UV casting for functional and decorative applications

Concept and technology

Nadir A G Ahmed

The ultra-violet cured coating process is already known in the field of printing to be able to produce very thin coatings with a high gloss finish. UV coatings can be applied by most conventional industrial coating machines including silkscreen technology. UV curable coatings can also be used to introduce a variety of properties to polymeric surfaces, including glare reduction, wear or scratch resistance, anti-fogging, microbial resistance and chemical resistance.

In recent years, UV curable coatings have been developed into the casting and curing process for decorative and high tech markets. Including nano and micro structures which can be cast onto flexible substrates for various applications including holographic, sensors, optical devices and decorative packaging products.

This article will discuss the technology of the UV casting and curing process and will outline some of its advantages for functional and decorative applications.

Introduction

UV coatings can be formulated in different concentrations up to 100% solid then applied over an ink printed paper substrate and cured by exposure to UV radiation. The high solid level allows the coating to be applied as a thin layer which can be cured quickly. Consequently, this can produce extremely reflective and high gloss finishes comparable to photographic paper or glossy magazines. When exposed to the correct level of UV radiation curing and drying is virtually instantaneous.

UV cured coatings can also be applied to glass and plastic items including sunglasses and automotive windows to reduce the amount of UV light that passes through them. The coatings can be used to impart a variety of properties to polymeric surfaces, including glare reduction, wear or scratch resistance, anti-fogging, microbial resistance, chemical resistance. Computer screens, keyboards, and most other personal electronic devices are treated with some type of UV-curable coating.

The coatings are very convenient for application to plastic substrates because the process does not require heat. Other applications include wood finishing to produce a smooth gloss surface and on aluminium cans for protection. In order to produce films with high productivity and lower cost, novel patterning methods have been introduced which includes lithography and nano imprint lithography to fabricate nano patterns at a lower cost. In general, lithography is a multi-step process that typically starts with the design of a pattern in the form of gratings, small features or data set. For holographic applications, laser or electron beam are used to make the gratings.

However, nano lithography represents the state of the art in high throughput nanofabrication. Such technology is based on a UV curable monomer resin to fabricate sharp, well defined nano imprints. This new process offers an alternative to the standard method of hot embossing of polymer substrate, which requires a high temperature and pressure and which was found to damage the nano imprints. Thus, nano imprint technology would be very useful in the production of high quality decorative and functional flexible films.

This new inline decorative process creates rich, high gloss micro or nano textured surface effects on a variety of substrates in both sheet fed or roll-to-roll web applications.

Concept

The UV casting and curing process is a new technique used for high volume manufacturing of micro or nano-structured flexible films. This process is different from the standard embossing method in that the process is derived from nano imprint lithography (NIL) and involves a number of distinct stages incorporated in a flexible film handling machine. UV casting and curing is a roll-to-roll manufacturing process.

Two processing steps are involved: the coating process and the imprinting-curing process (see figure 2). There are two versions of this technology; the first uses embossing roller and the second uses embossed film to transfer the im-

Figure 1: UV casting for packaging

Source: Idvac Ltd

print onto the film substrate. In the first version, a flexible substrate film such as polyester is unwound from a reel then a liquid phase UV curable resin is coated on the top side of the film by a two or three-step roller coating system. A drying stage can be added after the coating stage to remove solvent from the resin. The coating system is synchronised with the main imprinting roller to ensure uniform coating thickness regardless of web speed.

The film is then held in intimate contact with an embossing roller at constant pressure which is controlled by a pressure sensor. In this way, the microstructure defined on the embossed roller is replicated and cast in the resin coated onto the film. The resin should have some anti-sticking property to prevent sticking on the embossed roller. A high power UV light source is used at the point of contact to cure and harden the resin. In the final stage the completely cast and cured micro-structured film is rewound onto a reel. UV Casting films are available in a variety of diffraction patterns, similar to hot foils, which can also be customised with a proprietary design for brand identity and security applications.

