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TRENDS IN COATINGS TECHNOLOGY

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INTRODUCTION: EXPECTATIONS FOR COATINGS

Human intelligence has created a variety of chemical substances which have greatly contributed to the well-being of the human race. Today's coatings consist of many of these chemical substances in combination. There are probably no less than several thousand kinds of raw materials for coatings with natural and synthetic materials combined. While the accelerated technological progress in the past greatly improved the human living standard, it has now come to adversely affect the environment. Many problems have been recognized, such as air and water pollution by chemical substances, serious effects on forest and lakes by acid rain, destruction of the ozone layer by chlorofluorocarbons, global warming caused by carbon dioxide in the atmosphere, etc. In order to cope with these problems, world leaders came together at the UN Conference on Environment and Development in Rio de Janeiro. The year 1995 has become a historically significant year for human beings worldwide.

Coatings have been used from olden times in every aspect of people's lives. The fundamental function of coatings lies in protection and decoration. Coatings protect substances and help to make them last longer, thus contributing to the conservation of natural resources. Decorating the substances has brought about a bright and cheerful living environment. Coatings themselves have, on the other hand, a characteristic which causes environmental pollution. For coatings chemists, development technology which could reduce environmental pollution is a major subject.

Coatings are used in numerous fields in society. They have been expanding their scale along with social development and, more especially, with industrial development. Technological developments have been made to satisfy various social requirements in each period of time. Coatings technologies have been developed in Japan as described in the following brief history.

The 1970s were considered to be the mass production age. Various new synthetic resin coatings were developed. They contributed to the achievement of higher speed and the improvement of productivity of painting lines. Coil coatings for superspeed lines and high-performance automatic painting systems (ED coatings) represent this technology.

In the 1980s, environmental problems considered as a bad effect of rapid economic growth were highlighted, and air pollution caused by organic solvents in coatings became an issue. In addition, the oil embargo triggered the petroleum conservation campaign and in turn accelerated development of resource-saving coatings such as waterborne, powder, and high-solid types. Energy conservation and transfer efficiency improvement were also taken up as research topics.

On the other hand, quality improvement in coating film decoration and protection, which are their basic functions, is an everlasting research theme. In addition to rust prevention on metals, corrosion control on concrete structures became an important subject. Aesthetic factors such as smoothness, glossiness, and elaborateness have been pursued. Research and development for coatings with additional functions other than decoration and protection has recently become more active, and contributions to coatings market expansion are hoped for. Current requirements for coatings can be sorted out into the following items.

1. Environmental protection and energy conservation
2. Higher quality of coatings film; better appearance and design
3. New technology coatings with additional functions

PREVENTION OF AIR POLLUTION

Although disposal of organic solvents evaporated in the painting process is, in some cases, accomplished with incinerator or absorption equipment, it is impossible to dispose of this material in the case of a low-density solvent vapor. It is, therefore, rational to use a coating containing less solvent. Vigorous efforts to develop a "less-solvent coating" are currently underway at paint manufacturers all over the world. The various methods to reduce the level of organic solvents can be categorized as high-solid, waterborne, and powder coating technologies.

For high-solid coatings, two-pack polyurethane and epoxy display good film performance, and are comparatively easily formulated as high-solid. But their two-pack form is a disadvantage for workability. UV-cure and electron-beam-cure coatings with unsaturated monomers in place of solvents are in limited use due to the limited configurations of substances. High-solid coatings that are one-pack and that also can be applied in existing application facilities are required.

Waterborne coatings account for 18% of the total coatings production in Japan. Waterborne coatings consist mostly of emulsion coatings for architectural use and ED coatings for industrial use. Ordinary bake-type coatings are being developed to find their way into automotive (metallics) and sanitary can markets. In waterborne coatings, how to handle the water which functions as a solvent is an important issue. With the Japanese climate in mind, it is necessary for coatings to achieve good appearance under conditions of high humidity in the summer and also of low humidity in the winter.

Although powder coatings contain no solvents at all, they have disadvantages such as thick film build, high cure temperature, complicated coatings manufacturing process, etc. The use of powder coatings has been growing year by year and it will probably increase even more in the future, if less-disadvantageous powder coatings are developed.

Baking temperature in industrial coatings application is generally in the range of 120°–180°C. Energy reduction in baking operations indirectly works as an environmental countermeasure and lowers application costs. The majority of current bake-type coatings use methylol–melamine resin as a crosslinker. It is possible to lower the baking temperature by adding an acid catalyst but this would adversely affect film performance and storage stability. Polyisocyanate crosslinks at low temperature, but coatings which contain it should be two-packs, which is not suitable for industrial application. It is necessary to develop new crosslinkers which react at low temperature or to develop self-crosslinking polymers. Several types of crosslinkers have already been introduced and are about to be put into practical use.

When it comes to solvent-reduced coatings, it is not only the concept of a low organic solvent level which is required. Their appearance and durability should be as good as the current products. They should be advantageous in cost. For this reason, it is very important to develop new polymers and new crosslinking systems.

PREVENTION OF WATER POLLUTION

Pollution of inland waters by coatings has been remarkably reduced. Wastewater from waterborne coatings from painting facilities and from general water-washing painting booths is treated by appropriate water treatment facilities. In the case of ED coatings, water disposal itself has been greatly decreased by proliferated adoption of the ultrafiltration process, which is a closed system. On the other hand, seawater pollution by antifouling coatings has become an issue.

