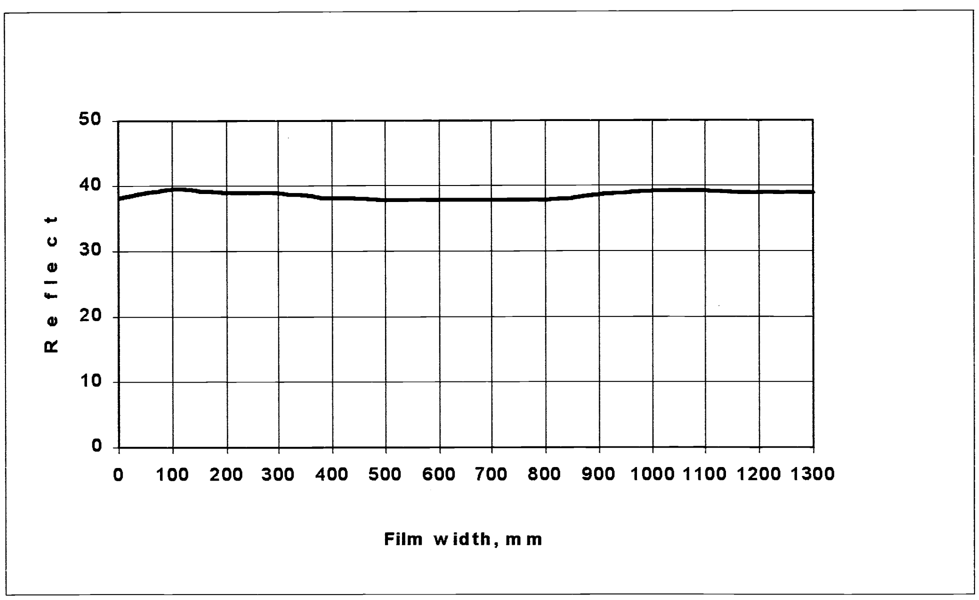

Figure 4. Uniformity of ZnS across 1300mm wide, 20µ base lacquered PET Film at a line speed of 200m/min

The absorption of the deposited ZnS coating was measured from the transmittance and reflectance data and found to be less than 2.8%. The stress level in ZnS coating, as observed by the film curl, was found to increase as a function of coating thickness. The stress was also influenced by substrate temperature. For this reason, the cooling drum in the roll coater was running at room temperature to reduce the stress level in the film. Fig 5 shows AFM image of ZnS coating structure on PET film. The coating exhibits columnar structure with low stress level. It is important to mention at this point that a plasma treatment would be required to improve the sticking coefficient of ZnS onto base lacquer.

