The Evolution of UV Photopolymerization

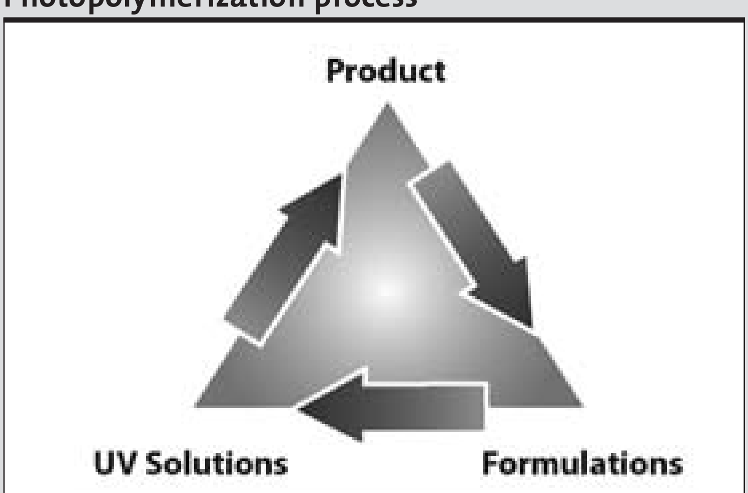
in Global Industrial Manufacturing Markets and the Promising Outlook for the Future of the Technology

By David Harbourne

This paper outlines the UV photopolymerization process, and the economic, environmental and other benefits that the technology brings to a multiplicity of industrial manufacturing industries. It also explores the challenges that must be overcome by all revolutionary manufacturing technologies and processes, and concludes with an overview of some exciting new technologies that could benefit from the inclusion of this UV photopolymerization process.

Figure 1

Photopolymerization process



Background

The UV-curing process is frequently described as “the making of a plastic in situ on a wide variety of substrates.” It is the crosslinking of a formulated mixture of oligomers, monomers, photoinitiators (that react to UV light) and other components (pigments, diluents, etc.) when exposed to UV energy (formulated products including printing inks, adhesives, coatings and varnishes). However, this too would be an over simplification of a process which is highly dependent on a variety of factors, none of which is insignificant and all of which have the potential to influence the outcome of the photopolymerization process. (See Figure 1.)

Yet a successful process is eminently straightforward and robust when properly implemented in a manufacturing operation.

The first recorded use of the photopolymerization process dates back 4,000 years ago when the ancient Egyptians used a type of coating that cured when exposed to sunlight for embalming mummies and also as a sealant for their wooden-hulled ships.

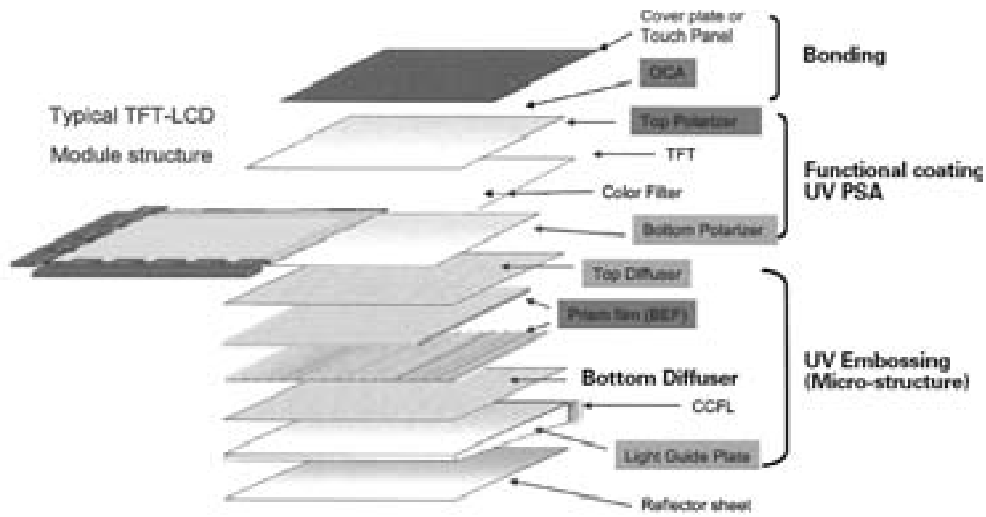
Today, the process has evolved to where products manufactured using the technologies are ubiquitous in the global living and industrial

Figure 2

Advanced batteries and energy storage

Optical Films inside TFT LCD

TFT LCD panels are built from several components, including glass substrates, liquid crystal, plastic frame and optical films. Optical films play an important role in the TFT LCD module in aiding in the control, diffusion and brightness enhancement of light and contrast ratios.



environment. It is "Invisible but Everywhere.™" (Mobile phones, display screens, DVDs, telecommunications, domestic appliances, food and beverage containers, automotive, flooring, electronics and many more.)

The key value drivers behind this evolution have been economic and environmental—namely energy conservation, usage efficiency and environmental conservation. However, a third and more telling driver that is often overlooked is that the UV-curing process has enabled development and production of new technologies and products that would not have been possible with the then current technologies. This shift to UV very often results in "more (quantity and quality) with less" (energy, space, defects, VOC and HAPs emissions, cost).

Governments and private industries around the world are all focusing their resources on the next-generation technology platforms. The frequently listed top 10 future platforms include flexible electronics, energy storage, smart materials and solar energy. However, the journey from research and development laboratories to a commercially viable production environment is filled with many roadblocks and challenges, and the route to success is not guaranteed.

