STRUCTURALLY COLORED COATINGS COMPOSED OF COLLOIDAL ARRAYS PREPARED BY ELECTROPHORETIC DEPOSITION

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Color has psychological and aesthetic importance in our daily life. Organic dyes and inorganic pigments have been used for a wide range of applications such as inks, glasses, ceramics, plastics and others. Inorganic pigments, which are superior in terms of high stabilities and resistance to climate conditions, have advantages over organic dyes because prolonged exposure to light causes color fading of organic dyes. However, there is growing concern that the toxic elements, e.g., Cr, Cd, and Pb, contained in inorganic pigments critically affect human health as well as the environment. Therefore, the development of alternative materials that are applicable as safe and environmentally-benign colorants is strongly desired. Structurally colored materials are expected as alternatives to conventional colorants that can be fade-resistant and free of hazardous materials. Structural color results from interactions between nanoscale structures and light, such as scattering, reflection, diffraction, and interference. Arrays of spherical particles with uniform sizes are typical materials that can exhibit structural color. Colloidal arrays can be categorized into two types. The first is a colloidal crystal, which has long-range order in the array of the particles. The colloidal crystal exhibits glittering colors with strong iridescence, as seen in opals, so they are suitable for ornamental jewelry and the decoration of accessories. The other type of colloidal array is a colloidal amorphous array, which only has short-range order in the particle assembly. Therefore, nanoscale design is a critical strategy to control structurally colored materials. The electrophoretic deposition (EPD) method is one of the most versatile methods with great potential for a rapid, low-energy consumption, and cost-efficient coating technology to prepare various types of colloidal arrays. In this lecture, our recent progress on structurally colored coatings consisting of colloidal arrays prepared by the EPD method is introduced [1−5]. The color contrast generated from colloidal arrays is usually very low because of strong incoherent light scattering across the entire visible range. To overcome this, black additives that absorb white light are essential to obtain brilliant structural colors. EPD of spherical SiO_2 particles with diameters between 200 nm and 300 nm with carbon black nanoparticles as black additives could provide colloidal arrays with vivid structural colors [1]. One of the advantages of EPD is that it can produce uniform coatings even on surfaces with complicated shapes. Uniform structurally colored coatings were obtained on stainless-steel forks (Figure 1). It is also possible to control the arrangement of particles in colloidal arrays by varying the conditions of EPD, such as the applied voltages and the pH of the dispersant, making it possible to create colloidal crystals and colloidal amorphous arrays. This enabled the production of both films with and without an angular dependence (iridescence) of coloration [2]. However, a critical obstacle remains conventional EPD coating films fabricated from SiO_2 particles. Abrasion resistance of films are very low because interactions between particle-particle and particle-substrate are very weak. Improving abrasion resistance is an important issue for the practical applications of structurally colored films. Therefore, robust structurally colored films were prepared by the cathodic EPD method with the addition of Mg^{2+} ions. In this method, $Mg(OH)_2$, which can contribute to enhance the mechanical stability, is electrodeposited between the particles at the same time as the EPD of SiO_2 particles and black additives (Figure 2) [4]. In addition, we have recently demonstrated preparation of structurally colored coatings with extraordinary high heat resistance of coloration, up to 900 °C [5].

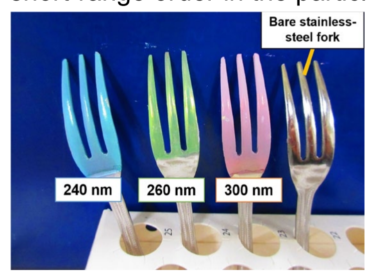

Figure 1 – Photograph of the coating films prepared using SiO_2 particles with various diameters on stainless steel forks via the EPD process.

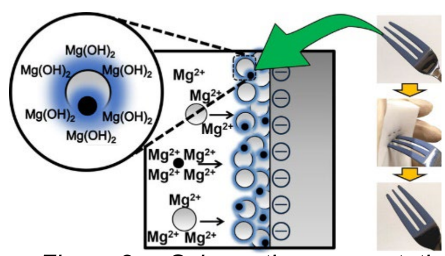

Figure 2 – Schematic representation of deposition of SiO_2 and black additives with $Mg(OH)_2$ on the surface of the cathode during application of an electric field.

References
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