NEW DEVELOPMENTS IN SURFACE ENGINEERING IN BRITAIN

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"All the Britons paint themselves with woad, which gives their skin a bluish color and makes them look very dreadful in battle" - surely one of the earlier military uses of surface engineering, as recorded by Julius Caesar. Although Britons seldom use woad any more, Europe in general, and Britain in particular, has remained a center of surface engineering for both military and commercial applications. Today many of the surface engineering technologies used in the US are developed in Europe and supplied by European companies.

Tom Bell of the University of Birmingham coined the original definition of Surface Engineering as "the design and modification of the surface and substrate together … as a system, to give cost-effective performance enhancement of which neither is capable on its own." He expects that limitations to the further advance of manufacturing industry in the 21st Century are most likely to be surface related.

Surface engineering encompasses everything from salt bath nitriding and painting to advanced coatings and ion implantation. The British surface engineering market is expected to grow to about $35 billion by 2005, according to a study, "2005 Revisited: The UK Surface Engineering Industry to 2010", compiled by Alan Matthews and co-authors of the Research Centre In Surface Engineering of the University of Hull. Because surface engineering is seen as a critical technology there are Centers of Excellence in surface engineering in British universities, and government-funded organizations to develop the technology and transfer it to industry (see side bar).

Perhaps the best way to capture the breadth of British surface engineering is to consider two applications at very different scales. Stents are small tubes (typically an inch long by 1/8" diameter) used to keep open a path through blocked arteries. A stent formed from an intricate stainless steel mesh has been developed in Britain to deliver an anti-thrombosis drug to the exact point where it is needed. However, the body is an extremely difficult environment for almost any material. On such a small part the manufacturing process can change the metallurgy of the surface, making it more susceptible to corrosion in the blood, while microscopic burrs could break off, with fatal consequences.

Figure 1. Stainless steel stent (courtesy Anopol Ltd.)

To overcome these problems Stainless and Allied Services (Anopol Ltd.) of Birmingham electropolishes the stent inside and out, which removes the damaged surface layer and any burrs, leaving a smooth, damage-free surface. They then passivate the steel to create a thin oxide layer that provides corrosion protection.

Figure 2. Bridge on the Thames - a large-scale, complex coated system (Courtesty International Protective Coatings Ltd.)

At the opposite extreme is a new pontoon footbridge on the Thames, in London. The bridge is designed to be an elegant, open structure, affording a sense of freedom and unimpeded views of the area. In common with most bridges, the beams and hand rails are made of steel, which must be protected from corrosion with a 20-year coating. Unlike most bridges, however, the color is central to the design - a luminous lime-green, evoking a brightly-colored insect, its legs just touching the water.

International Protective Coatings of London solved the problem with a three-layer treatment whose elements vary with the diverse requirements of different parts of the structure. A zinc primer provides the basic corrosion protection. A high-build epoxy covers the main body of the structure, with a micaceous iron oxide epoxy for extra corrosion protection on the hand rails. The topcoat, which carries the unique color, is a gloss polyurethane, chosen for its minimal surface preparation requirements and easy maintenance. At the waterline, an environmentally friendly coating filled with abrasion-resistant glass flake protects the pontoons from corrosion and particle erosion.

The engineered surface of the bridge is only a little thinner than the entire diameter of the stent, yet both are examples of surface engineering. Both need a smooth surface finish, and both provide protection against corrosion in a difficult aqueous environment. However, one size does not fit all - the surface treatment had to be chosen to provide the right properties for each environment and application. Recent surface engineering developments in Britain illustrate how this applies in various industries.

Plasmas are central to a great many treating and coating processes, especially in the semiconductor industry. As Alan Matthews has observed, technologies developed for electronic and optical thin films are often transferred into the engineering coatings sector, leading to wider use of ion and plasma-based techniques.

