UV lighting the way

Ultraviolet curing can dry paint applied to plastics, reduce film thicknesses and cut environmentally unfriendly emissions but, as John Osborne explains, success also depends on automakers balancing the chemists' needs with those of UV equipment makers

UV technology is well established in the graphics, converting and wood finishing industries. There it has enabled users to virtually eliminate volatile organic compound emissions, enjoy rapid curing, reduced process space and improved performance in areas such as scratch and stain resistance, high gloss and other special effects. However, it has still to gain widespread acceptance in automotive paint shops, mainly because of the high cost of the UV lamps. Kevin Joesel is Director of Automotive Markets at Michigan-based Fusion UV Systems, a leading supplier of UV lamps to the industry. He stresses that the company understands the challenges facing automakers that are considering installing the equipment.

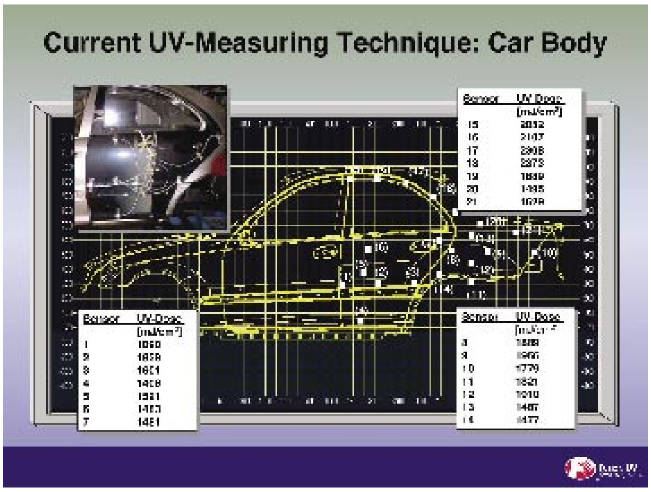
One of the attractions of UV is that fewer materials are needed and less energy is required. "It is supposed to use less energy", says Joesel. However, unless there is a specific coating with known energy requirements, it is difficult to know. "The other driver is improved scratch and mar performance. UV curing technology has been investigated and test vehicles are on the road. The use of nanomaterials also provide improved scratch and mar performance; this, without the additional capital expense of UV lamps. However, these coatings are expensive and there is a niggling concern about weatherability."

UV chemistry

If UV curing is to take off it stands more chance of succeeding if coatings are available in the forms that are most likely to be used in the future, and these include powder. However, automakers will have to familiarize themselves with UV chemistry.

"It is a bit different to thermal technology," explains Joesel. "The primary use of UV chemistry is for free-radical polymerization. Basically, the UV energy is absorbed by a photoinitiator, causing it to cleave [and] creating the free radicals that react with acrylate functional groups on the resins (acrylate is unsaturated carbon to carbon bonds). This reaction takes place at ambient temperature and is one million times faster than the typical thermal reaction using condensation reactions. This free-radical polymerization typically takes place in the reactor at the resin manufacturing facility."

He adds: "There are two primary processing issues with UV curing technology utilizing free-radical reactions: the need for "line-of-sight" to achieve cure and, oxygen inhibition. Oxygen inhibition takes place when the free radicals, once they are created, react with atmospheric oxygen dissolved in the coating and at the surface." Joesel observes that "this can be overcome by using higher intensity UV energy by creating such a high free-radical flux that it overwhelms the oxygen reaction. The other means is to remove or displace the oxygen in the UV curing area through a vacuum or by providing an inert atmosphere."



Fusion UV Systems offers a full UV curing capablilty to automotive customers, including measurement

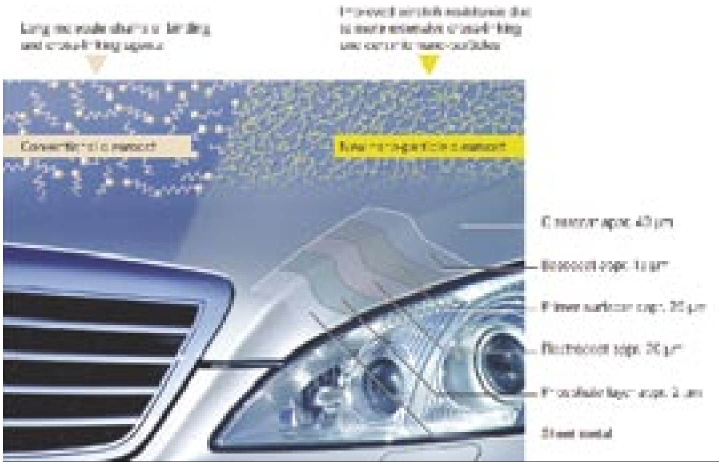
Clear coat applications

It appears that a battle is going on for hearts and minds. It is going on in laboratories, in pilot plants and in conference venues. Perhaps one of the most important events in the automotive coatings calendar took place between 1-3 June 2005 in Cannes, France – The 22nd International Conference on Automobile Body Finishing, otherwise known as SURCAR 2005. Here the technical challenges were outlined for several aspects of UV curing including those affecting chemists.