Organic tin compounds have long been used in antifouling marine coatings. They are now blamed as the most poisonous source of pollution of inshore seawater.

Existing antifouling coatings contribute to the conservation of energy in navigation and the maintenance of heat exchange efficiency at electric power stations. This can be brought about by keeping the surfaces which are immersed in water relatively free of the accumulation caused largely by biotics in the environment. The biocides incorporated in the coatings, being poisonous to the fouling organisms, repel or kill their larvae before they can attach permanently and grow on substratum. Since the sea pollution problem with these hazardous biocides, particularly with organic tin compounds, is now the source of increasing concern, the use of the coatings is restricted in many countries.

This situation necessitates the development of a new, environmentally friendly antifouling system. For this purpose, basic research on marine growths and their affinity with paint film is important. The development of antifouling coatings which do not contain any biocide nor any heavy metal is in progress on the basis of the research on the interface between coatings film and marine growths.

Kansai Paint has developed new technology for foul-release coatings (BIOX).

HIGHER PERFORMANCE OF COATINGS

Since protection and decoration are the basic functions of coatings, these have always been required in the past. Customers who use painted products want the coating films to retain their beauty longer and want them to keep the substances rust-free. Longer protection of numerous substances extends their useful years, thus resulting in natural resource conservation and energy saving.

For heavy protection of ships and structures, inorganic zinc-rich coatings and epoxy coatings have been widely used. On the long bridges linking Honshu (the Japanese main island) and Shikoku Islands, such protective coatings and high-durability coatings are used. It is hoped that research and development on binder resins, crosslinkers, and also pigments will make further durability improvement of coating films possible.

From the protection and the durability viewpoint, in addition to the silicone and silicone-modified polymer types hitherto known as a high-durability coating, a coating based on fluoropolymer has recently been commercialized. Kansai Paint has succeeded in the development of two unique technologies utilizing silicone- and fluorine-modified polymers. One is a new crosslinking system with silicone-modified polymer (ESCA). The other is a nonaqueous polymer dispersion with fluoropolymer as the dispersant (F-NAD).

"ESCA" is the acronym for epoxy, silanol, curing, and acrylic. That is, ESCA resins have epoxy and silanol groups besides hydroxyl groups in their acrylic polymer structure, and they are cured with metal chelate compounds. Two new vinyl monomers have been developed to apply this system to ambient curing coatings. They are polysiloxane vinyl monomers with silanol groups and alicyclic epoxy functional vinyl monomers.

All crosslinking reactions are initiated by complex compounds which are formed from silanol groups and metal chelates. One reason for the low-temperature curability of ESCA system is that many crosslinking reactions competitively take place among silanol, epoxy and hydroxyl groups in the polymers. The new curing system ESCA shows some remarkable characteristics:

1. Low (ambient) temperature and short time cure
2. Good one-package stability
3. Less humidity influence in ambient curing
4. Excellent film properties: chemical, weathering, and stain resistance
5. High solids
6. Low toxicity

Nowadays, new automotive clear coatings, architectural paints, and some general industry coatings based on ESCA technology are being put into practical use, and their most important sales point is the superdurability. The reason for the high durability and the stain resistance of ESCA coatings is considered to be the resistance of their crosslinking bonds to water, chemicals, and ultraviolet. Three factors dominate the durability, and they are the structure of the resin, the curing method, and the crosslinking density.

The second new technology, F-NAD, uses fine dispersions of acrylic polymer in a fluoropolymer matrix prepared by means of dispersion polymerization. The dispersant is the copolymer of fluoroethylene and vinyl ethers (or vinyl esters), which has some hydroxy functionality and is soluble in various organic solvents.

F-NAD is distinguished by a narrow particle size distribution as well as outstanding stability. Surface coatings formulated with the present dispersion retain the excellent weather and chemical resistance of the fluoropolymer. Furthermore, high-solids dispersions which form low-VOC (300–400 g/L) surface coatings can be prepared with the same features.

F-NAD is curable over a wide range of temperature with crosslinkers (melamine–formaldehyde resins; polyisocyanates). Surface coatings formulated with F-NAD show superior features:

1. Short time cure
2. Satisfactory workability as coatings
3. Excellent film properties: chemical, weathering, and stain resistance
4. High solids

F-NAD coatings are already in general use for automotive coatings, architectural paints, and some general industry coatings as higher-performance coatings.

CLOSING: ROLE OF COATINGS TECHNOLOGY

The basic functions of coatings—which are protection and decoration—will continue to be utilized in many aspects of human life, and the value of coatings will not be diminished in the future. We have accumulated the knowledge and experience gained in establishing our current coatings technologies, by our development efforts in the past years. In order to cope with this difficult subject, we must make the utmost efforts to develop new coatings technologies by working on polymers, pigments, and various kinds of materials, and also to improve and to develop application methods and relating facilities. Coatings will hereafter be further improved in performance and will be provided with a new, third function. And then they will expand to new frontiers such as the ocean and outer space.

Coatings, which have been developed by the intelligence of human beings, need to advance along with the human race. Coatings technology, in this respect, must play an important role.