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Surface Finishing in the 2000s
As Predicted in 1992

Technical Editor's Note: In the December 1992 issue of *Plating and Surface Finishing* [*P&SF*, **79** (12), 20-23 (1992)], an interesting set of articles was published, predicting the future of the global surface finishing industry in the 21st century, then due to arrive in less than a decade. The series dealt with the view from overseas - in particular, the view from Europe and Asia. The authors, both recipients of the AESF Scientific Achievement Award, Drs. David Gabe, of Loughborough University of Technology in the U.K., and Dr. Tadao Hayashi, of the University of Osaka in Japan, presented their views at SUR/FIN 1992 in Atlanta, Georgia.

In 1992, cell phones were few and far between, personal computers were in their infancy, and the Internet was a curiosity. Social media was non-existent, and at the end of the Cold War, the geopolitical situation was far different than what is seen today. Concerns about "REACH" and "PFAS" still lay in wait. The importance of rare earths to commerce in electronics was on the far horizon. In exploring these articles today, the reader will find that some of it was spot on, while much of it ... not so much. The world of 2019 is much different than the world of 1992, and no one could have predicted the events that have followed which have in turn brought the surface finishing industry to where it is today - but the common thread of environmental concerns exists in both eras.

A European View

by
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In this second half of the Twentieth Century, the world has seen two major political changes in Europe which dominated nearly all events: The rise and fall of Communism in the East, and the creation of the European (Economic) Community (EC) in the West. Entry into the next century has to be previewed within this political framework, from which environmental and resource considerations emerge - each having a strong political base.

Modern surface coating technology is substantially a European invention. Through the years, technology has shown much international transfer, and it is not likely that Europe will differ much from the rest of the world, where the transition from electroplating and metal finishing to surface technology, or surface engineering, will be rapid. Industrial leadership by the U.S. dates from Detroit's domination of the mass-produced automobile in the early 1900s, and now appears to be shifting to Japan, via the electronics revolution.

The surface finishing industry of the future will be dominated by a number of considerations - notably of the environment and resource availability - yet will have to continue to function within several major frameworks.

Political framework

At the end of World War II in 1945, Europe split into two extreme political camps. The East - dominated by the USSR - was obliged to adapt to totalitarian Communism, under which leadership decided all matters of policy, and no "public opinion" was possible. Because the first priority was defense and a domestic consumer policy was non-existent, technological development was extremely unbalanced: It was easier to be launched into space than it was to travel across the Soviet Union in one's own car!

Western Europe returned to the capitalist, or "free enterprise" economy, through Marshall Aid and the Schumann Plan for steel and coal; and through a well-directed industrial effort, had become economically independent by the mid-1950s.

The two halves of Europe were organized effectively only in defense matters, through NATO and the Warsaw Pact, until 1957, when the EC was formed by six countries (Belgium, France, Germany, Italy, Luxembourg and the Netherlands), under the Treaty of Rome. These six were joined in 1973 by Denmark, the United Kingdom (UK) and Ireland; and in 1988, by Greece, Portugal and Spain.

The Treaty of Rome addressed trade, economic barriers, social growth, investment and agriculture, and was always seen as a "first stage" in closer development. The second stage commenced with the 1992 Single European Market Act. Only then was the environment specifically mentioned, in terms of needing preservation, improvement and protection. Until now, pollution control largely has been a matter of national interpretation, in respect to social amenities and resource maintenance. Since the 1991 Maastricht Agreement, majority decisions can prevail and directives on environmental policy have been accepted. Eco-Auditing, Energy Accounting and Environmental Crime are now all official areas of policy.

Environmental framework

The environmental framework has a longer history than it may appear, though in the past it has focused on more obvious toxic agents, capable of giving rise to acute, rather than chronic poisoning. The distinction between process and product is worth making: A metal in its processing form (*i.e.*, dissolved ionic state) can be much more dangerous than as a final product (*i.e.*, solid metal).

- Chromate ions are toxic; chromium metal is safe.
- Cadmium ions are toxic; cadmium metal is safe.

Lead may be unsuitable for water pipes, but as pewter, makes good beer tankards. Mercury was recognized as a hazard for fish long before its demise as a dental amalgam.

But even if agreement can be achieved in principle, determinations may still prove elusive. Cadmium is undoubtedly poisonous, but at what level? Molybdenum is touted as an alternative to chromium, but is it really non-toxic - and at what level? The absence of definitive data is, in fact, alarming. Will it take a few more well-documented deaths to reach the necessary conclusions?