In a presentation entitled 'Recent and Future Developments in Clear Coats', E. Wegner, F. Bloser and A. Popper of BASF Coatings, and BASF's Michael Kutschera explained what is currently available in clear coats. They said that by "employing low molecular weight acrylic functional resins, in particular esters or urethanes, extremely scratch resistant surfaces are created after a very short period of UV irradiation. Extreme resistance is obtained, if highly branched highly functional acrylic resins are used."

They added: "It is possible to use extremely durable resins, such as urethanes and or aliphatic esters, resulting in surfaces having excellent etch resistance. Also a very good appearance in combination with high solids contents is usually obtained, since low molecular weight raw materials leads to enhanced levelling."

However, they identified certain challenges: that UV lamps are needed and base coat hardening must be adapted to UV. They said that the best results have so far been "obtained by curing those clear coats under an inert atmosphere. To adapt inert atmosphere technology, further installations and an increase in total process costs are expected."



The clear coat of the new Mercedes S-Class is based on nanotechnology and is appreciably more resistant to scratching than conventional paint

Curing shadow zones

One way of overcoming the problem of shadow zones (areas where the ultraviolet light is unable to cure the paint) is to use thermal and UV curing material. The BASF personnel mentioned BASF's TwinGloss. They claim that these "dual cure coatings exhibit a reasonable compromise in improved scratch resistance in between the 100 per cent UV cured clear coats and state of the art 2K clear coats. Moreover, excellent appearance at solids contents of 70 per cent or more and very good resistance against chemicals is achieved."

Reinhard Kraus is Manager, Process Department, Paints, at DaimlerChrysler's plant in Sindelfingen, Germany. In 'Scratch Resistant Clear Coats for the Automotive Industry Development and Experiences at Mercedes-Benz' he explains how better clear coats have been produced. He also predicts that non-thermal curing is likely to be used to produce the next generation of scratch resistant clear coats.

Kraus says that "this generation of clear coats has to achieve a further increase in the resistance against acid, alkaline attacks, as well as attacks by other substances." He also says they will probably be produced using the following:

• Purely UV curing clear coat systems (UV mono cure)
• Clear coats with new reaction mechanisms
• Clear coat curing with inert gas
• Plasma curing clearcoats.

Kraus adds that a combination of those systems are also likely to be used.

Powder coating developments

Powder coatings designed for use with UV curing have been available for some but there have been some recent developments in this area. The 8th Nürnberg Congress was held in Nürnberg, Germany from during April and amongst the sessions was one on 'Creative Advances in Coatings Technology'. Dr Wolfgang Paulus who works for BASF in Germany was chairman and he observed that "UV powder coatings are making strong inroads into the market, especially for temperature sensitive substrates. Recently found catalysts for blocking agent free polyurethane powder coatings lead to a dramatically reduced curing temperature. Also, new binders and cross-linkers are under discussion."

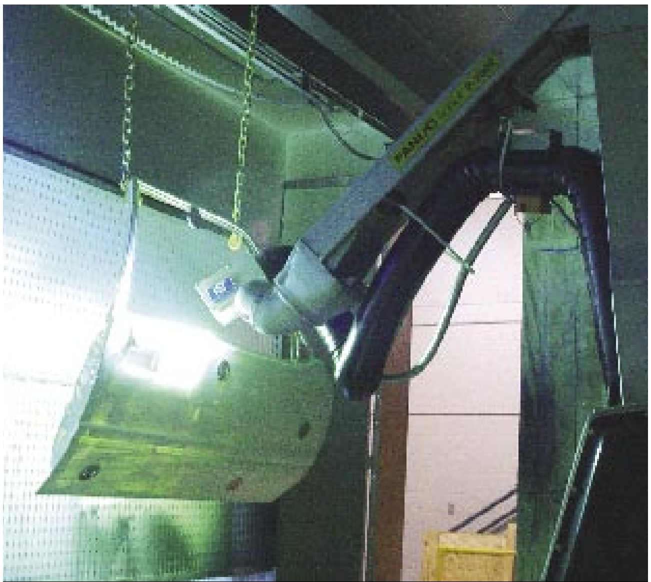
The chemistry is available to help automakers ensure that UV curing will live up to its promises. Implementation is still under discussion though. Paul Mills, President, UV Robotics, based in Cleveland, Ohio, says that UV Robotics is an expert in robotic UV curing of car parts and bodies. Mills also runs the North American Automotive UV Consortium, which is based in Strongsville, Ohio, and was formed to help solve difficult technical problems associated with UV curing of large, complex, 3-D parts. Working as a team of equipment and coatings suppliers, the consortium's goal is to advance UV curing technology so that technically robust and affordable solutions are available.