All of these processes take place on a single continuous machine, in a clean room environment depending on applications. The front side of the machine can be housed in a class 100 clean room, while the rest of the machine can be located in a class 10,000 clean room to keep the process clean from any dust or other contamination. The process is mainly used for polymer film such as 12–350 micron Polyester, Polypropylene, polycarbonate, cellulose di-acetate and cellulose tri acetate films. Foils and papers can also be handled.

In the second version of the UV casting technique, which is called cold UV Embossing, an embossed holographic film is used as a "master" to transfer an embossed image onto the film substrate. This type of machine has been developed for paper, board or flexible films for packaging and security.

In this process (see figure 3) the substrate, i.e. film, is coated with a liquid phase UV curable resist material by a two or three roller coating system. The substrate is then partially cured by soft UV radiation and brought into contact under pressure (laminated) with a reel of surface-relief embossed film. In this way the relief image is cast into the UV coating on the film substrate. The film substrate is then separated (i.e. de-laminated) from the embossed film (master) and immediately cured with UV light to harden the embossed image. The embossed film (master) is rewound for further use.

Cold (UV) embossing may be preferred for critically dimensioned materials. It can be a room temperature process, eliminating the heating and cooling times and thermal expansions/contractions of hot embossing. It allows single or repeated multiple patterns to be layered on one or both sides of a substrate in accurate alignment.

Both sides of the film substrate may be embossed with identical or different patterns. For applications with more critical planarity, dimensional tolerances, or environmental requirements, cold embossing of photosensitive organic-inorganic sol-gel materials gives results close to those of glass.

The film which is coated with UV curable resin is laminated on top of a master embossed film, exposed to UV for curing then de-laminated to copy the embossing details (see figure 4)

UV curing principles

The UV process uses UV energy and light from the visible light spectrum in the wavelength range from 200 to 480 nm. UV energy "cures" inks and varnishes in a fraction of a second. This energy is produced by a mercury discharge lamp and is absorbed by a sensitizer, causing a reaction in the monomer which makes it hard and dry. The rate of the curing process depends on the following:

Monomer compounds in the UV resin

Each monomer cures at a different rate, depending on the amounts and compositions of sensitizer, pigment, and chemical additives.

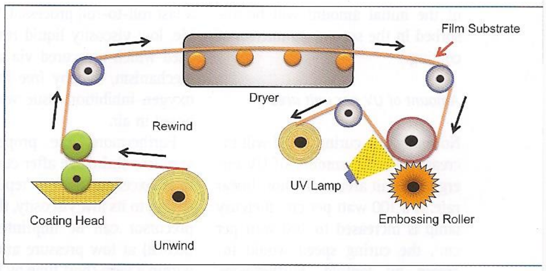

Figure 2: UV embossing process

Coating thickness

The thickness of UV coating is not directly proportional to exposure time. The amount of UV energy inside a layer of coating decreases exponentially with depth. A two-fold increase in the thickness requires a ten-fold increase in UV intensity. For example, for a 50 micron thick UV coating, if 70% of the UV energy is absorbed in the top 25 micron of coating, then 7%