Today's approach seems to be to establish levels of contamination that can reasonably be attained using best current practice and seems reasonable for now. The absence of financial incentives to invest in pollution control is surprising, because it could be more effective as a means of encouragement than punitive legislation would. Once it is established that toxic effluents can be treated quickly, successfully and safely, a two-fold advantage can be pointed out: First, that the toxic species can continue to be used by industry; and second, that its presence and ecological effects in effluents can be neutralized. A classic example is cyanide - a well-known poison and probably the most versatile, inexpensive chemical complexant. While not quite irreplaceable as an electroplating complexant for gold, silver, copper, cadmium and zinc, cyanide offers considerable advantages and remains in use, because its effluent treatment is familiar, well-understood and can be carried out effectively.

When the public applies well-directed pressure on industry to clean up or protect the environment, there are results. And public reaction to the vulnerability of the ozone layer has been very effective in promoting a research-and-development program to find alternatives for CFCs. And chemical companies have yielded to public pressure, finding alternatives, so the EC can target offending compounds:

- CFCs (chloro-fluoro-carbons used in aerosols, refrigerants and solvent cleaners) are to be phased out by 1997, with a cut of 50% by 1993 and 85% by 1996.
- Halons are to be phased out by 2000.
- Carbon tetrachloride is to be phased out by 1998, with a 50% cut from 1992 and 85% cut from 1995.
- 1,1,1-trichloroethane solvent cleaner use will be frozen from 1992, reduced by 30% by 1995 and 70% by 2000, and eliminated by 2005.
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Plus, acid rain, vehicle emissions, rivers, beaches, etc., are all now part of the international pollution control effort going on in Western Europe.

In Eastern Europe, though, the story is markedly different, and necessarily affects the West, because pollution recognizes no national frontiers, nor does it have to pass through customs to cross borders. Incredibly, the nuclear contamination from the Chernobyl accident is still preventing hill farmers in my native Wales from marketing lamb as a meat, with only the wool relatively unaffected.

Resource framework

It has been obvious for some time that world resources are diminishing. But new ones are continually being discovered and shrinking ones are being used more conservatively and economically (*e.g.*, chromium in Turkey). It is also true that some resource shortages are either self-inflicted or political in origin (such as cobalt from Angola, palladium from Russia, tungsten from China), or caused by labor relations (the 10-month nickel strike in Canada during the 1970s). Some metals were earmarked as having only a 10-or 20-year future availability. Yet their presence has remained remarkably constant, as new ore bodies have been located, and the 1970 U.S. prediction that the world would run out of gold by 1995 is in no danger of coming true.

Future resource difficulties are likely to involve energy and water supplies, and oil - the basis for petrochemical products, such as plastics - could become the most acute problem by 2030. But the opportunities for alternative, renewable energy sources are sufficient to eliminate energy, itself, as a shortage problem: Solar, tidal, wave, wind, and nuclear energy-generating methods can be employed to hold off any energy crisis for the foreseeable future.

Ultimately, the most serious problem we will face will be the shortage of water - or more accurately, the shortage of pure water. As The Ancient Mariner* put it: "Water, water, everywhere ... nor any drop to drink."
In addition to domestic use and drinking, pure water is needed for many process industries and typically has been discharged, contaminated, back to the rivers. In Europe, the largest rivers are highly polluted (the Rhine and the not-so-"Blue" Danube), though some important ones are now safe water courses (the Thames). But continual extravagant use of water has meant that lakes are drying up or becoming more saline (Caspian Sea, Dead Sea), and rivers are being diverted to counteract this loss. In the UK, a series of dry winters, perhaps coupled with the "greenhouse effect," has meant serious water shortages in the London area. These shortages have prompted water transfer from the North and Scotland, via long-out-of-use canal systems.

There is no lack of technology for cleaning up process waters - from traditional precipitation with alkalis, to high-tech methods involving ion exchange, reverse osmosis, dialysis, etc. But the economics are only visibly attractive for valuable metals, like gold or silver. They become more attractive, though, if a full economic appraisal is made of all resources, including water, and may actually be the only way to stay in business.

Improving one's use of resources is not often driven by deep national or political motivations, but by circumstance. When nickel was in short supply in the 1970s, manganese was substituted in alloy steels. The price of tin rose to an all-time high in 1964, and chromium was introduced as an alternative coating for tinplate, with subsequent lacquer coating. This stop-gap solution became an opportunity for the aluminum industry, which has been able to make large, permanent inroads into what had been traditionally a steel market.

