

STRUCTURAL COLOR COATING FILMS COMPOSED OF AN AMORPHOUS ARRAY OF SILICA AND CARBON BLACK PARTICLES BY ELECTROPHORETIC DEPOSITION

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The color of a dye or pigment is an inherent property of the material that depends on its chemical nature. Some of these paints, especially those containing organic dye molecules, easily fade over time or upon exposure to light. In addition, there is concern over unfavorable influences on health and the environment, as some paints contain harmful substances. Therefore, coloration free from photo-bleaching or toxic materials is a central goal of paint research. Structural color is one of the most promising candidates to solve this challenge [1]. Submicron-sized microstructures reflect or scatter light so that waves of certain frequencies can constructively interfere to form this type of color. Because electronic excitation is not involved in the coloration mechanism, the structural color is not susceptible to fading unless the microstructure is destroyed. Structural color from particle arrays is advantageous in the sense that the color can be tuned merely by choosing the size of the microstructure without changing the material design. However, structural color from crystalline array of particles typically exhibits angular dependence, which is unfavorable for general purposes. Commonly used paints ideally appear the same color regardless of the viewing angle. In this study, we describe a novel and simple procedure to create a low angular dependence structural color coating by the electrophoretic deposition (EPD) process using SiO₂ particles. A homogeneous coating film composed of an amorphous array of SiO₂ particles was obtained by the EPD. However, the structural colors emitted from these arrays are very pale because the incoherent light scattering across the entire visible region is very strong. To reduce the contribution of incoherently scattered light to the overall scattering spectrum and to enhance the structural color of the colloidal amorphous arrays, black components, which absorb light uniformly across the entire visible region, can be incorporated into the films. Carbon black (CB) is one of the most common and environmentally preferable black substances and reflects very little light in the visible region of the spectrum. Sufficient visibility of the structural color was achieved by the co-deposition of carbon CB. The thickness of the coating films can be controlled by varying the applied voltage and/or deposition time. When the EPD process is carried out with a low applied voltage, a close-packed array of SiO₂ particles that exhibits an iridescent structural color is obtained (Figure 1a). However, an amorphous packing state can be acquired at a high applied voltage condition (Figure 1b). The structural color generated from such coating films has a low angle dependence. These results indicate that the arrangement of particles in the array and the iridescence of the resultant structural color can also be controlled by varying the EPD conditions. Various vividly colored coatings can be produced from SiO₂ particles with diameters between 200 and 300 nm. Moreover, coatings on materials with curved surfaces and complicated shapes, which are difficult to obtain by commonly used techniques were also successfully prepared via the EPD process.

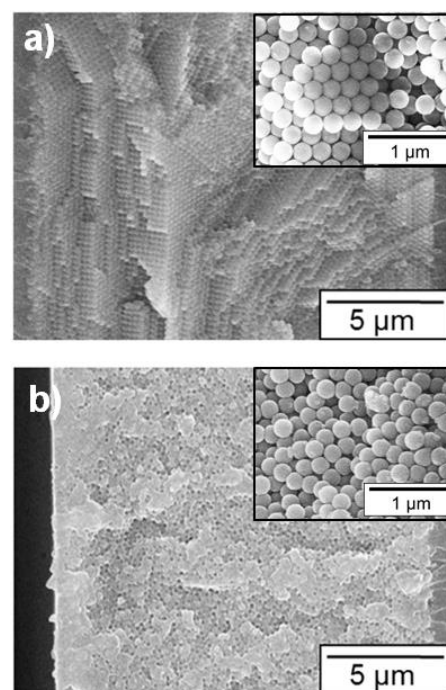


Figure 1. Cross-sectional SEM images of SiO₂/CB coating films prepared by EPD. Applied voltages and EPD times were (a) at 5 V for 25 min, and (b) at 90 V for 1 min, respectively. Magnified images were given as insets.

[1] Y. Takeoka, Polymer J., 47, 106 (2015)