Structural Color for Security Printing: Patterned Robust Colloidal Crystals

Takaharu Kobayashi, [1] *Mark Owens,* [2] *William Cross,* [2] *Jon Kellar,* [2] *and Grant Crawford,* [2]

[1] *Research Institute of National Printing Bureau, Odawara, kanagawa, Japan*
[2] *South Dakota School of Mines and Technology Center for Security Printing and Anti-Counterfeiting Technology (SPACT) Rapid City, SD, 57701, USA.*

Abstract:

Structural color is a unique optical property of nano- or microstructured materials with periodic dimensions similar to the wavelength of visible light. Characteristic color is produced through reflectance, interference, scattering, diffraction or refraction of incident light of a specific wavelength in visible spectrum, thereby producing a specific color or so-called structural color. Structural color is seen throughout nature, notably Morpho butterflies and opals present a striking sheen and accompanying vivid hue. Prior analysis of minerals and organisms that produce these distinctive colors allows for continuing analysis of color developing mechanisms [1]. Recently, with improvements in micro-fabrication, trial reproduction of these naturally occurring structural colors is proceeding across the field of Biomimetics [2].

Mono-dispersed micro-particles, structured in an ordered arrangement, are called colloidal crystals. Through Bragg reflection they exhibit structural color with a vivid hue. Colloidal crystals are relatively easy to produce by self-organization, and since dielectric periodic structures can be used as a photonic crystal for controlling electromagnetic waves, it has been extensively studied as a structural color element and photonic crystal. Some of the methods for manufacturing colloidal crystals include capillary method, electric electrophoresis, spin coating, spray coating, and substrate raising [3 - 6]. The color developing mechanism for structural color differs from pigment and does not absorb a specific wavelength, therefore in principle, fading from UV rays should be reduced. These materials can be used in applications that require pigments with excellent light-resistance and durability. In addition, since these colored micro-particle aggregates are non-toxic with a high level of safety, they show promise for wide use in printed materials.

Here we present research results involving the formation of a pattern of stable colloidal crystals on various substrates and exploring their suitability for use in printed materials. Monodisperse silica nano-particles with a diameter of 300 nm were dispersed in a highly polar solvent. As the solvent evaporates the particles self-assemble into colloidal crystals. By depositing this dispersed suspension as an ink with a direct write printer (aerosol jet) we confirmed the ability to print colloidal crystals with structural color in any pattern. The cohesion of self-assembled colloidal crystals relies on electrostatic attraction making them extremely brittle with limited practical use. As such, a polymer was added to the suspension to reinforce the colloidal crystal structure with limited influence on the self-assembly mechanism. Thus, a strong coating is produced while also producing the desired color effect.

Printed colloidal crystals produced by this method are difficult to reproduce by color copying and traditional printing methods considering the color and gloss change depending on the viewing angle. Figure 1 shows a feature printed using the colloidal crystal ink under various lighting/viewing conditions. Also, since it is possible to direct print any pattern, the method is amenable to variable data printing, providing a tamper prevention effect. Thus, these materials are attractive for use in security printing applications.

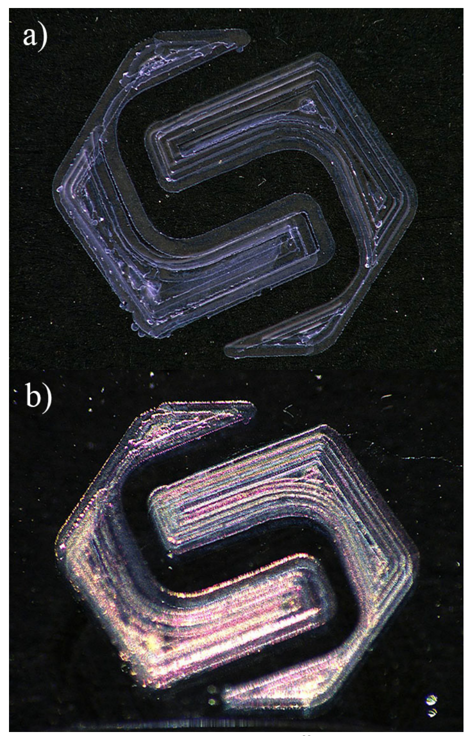

Figure 1. a) Patterned colloidal crystal under diffused light. b) Patterned colloidal crystal when observed under specific angled light.

Keywords:

Security printing, Colloidal crystal, Structural color

Author Biography

Takaharu Kobayashi graduated from Chiba University in 2004, completing a graduate program with a major in Image Science, and in 2005 he joined the National Printing Bureau, Japan. He joined the bureau's Research

Institute in 2009, after gaining experience in the quality control department of the banknote printing plant. Since 2014, he is working as visiting researcher in the Center for Security Printing and Anti-Counterfeiting Technology developing security printing technologies.

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