Technological framework

This framework recognizes at least three separate strands of development:

- Natural, historical development of industrial technology
- Response to external pressures (political, environmental)
- Changes in philosophy and organization

Electroplating is one important technique within the scope of surface coating technologies. Its primary aim is to enhance the surface of a solid, providing superficial, rather than bulk characteristics. Electroplating's main purposes include:

- Decorative or aesthetic appearance
- Protection against corrosion

* From *The Rhyme of the Ancient Mariner*, by Samuel Taylor Coleridge.

- Protection against wear
- Electroforming of whole products
- Manufacture of electronic components
- Repair and reclaim worn parts

In practice, however, many of the coating processes are chosen for what is feasible, as well as for what is economical. One criterion would be the coating thickness required. Consequently, coating processes are complementary and not competitive, and inevitably encompass widely differing disciplines:

- Electroplating and metal spraying
- Hot dipping; physical vapor deposition
- Electroless and conversion coating

For this reason, the concept of the dedicated electroplater is fading; that of the metal finisher has passed its "sell-by" date, and the surface technologist is becoming the norm. The future of coating technology will probably be one as a portfolio of processes and not electroplating as the technique of choice against all comers. In the past, the industry has been remarkably conservative in the face of new process technology, but change is coming - primarily driven by aerospace and military demands.

As a rule, it takes about a generation for a new process to find its rightful niche in the manufacturing world: Electroless nickel was invented in 1945 and became a major process by 1960. It is probable that PVD and CVD processes are being oversold by proponents right now, but by 2010, will attain their own identities as processes-of-value.

But what of coating materials themselves? It has been said that the latter half of this century has been the era of polymers, while the next 50 years will be one of advanced ceramics. If so, the important processes will include:

- Composite electrodeposition
- Electroless deposition
- Chemical vapor deposition
- Physical vapor deposition/ion plating

Much has been written about the virtues of ion implantation for modifying surface layers, but cost will probably preclude its use in mass finishing operations.

External pressures have long been recognized as important influences on development - though not always for the good. Political pressures, in particular, are more attuned to public posturing and do not always make valuable contributions. So, avoiding certain countries' export commodities for moral or philosophical reasons (palladium from the former USSR, chromium or vanadium from South Africa, oil from Iraq, or nickel from Cuba) often has a negative impact, such as promoting black-market trading.

Environmental pressures, though, have a wide base of public acceptance, and in Europe have had substantial effects on nuclear policy, use of toxic metals, pollution control and materials recycling. And while avoiding certain metals or reagents necessarily imposes some limitations on the industry, the general effects are an improved and widened processing capability and a protected environment. In the case of CFCs, replacement with alternatives has proven to be surprisingly easy and the EC has been able to provide a clear directive to phase out these ozone-destroying compounds by 2000.

About Dr. Gabe (1992)

Dr. David R. Gabe is Director of the Institute of Polymer Technology and Materials Engineering (IPTME) at Loughborough University of Technology (UK), where he leads a substantial research program in metal finishing. He graduated from the University of Wales in Cardiff and received his Ph.D. from the University of Sheffield.

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In Asia: The Year 2000 and Beyond

by
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(Prepared from Dr. Hayashi's presentation at SUR/FIN 1992 - Atlanta)

In summing up expectations for surface finishing in the Asia-Pacific hemisphere, Dr. Tadao Hayashi says that the growth rate of electroplated products, such as consumer electronic equipment and automotive parts, has been increasing over the past 10 to 20 years. However, the technology of each country has been different, depending on the economic conditions, so emphasis has shifted from consumer products toward more industrial products. Korea and Hong Kong are moving "off-shore" with low-end products and stepping up marketing efforts in the U.S. and European Economic Community (EC), as Japan has done.

Hayashi projected that industry problems and concerns throughout the world will be environmental ones - especially effluent treatment. He noted that, as far as technology is concerned, each country has a different level of activity. However, safety and environmental projects have the same goal, everywhere, to establish and meet proper regulations for hazardous-waste-producing processes.

Future trends in surface finishing technology may be forecast from the current activities of research and development in surface technology in Asian countries. Statistics of the electroplating technology in Japan were compiled from a survey of the titles of technical papers published in the *Journal of the Surface Finishing Society for Japan*. The number of papers in their subject categories "draw" the picture of where interests lie. Comparison of the total number of contributions in their subject study clearly shows that papers dealing with electronic applications were predominant during the period of 1986-91.