A novel non-equilibrium plasma treatment method with unusual characteristics is being developed by EA Technology Ltd of Capenhurst, near Chester. The process acts like a low pressure non-thermal glow discharge, and appears to provide many of the conditions needed for plasma surface engineering, yet it runs at atmospheric pressure. Atmospheric deposition is generally much simpler than traditional vacuum plasma deposition, while its higher reactant concentrations makes it much faster, and therefore more cost-effective.

The equipment needed for this new approach is little more than a modified commercial microwave oven, in which the plasma is sustained within a flask using microwave energy. Processing can be done either within the plasma or in a downstream gas flowed through the flask. In-plasma treatment is more energetic, and those materials which can withstand high temperatures can be coated within the flask. Downstream processing is “softer” and especially effective in coating polymers, such as polymethyl methacrylate and epoxies, with materials such as titanium dioxide for improved weather resistance. The plasma can even be used to break down noxious gases, such as volatile organics, with more than 97%efficiency.

Figure 4. CD mold coated with very smooth, high-quality PVD coating (Courtesy Tecvac Ltd.)

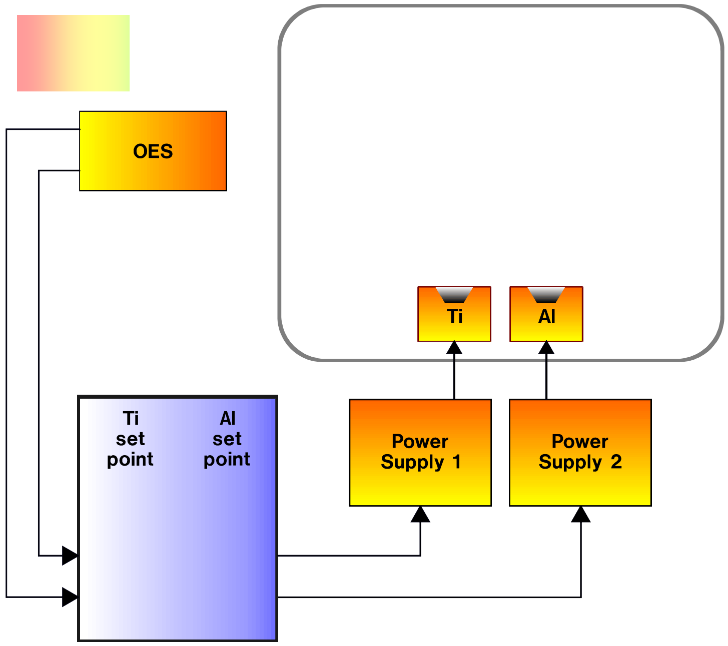

Figure 3. Alloy deposition control system (Courtesy Tecvac Ltd.)

Vacuum plasma processing is at the heart of the advanced Physical Vapor Deposition (PVD) coatings used on tools such as molds, dies, drills, and cutters. Although the most widely used of these coatings is TiN, many demanding applications now use TiAlN. The highest quality PVD coatings are produced by electron beam evaporation of the metal in the presence of a nitrogen-rich plasma that bombards the substrates. Electron beams, however, cannot be used to evaporate alloys such as TiAl, since the vapor pressure of Al is a hundred times higher than Ti.

To overcome this problem Tecvac Ltd. of Cambridge has used LINK funding (see sidebar) to develop a new control technology for its e-beam deposition systems that is based on measurement of the optical emissions from elements in the plasma. The system picks up characteristic Ti and Al emission lines and uses them to control individual e-beam sources for the elements of the alloy. The result is complete control of the composition of the alloy coating, even to the extent of grading the coating through its thickness, which is not possible with alloy arc and sputter sources. “This takes us from the situation where we could not produce alloy coatings to the point where we have more control than anyone else”, says Brian Garside, Tecvac’s Managing Director.

An entirely different approach to tool coatings has been taken by Teer Coatings of Hartlebury, near Kidderminster. Rather than taking the "harder is better" approach, Teer is taking the path of least resistance with its MoST PVD technology, which is based on MoS_2 coatings. Unlike MoS_2 sprays and powders, which provide good lubricity but easily come off, Teer's MoST coatings are deposited by unbalanced magnetron sputtering, and are so well adhered that they can even be used for high stress applications such as coining dies.