Mills says that he has been involved in UV powder coatings since 1986 was part of a small team that installed the world's first UV powder line in 1988: "But UV powder has been slow to take off. People have asked me: 'Why didn't it work out?' and 'what's wrong with UV powder?'. The answer is nothing that a good economy wouldn't fix."

He added that the North American Automotive UV Consortium is "assembling a team to re-energize some UV powder efforts that could dramatically affect automotive. Powder has been embraced in many finishing operations in the US and Europe with BMW and other using powder topcoats and many OEMs using powder primers."

Hardware and headlamps

If automakers can get the chemistry right the next hurdle they face is finding the appropriate hardware. At SURCAR 2005 Paul Mills gave a paper called 'Robotic UV Curing for Automotive Exterior Applications'. In it he referred to a Ford



IST Metz has installed a sophisticated ray tracing analytical tool to find out exactly how UV energy travels from their lamp

2003 concept car. The car had a UV cured clear coat developed by Akzo Nobel. However, Akzo is not in the OEM market and has not commercialized. Mills claims the paper was well received but Joesel maintains that there are mistakes in it.

The big issue is whether UV lamps can be arranged in a commercially viable way to cure car bodies on the line. There is a debate about whether it is possible to scale up lamps – the hardware – and use robots.

Joesel says that Fusion UV Inc.'s competitors do not have enough experience of the automotive sector. In particular he says that they have used UV curing on many non-automotive products. He doubts whether that experience can be successfully transferred to a car paint line.

That may be so but a German UV lamp manufacturer said that over the last 10 years component suppliers have adopted UV curing. In a paper called 'UV Applications in the Automotive Industry', Oliver Starzmann of German company IST Metz, says that UV curing has been used to cure finishes applied to headlamp lenses and many other products. The list includes: reflectors, protection strips, central consoles, instrument panels, cylinder-head gaskets, steering wheels, brake linings, clutch linings, wheel hubs and car windows.

According to the paper, UV technology has been successful because it has enabled manufacturers of headlamp lenses to protect their products. "For some years polycarbonate lenses have displaced the older glass lenses providing greater geometrical design flexibility and lower weight. Polycarbonate, however, must be varnished as it is not scratch resistant and has a tendency to yellowing. UV varnishing provides the properties required by the end-user (hardness, resistance to chemicals, light protection). "

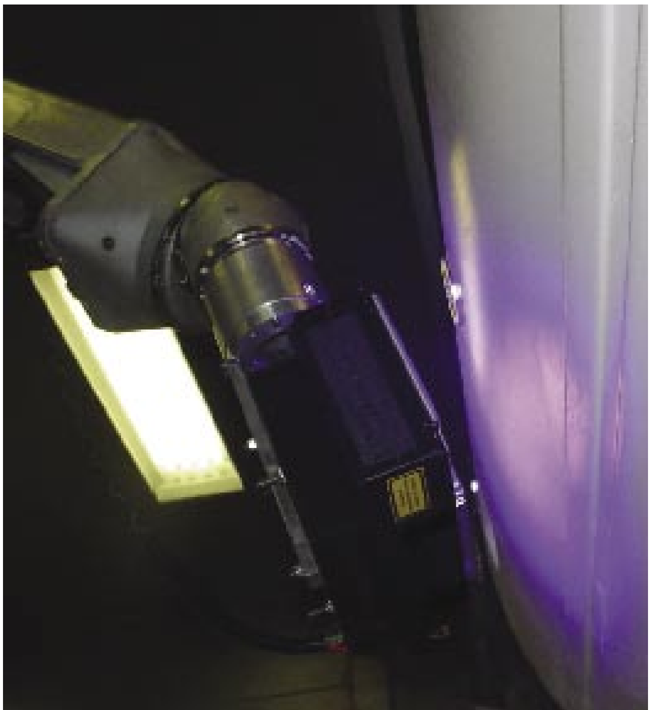
IST Metz is confident it has the knowledge required to make UV curing work in an auto plant. In the first issue of its 'Consortium Report' the North American Automotive UV Consortium explained how IST Metz has demonstrated its expertise. The report says that the company has "recently installed a sophisticated analytical tool for analyzing exactly how UV energy travels from their lamps. This allows the company to develop specialized reflectors and lamps which are engineered for optimum performance." It also allows IST Metz's customers and coating suppliers to see how the lamp will interact with the coating line and formulation.