Papers dealing with plating such precious metals as gold, silver, palladium, platinum and others, are concerned with electronics applications. Plating that relates to the automotive industry is down because of the worldwide recession.

Hayashi turned to the new trends in plating, especially in Japan. The first was non-cyanide silver plating baths. Silver deposits obtained from the non-cyanide baths have similar properties to those of deposits obtained from conventional cyanide baths, and the non-cyanide plating baths seem to be very stable and long-lasting. One such new silver plating process has been applied for printed wiring boards (PWBs). Also, silver plating on steel and stainless steel wires has been used successfully for the production of contact pins.

The second trend Hayashi mentioned is low-concentration baths. In order to reduce industrial wastes, and to conserve the materials used in electroplating, low-concentration plating baths have been proposed and tried, such as: low-concentration chromium baths, low-cyanide zinc plating baths, and low-chromate treatment baths.

Hayashi introduced computer-assisted alarm and control systems, currently in use in his region for effluent treatment. Computer-assisted alarm and control systems were installed in electroplating job shops in Osaka last year, and the system is now under operation. The total control system's main computer is set at the head office of the electroplating industry association and a small personal computer is provided at each plating job shop.

Alarm and control signals are telecommunicated through commercial telephone lines. Checkpoints on-site are properly set by using the conventional sensors relating to the checkpoints, which are generally the pH of the plating bath, upper limit of the cyanide waste treatment and hexavalent chromium waste treatment, the acid-alkali waste treatment tank, and the lower and upper limits of the chemical storage tank.

If an alarm sounds at any factory, the signal is telecommunicated to the "mother" computer and the appropriate instruction is forwarded to the person in charge at that location. At this time, 14 companies have joined this system and more experiments are now underway. Mishandlings or accidents in the effluent treatment operation in each company are always found and fixed by this alarm system. In order to establish sound and safe effluent treatment, these types of alarms and control systems seem to be essential in electroplating factories. Furthermore, by applying this system in the electroplating industry, it is expected that the shortage of skilled engineers, able to deal with important control problems, can be overcome.

In Hayashi's opinion, it is inevitable for certain future applications that there will be many combinations of alloys - electroplated and electroless-plated.

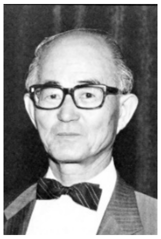
He went on to tell about the recent study on electroless palladium, used for plated-wire board production, wherein an electroless palladium plating system was developed for a new application in the electroless industry. One of the unique applications of this method of electroless palladium plating is a heat-resistant pre-flux used for the printed wire board production. He predicted that products created with this technology will have a good solubility, low contact resistance and also better corrosion resistance.

Finally, Hayashi touched on the prospects of the printed wiring board industry in Asia, saying it is not easy to forecast trends of the electroplating industry in the year 2000 and beyond. He did say, however, that production of the printed wiring board seems to be one of the major elements, in analyzing the future trends, in surface finishing technology. Printed wiring boards will be produced and used in many electronic devices, with ever-higher performance demanded of these products. Such results are achieved only by advances in integrated technologies, which support printed wiring board production. In Japan, this technology is becoming more and more advanced, and he feels the country will be able to maintain a leading position in PWB technology.

The consumption of single-sided printed wiring boards will see further decline in Japan, but the improvement of the living standards of the world will mean that the consumption of PWBs will increase in the year 2000 and beyond. The production of multi-layer PWBs in the past two to three years concentrated on six to eight layers in Japan. However, the packaging density of these multi-layer PWBs is changing rapidly from 12 layers to 18, 24 and sometimes 30 - even more than 30 layers, in some cases.

Hayashi concluded that it is difficult to forecast trends of electroplating and related fields toward the year 2000. It seems, he says, that focus in the electroplating industry will be on environmental programs and new technological developments. He sees Japan as likely to remain in the leading position, at least among Asia-Pacific countries, in promoting new electroplating technology and assessment of environmental programs.

About Dr. Hayashi (1992)



Dr. Tadao Hayashi is professor emeritus of electrochemistry at the Department of Applied Chemistry, University of Osaka Prefecture. He has published more than 130 papers in electroplating and related fields. He received a B.S. in chemistry from the Tokyo University of Literature and Science and a doctorate in electrochemistry from the Tokyo Institute of Technology. Hayashi was AESF's Scientific Achievement Award winner in 1990 and gave the William Blum Lecture at SUR/FIN 1991 in Toronto, Ontario.