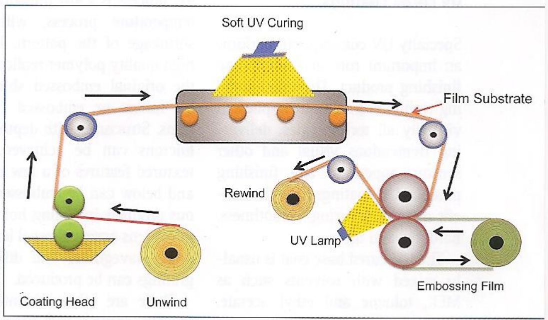

Figure 3: UV cold transfer process

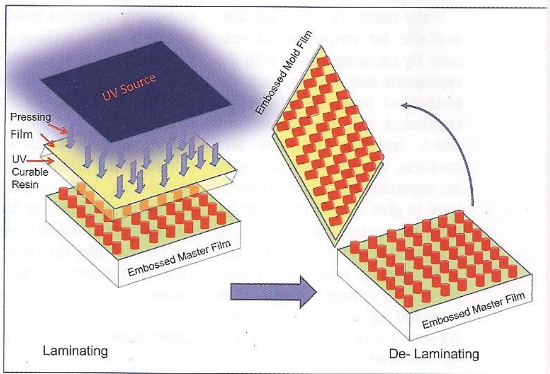

Figure 4: Cold UV casting and curing process

of the initial amount will be absorbed in the second 25 micron of coating.

Amount of UV per unit area

Normally, the curing speed will increase with the amount of UV energy per unit area at the non-linear rate. If a 100 watt per cm^2 mercury lamp is increased to 200 watt per cm^2, the curing speed would increase by tenfold. Furthermore, special metal halide lamps can trigger the receptor at an even faster rate with a standard 200 watt per inch lamp. The sensitizer used in the UV resin should absorb UV in the range which is not absorbed by the monomer or pigment. The wavelength produced by a medium pressure mercury lamp or metal halide lamp should match the wavelength absorbed by the sensitizer.

UV cured coatings

Specialty UV coatings can perform an important role in any off-line finishing product. The latest coating technologies can be applied to virtually all technologies, delivering tremendous visual and other sensory appeal to any finishing product. UV coatings have the benefit of instant curing, smoothness, hardness and more

The UV cured base coat is usually mixed with solvents such as MEK, toluene and ethyl acetate. photo-crosslinkable acrylate or methacrylate oligomeric resins are used as base coats.

Water-based UV resins are also available for environmental reasons. By choosing a resin with the appropriate chemical structure, the mechanical properties of the UV crosslinked resin can be modified which includes brittleness and hardness. When optical properties are important, resins can be formulated to give specific refractive indices in the range of 1.44 to 1.6 (measured at 633 nm). The UV resin is cured in a nitrogen atmosphere if oxygen inhibits the cross-linking process. A mercury UV source with an output power of 50–100 Watts/cm^2 is used to cure the resin. However, UV power depends on the type of resin used. For a fast roll-to-roll process, UV curable, low viscosity liquid resins are used which are cured via cationic mechanism, thereby free from the oxygen inhibition issue when exposed in air.

Furthermore, the property of very low shrinkage after curing allows excellent pattern replication. Owing to its low viscosity, the resin precursor can be imprinted (embossed) at low pressure and cured within a very short time by focused UV light. High quality, low pressure and room temperature embossing are the main advantages of the roll-to-roll UV embossing process. Other resin parameters which should be considered are transparency, temperature resistance, refractive index, antistatic properties and adhesion to film substrates.

Advantages

In general, the UV casting and curing process is a low pressure, room temperature process, with little shrinkage of the pattern. It gives high quality polymer replication of the original embossed shim used on rollers or embossed (master) films. Structures with depths of 50 microns can be achieved, while textured features of a few microns and below can be embossed. Various products including holograms, micro lens arrays, Fresnel lens, polymer waveguides and diffraction gratings can be produced.

There are other advantages of the UV casting and curing technique over conventional surface structuring processes such as hot embossing, injection molding and extrusion. This technology does not require heat to cure the resin, thus it is very useful for applications on heat sensitive structured films.

This technique is currently considered as the preferred method of reproducing high contrast nano and micro structures for decorative and high tech applications. Different types of film substrates can be surface structured for many applications.

Conclusion

UV embossing is a new technology employed to produce high quality holograms as compared with standard hard or soft embossing processes. Roll-to-roll, large width UV embossing would enhance throughput and reduce the cost of high quality holographic products. It would also offer the opportunity to produce advanced polymeric micro-optical components and holograms of high quality at low cost. This is convenient for high quality packaging products.

Source: The Double R Company Ltd., UK

| *Figure 5: UV casting and curing machine*

Further readings

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