Technology Platforms of the Future and Potential Applications for UV Curing

What is the potential role for the UV-curing process in these "new technology platforms" (markets)?

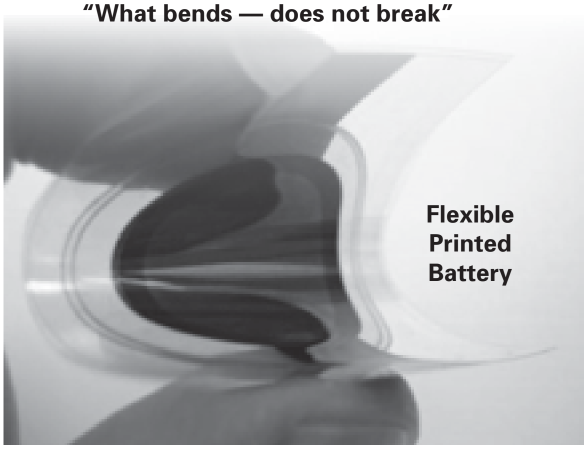
Flexible Electronics

This group includes polymer sensing coatings, OLED displays, flexible chip modules, polymer solar cells, printable electronics, photovoltaics and for use in displays, batteries, RFIDs, lighting and display products. This industry is forecast to grow at a rate of 19.5% (Compound Annual Growth Rate) to the year 2014. The biggest growth driver for the technology is less about cost and much more about "form factor"—devices that are flexible, conformable, rollable, producible in large formats, and that provide properties and characteristics that cannot be or would be difficult to fulfill with current conventional techniques. As with many new technology platforms, there is not likely to be a direct route from R&D/technology development to the large, high-volume consumer market. There will likely be a transition from the low-volume/high value-added market to the high-volume markets (military/medical devices to e-books and flexible touch screens). UV curing will enable the production of printed flexible electronics with only 25% of the production steps used in

Figure 3

Advanced batteries and energy sources

"What bends — does not break"



the production of current devices, significantly reducing production costs, opportunity for defect occurrence and environmental impact. Today's e-book products are the forerunners of very large flexible display markets, including point-of-purchase displays, advertising signage, real-time traffic signage, and large capacitive touch screens. The UV-curing process used in the production of "optical films" will enable improvements in anti-reflectivity, brightness and energy consumption of all such devices. (See Figure 2.) The bold text highlights are manufacturing processes that are or will be completed with UV curing.

Advanced Batteries and Energy Storage

As with the solar energy and flexible electronics platforms, there is some overlap of technologies between each of these platforms. In 2010, the global market demand for batteries for the consumer electronics market will total about $76 million (PDA, mobile phone, notebooks, etc.). Experts are predicting that the demand for electric-powered vehicles will stimulate an explosive need for batteries by 2012-2014. This demand projection is driving multi-million dollar investments in rechargeable battery technology. The application of UV curing in this market segment is currently in its infancy. However, significant funds are being channeled into the development of UV-cured separator membranes for this and other configurations of rechargeable batteries. (See Figure 3.)

Smart Materials

For some time now, scientists have been researching materials that would behave similarly to those found in nature's biological system, materials that have the inherent "self-heal" mechanism. This science is sometimes referred to as "bio-mimicry" (science duplicating nature). Initial developments of such "smart materials" have been successful and some materials are commercially available at this time. Self-healing (autonomic) coatings that repair themselves without external intervention are useful in a wide range of applications in the oil, gas, marine and aerospace markets—where the items to be protected are frequently located in extremely remote areas and where field repair may be extremely difficult or even impractical (wind turbines, oil pipelines, bridges, etc.). These coatings begin repairing themselves as soon as the damage occurs. (See Figure 4.)

Combining these self-healing properties with the environmental

Figure 4

Smart materials

Autonomic — How the self-healing works

Courtesy of Advanced Materials

and cost-saving benefits of the UV-curing process provides a compelling justification for the adoption of this coating technology. UV coatings also have the capacity to enable new, high value-added finishes to metal coil substrates (e.g., anti-fingerprint, anti-microbial and heat transfer coatings).

Solar Energy

This represents perhaps the ultimate green technology as a source of renewable energy (power). Innovation and new technologies are in the process of transitioning from promising results to affordable, manufacturable solar energy harvesting and converting products. Governments around the world are investing significant technical and monetary resources in an effort to speed up deployment of solar energy technology. Lowering the cost, while increasing the efficiency, of solar devices is a key focus of these endeavors.

Organic photovoltaics (OPV) is an innovative solar cell technology that is based on conductive plastic materials. Such devices can be fabricated using ultra-low-cost, roll-to-roll printing techniques that frequently utilize UV-curing processes. Such solar cells will be thinner, lighter and produced at a cost of about U.S. $1/W—which is 25% to 30% of the cost of current devices. These OPV products currently have a lower efficiency rating than off-the-shelf silicon modules, but this is offset by large, usable receptor areas; lower weight; and less carbon integration. Initial applications for OPVs include portable battery chargers, outdoor power generation and lighting, and emergency power generation. These markets are regarded by some as niche markets, but they are merely steps in the journey to building integrated applications such as solar roofing.

Conclusion

In the past 4,000 years, we have transitioned from utilizing the sun's UV photons for embalming mummies and sealing wooden ships to utilizing UV photopolymerization processes for capturing energy from the sun and utilizing that energy to satisfy the power demands of the world's industries and populations. This transition has decreased our dependency on non-renewable fossil fuels and minimized the negative impact on the global ecological environment—a journey that these wise Egyptians, who first realized the benefits of UV curing, could never have imagined. ◗

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