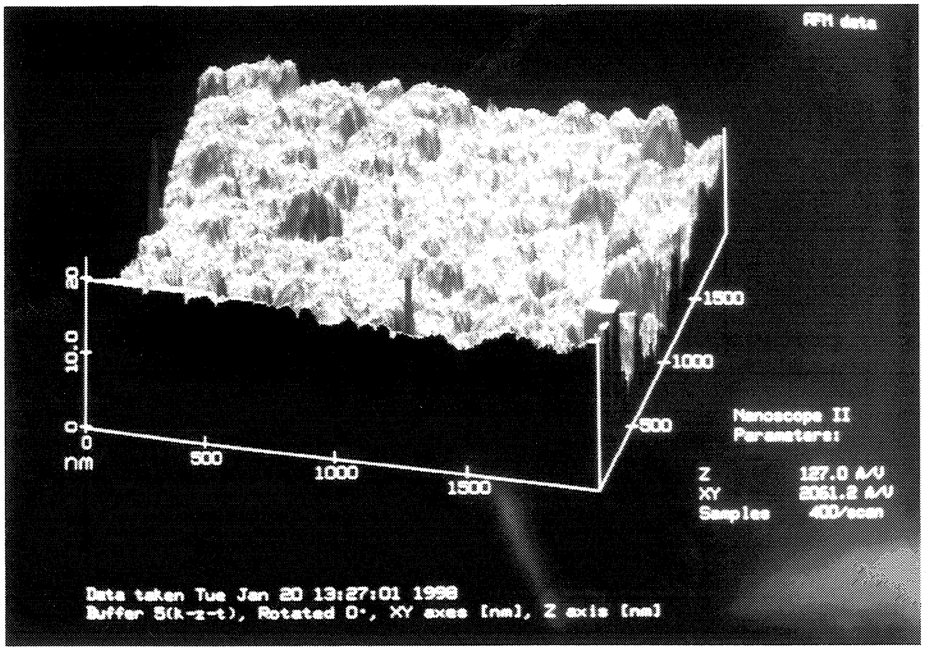

Figure 5. AFM image of ZnS coating on PET film

Fig. 6 shows the increase in ZnS coating thickness following plasma treatment. At a line speed >1m/s ZnS would not stick onto some type of base-lacquers. It is possible that such lacquers are not fully cured and may retain solvent. The solvent would be released during coating process to prevent adhesion. However, following plasma treatment the adhesion of ZnS improves drastically as shown in Fig. 6. The plasma treatment also improves coating uniformity across the film width. It is possible to propose that plasma treatment removes solvent from base lacquer and modifies the surface for chemical bonding. Plasma can also improve surface crosslinking of base lacquer to enhance adhesion.

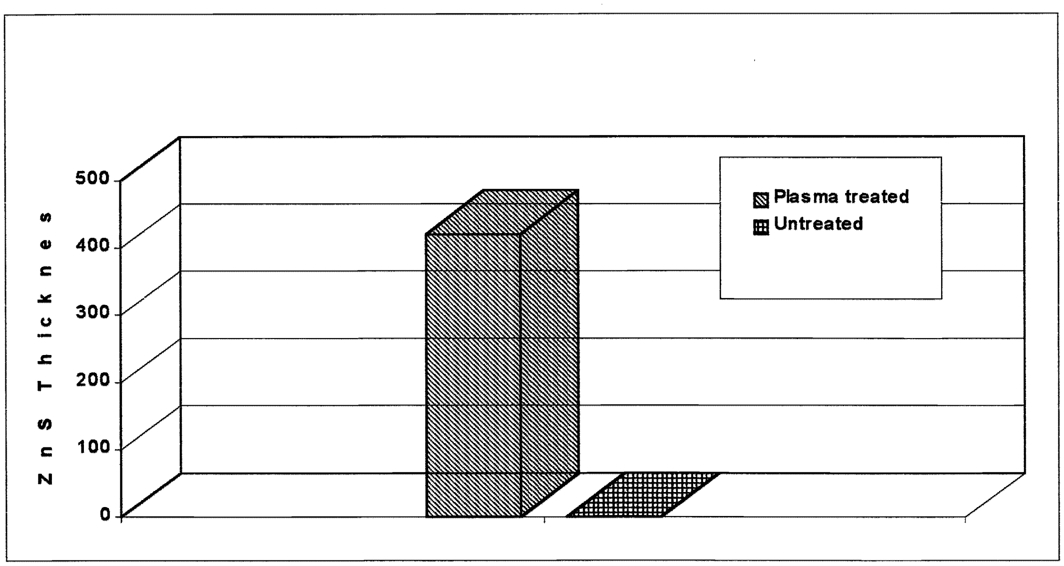

Figure 6. The effect of plasma treatment on ZnS adhesion onto 20μ base lacquered PET Film

CONCLUSIONS

The present work has shown that high index optical coating such as ZnS can be deposited onto variety of substrates such as polyester, polypropylene and paper at a line speed of 200m/min. ZnS coating produced at a line speed of 200m/min exhibits a refractive index of 2.3, absorption coefficient <2.8% and 35-40% reflectance at 500nm wavelength. The coating uniformity across film width is better than ±5%. ZnS coating may not adhere onto some type of base lacquers. In this case plasma treatment would be required. ZnS coating is mainly used as a high index coating to produce security holograms with iridescent colours.

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