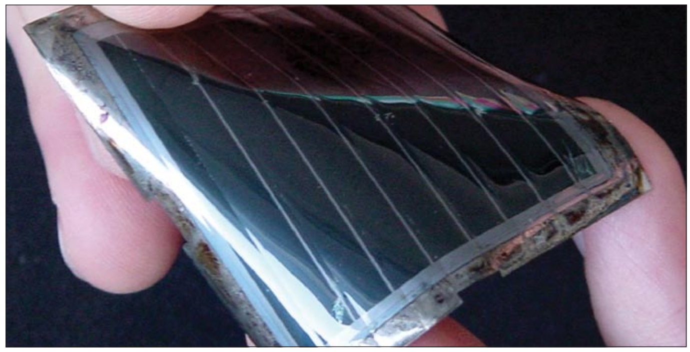
Versatile polymers offer big potential

Vacuum deposition of polymers is opening up a myriad of applications, as Charles Bishop reveals.

The use of polymers in vacuum-deposition processing is currently in the spotlight because of the rapid growth in popularity of solar power and the need to reduce the cost of solar-cell technology. One route to achieving this is to make solar cells based on flexible polymers rather than on the rigid glass or silicon of earlier designs.

Polymer solar cells are significantly cheaper because they can be manufactured using a technique called roll-to-roll (R2R) processing. Thin sheets of polymer are rolled up and processed by coating, patterning, embossing and so on as they are wound from one reel to another. A huge area of film can be coated in a very compact vacuum chamber, thus making it much cheaper than other methods. Indeed, thanks to R2R processing, vacuum-coated polymer films are now ubiquitous, with applications ranging from food packaging to banknotes.

The coatings are often simple reflective metals (as with the aluminium metallized polymer films that are used to make crisp packets) but, as they are often only a few tens of nanometres thick, they can have holographic structures embossed on them. These coatings are often used as anti-forgery devices on banknotes.



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Solar cells based on flexible polymers rather than rigid glass or silicon could ultimately reduce the cost of solar power.

There are several types of polymer film, each of which has properties that make it more suitable for certain applications than others. It is possible to make a thin web of a polymer either by extruding and stretching the material (tentering) to thin it out or by casting a thin film onto a belt and peeling it off when it has cured. Tentering orients the polymer chains, thus giving the material good tensile strength in the direction along which the chains are aligned. This is what gives magnetic recording tape such high tensile strength.

Polymers used in food packaging, for example, have to deliver tear and impact resistance, and offer tensile strength. They must also act as an oxygen and moisture barrier. They need to be able to withstand the vacuum-deposition process, during which the temperature can rise to more than 100 °C. Polymers typically used for this type of application include polypropylene, polyester, polyethylene and polyamide (nylon).

R2R processing is also used to make flexible displays, which could one day replace paper, and the technical requirements for this application also pose significant challenges. Flexible displays contain organic, light-emitting materials, which can be degraded by moisture or oxygen, so the polymer substrate must be a good oxygen and moisture barrier. To put this into perspective, the barrier required for an organic display is approximately six orders of magnitude better than that typically used in food packaging. These materials are known as "ultrabarriers" and are generally difficult to produce.

The problem is largely down to the surface quality of the polymer film. If the surface is too smooth, then the rolled-up polymer sticks to itself due to an adhesive effect known as "blocking", which occurs when two smooth surfaces are in intimate contact. Blocking is usually prevented by the addition of talc, silica or limestone to the polymer, because these protrude from the surface and prevent such intimate contact. Another problem is that as polymers are wound and rewound during R2R processing, they pass over rollers (metal or elastomer-sleeved metal) and the mismatch in materials means that the film can build up a tribo-electric charge, which attracts dust onto the surface.

The fillers and the dust make the polymer surface rough, which means that it is difficult to produce a perfect barrier coating via R2R processing. One solution is to deposit an extra layer of polymer – often an acrylate – onto the roll of substrate material inside the vacuum system before the inorganic coating is deposited. The extra polymer layer reduces the number and size of the surface defects on the substrate, thereby allowing a better inorganic layer.

These vacuum-deposited polymers can be fully cured (i.e. polymerized), as in the case of the acrylates mentioned above, or they can be partially polymerized, meaning that the coating can later be dissolved from the substrate reasonably easily. This enables thin inorganic coatings to be deposited onto the substrate but removed at a later stage, which is the process used to make the fine metal flakes in metallic inks and paints.

Polymers are hugely versatile but most of us never appreciate the range of options that they offer. If you have an application that requires coating a large surface area and that could benefit from using one of the variety of lightweight polymer substrates available, then R2R vacuum coating could be the ideal solution.

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