Figure 5. MoST-coated coining die (Courtesy Teer Coatings)

MoST-coated dies used to stamp commemorative coins have lasted 8 times longer than uncoated dies, and 2 ½ times longer than standard chrome plated dies. Similar results have been obtained with perforating punches. In a similar vein, Teer has used LINK funding to develop a lubricious carbon coating, Graphit-iC, which is being used in the textile, food, medical, and oil industries.

Mass-market coatings, on the other hand, require high speed, low cost surface engineering. Take the lowly glass bottle, for example. Because glass bottles break easily due to microcracks in the glass surface, they must be made thicker and heavier than is strictly necessary. The British Technology Group (BTG) of London is marketing a coating developed by the University of Sheffield that almost doubles the burst strength of glass bottles by "healing" surface flaws.

The coating is an aqueous emulsion of a polymerizable silane coupling agent and an epoxy resin that is environmentally sound since it avoids the use of volatile organics. When the bottle is dipped or sprayed, it forms a 3-10 micron coating. A rapid UV curing cycle keys the silane into the surface of the glass and essentially welds the microcracks closed, while the epoxy protects the glass from further damage. BTG believes that the coating will make it possible to use thinner bottles, to reclaim some of the packaging market lost to plastic, metal and paper.

Surface engineering is not, however, limited to passive protective or property-enhancing coatings. One example is electron emitting coatings for large flat panel displays. Although there is a great deal of work under way on electron emitting diamond films, large area displays based on this approach are not easy to make.

Printable Field Emitters, a start-up company in Hartlepool, is using a SMART award (see sidebar) and private investment to develop an electron emitting composite film that can be printed rather than grown in vacuum, as diamond has to be. Printing will allow the complex patterns of dots required for a 3-color display to be laid down inexpensively over very wide areas. Although TVs and computer monitors are the holy grail for flat panel technology, large displays used for advertising and sports stadia are likely to be its first target market.

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SIDEBAR

Surface Engineering R&D in Britain

The perennial shortage of R&D funds has stimulated innovative ways of targeting government funding, leveraging it with commercial money, and linking government labs, universities, and corporations to develop and rapidly commercialize surface engineering technologies.

The LINK program, run by the National Physical Laboratory, funds commercial exploitation, and currently has projects on such diverse technologies as multilayer PVD coatings (Sheffield Hallam), decorative glazes (CERAM Research), fire retardant textiles (Textile Research Council), electron beam PVD coatings (Tecavc, Ltd), smart overlay coatings (Diffusion Alloys, Ltd), chromate-free passivation (Metal Finishing Association), diamond-like carbon coatings (Teer Coatings), non-wetting coatings for inkjet printing (Xaar Ltd), and optimization of biomaterial surfaces for bone repair (M4 Technologies, Ltd). Each program is carried out by a partnership of companies, trade organizations and universities, with most projects headed by companies.

The UK Department of Trade and Industry also runs a SMART award competition (Small Firms Award for Research & Technology) to support non military innovation in Small & Medium Enterprises (SME's). Stage 1 SMART awards typically fund 75% of a project, with the balance from the company itself. Stage 2 awards cover up to 30% of costs, to a maximum of about $150,000.

Several organizations move surface engineering technology into industry. AEA Technology plc and its National Center for Tribology (NCT) are heavily involved with friction and wear surfaces, plasma and ion processing, and quality assurance and control issues. The National Surface Engineering Center, NASURF, helps industries to identify and adopt surface engineering technologies.

Two universities have centers for surface engineering that work closely with industry - the University of Hull (whose Research Centre in Surface Engineering is headed by Alan Matthews), and Sheffield-Hallam University (whose work is headed by Dieter Munz). With the support of NASURF these universities have joined with Loughborough and the University of Nottingham Department of Materials Engineering and Materials Design to offer an MSc degree in Surface Design and Engineering, which is intended to teach surface engineering technology to practicing industrial engineers.