Using a technique called ray tracing, which relies on mathematical modelling techniques, IST Metz's scientists are able to understand how the UV light will propagate in every direction. "This tool helps us to understand how to better design our equipment, and also how to cure properly with it," explains Dr Oliver Treichel, Head of the R&D Department at IST Metz. "We can understand how far a lamp needs to be, and how to overlap lamp patterns to obtain the most consistent results", says Treichel.

The consortium's report continued: "IST used this data to refine the design of a UV lamp designed specifically for curing automotive parts with robotic curing. The unit is lightweight enough for a robot with a minimum of connections for power and cooling air."

Safe substances

Another area of concern is the type of lamps that should be used in auto plants. Mills believes that automakers should be looking at UV LEDs "as they have no mercury, produce



UV LEDs developed by Phoseon Technology use electrodes or microwave energy to excite mercury atoms that emit UV light in the process [picture courtesy of P Mills/UV robotics]

no ozone", and "are very energy efficient". Mercury is a hazardous substance.

At the beginning of June this year the Pennsylvania Department of Environmental Protection said that in the environment "mercury is transformed into methylmercury, which accumulates through the food chain. Once mercury enters the environment, it can remain as an active toxin for more than 10,000 years."

Mills claims that UV LEDs are "an emerging UV technology". He cited the work of Phoseon Technology as an example of what is being done in this field. According to the North American Automotive UV Consortium's first report

UV LEDs developed by Phoseon Technology use electrodes or microwave energy to excite mercury atoms that emit UV light in the process [picture courtesy of P Mills/UV robotics]

the dominant technology used for industrial UV sources has relied on a quartz tube containing mercury. Electrodes, or microwave energy, excite the mercury atoms, which when energized emit UV light in the process.

"UV LEDs are a natural progression," insists Mark Owen, President of Phoseon Technology, an Oregon-based company which has been working in the semiconductor business for many years. He says that LEDS "last much longer than mercury lamps, have instant on and off ability, are very energy efficient and do not generate heat from the face of the lamp unit the way a mercury lamp does." The report explains that mercury lamps produce a very broad spectrum of UV ranging from 200 to 400 nanometers. However, "LEDs emit a very narrow, laser-like bandwidth, only a few nanometers wide."

Mills believes that such technology is more suitable for use in an auto plant than that produced by Fusion UV. He claims that the "sort of technology that Fusion makes could make it hard to put on a robot." He said the company uses a microwave generator, which he claims is heavy.

"Up until now", says Mills, "the approach has been to use a bigger hammer... more lamps, more energy." He says that that is "a brute force solution which tries to use tools built for a different purpose." The North American Automotive UV Consortium was formed to try to creatively solve those problems, according to Mills, and it aims to provide "not just a better technical solution but one that doesn't cost the GNP of a small country to install. The UV Robotic work is a perfect fit".

However, Joesel is concerned about UV LEDs and the approach that the consortium had adopted. He said that Phoseon Technology's lamps "are not commercially scalable because they don't have any history. They have no proof of concept. They are just trying to get interest."

Work to be done

UV curing technology is still developing and in the automotive sector the most likely winners will be those who can demonstrate an understanding of the chemistry, lamp and scalability issues. There is still a lot to be learned.

Joesel is confident that Fusion UV has the most appropriate approach because it has worked closely with formulators and automakers. He agrees that there are technical challenges: "The lamp-on-robot situation is that it is not a proven, robust process. We do it, and it has its issues."

DuPont has a pilot facility in Wuppertal, Germany that uses lamps that move in the vertical plane. Joesel explains that "this is to cure the horizontal surfaces and follows the vertical profile of the vehicle." Joesel describes that in this arrangement the lamps rotate "to illuminate the leading edge and trailing edge of the body panel. Though this is not a robot-on-a-lamp, it has lamps moving in two planes."

Joesel also believes that solutions can be found. For example, the line-of-sight issue. This is often quoted as a major obstacle to greater use of UV curing because it has been claimed that lamps cannot get into tight corners. He says that UV curing could be supplemented with thermal curing.

"Automotive part manufacturers have an advantage when utilizing UV," says Joesel, "they can find the means to envelope the part by the UV lamps. Also, there are means to move lamps into tough-to-reach areas by using automation to move the lamps in several planes or about several axes. In some cases, robotics has been used to manipulate lamps or manipulate the part in front of the lamps."

The debate about the most appropriate combination of chemistry and hardware is likely to continue. After 2010 Kraus thinks that inert gas thermal and inert gas UV could be in use. It will be interesting to see the solutions that the chemists and the lamp manufacturers adopt. ●