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CONTENTS

Opal photonic crystal films as smart materials for sensing applications

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Opal photonic crystals have been attracting much attention due to their novel functions as 3D Photonic crystals and to their structural color. Here we will report tunable structural color and potential applications. In addition, one of key issues for industrial use is how to make high-quality colloidal crystal films. We also have been developing a coating technique based on a crystal growth of opal films onto solid substrates past a decade.

A kind of opal photonic crystal shows response to external stimuli, such as swelling, electric field, magnetic field, thermal change and mechanical strain [1]. From the viewpoint of smart materials, this tunable structural color shows large potential applications as new sensor material and device. Here we will present a soft opal film with tunable structural color by applying external force and its sensing applications [2].

Figure 1 shows a soft opal film made of arrayed PS colloidal spheres and infilled with PDMS elastomer. Mono dispersed PS spheres are self-assembly forming a face center cubic, fcc, lattice in colloidal crystal, concept image A. The fcc (111) planes play a key role of the structural color. The among of PS colloids are infilling with PDMS elastomer. This elastic material enable to change the spacing of d_{111}; i.e., tuning structural color by an external stimuli. An SEM image B shows the soft opal film with arrayed 200 nm PS colloids at the cross-sectional region. The soft opal films were coated on a black color rubber sheet and PET sheet. Photograph C shows changing structural color of the soft opal film on the rubber sheet by stretching. This color changing is reversible and repeatable. We call this sheet as “Photonic rubber sheet” [3, 4]. In contrast, photography D shows the irreversible color change by plastic deformation of PET sheet. The soft opal film coated PET sheet adhered to the Aluminium plate. Then the Al plate was stretched with a tensile test machine. The structural color of the opal film was changed from red to green. This means that strain of the metal deformation is visualized as a change of the structural color. Here we demonstrate the soft opal films as smart material for sensing applications. One of sensing applications is to structural health monitoring in civil engineering, such as bridge, building and tunnel. Many developed countries, such as EU, US and Japan, are facing on the serious issues of large number of infrastructures aging. We have been developing an easy, simple and low cost method using opal photonic crystal film with tunable structural color [5].

An opal film crystal growth under silicone liquid film was reported in 2004 [6]. Based on this phenomena, we have been investigating the crystallization mechanism and developing high quality opal film coating methods [7]. Figure 2 shows vertical equipment, opal film coated on PET sheet and cross sectional SEM image. High quality opal film is coating on black color Poly Ethylene Terephthalate (PET) sheet. Using the equipment shown in Fig. 2A, we can fabricate opal photonic crystal film of a rectangle (up to 10 cm by 20 cm) on the PET sheet. The surface image, B, and the cross sectional SEM image, C, indicates high quality film condition; uniform structural color and film thickness. This coating method is fundamentally scalable process for mass production.

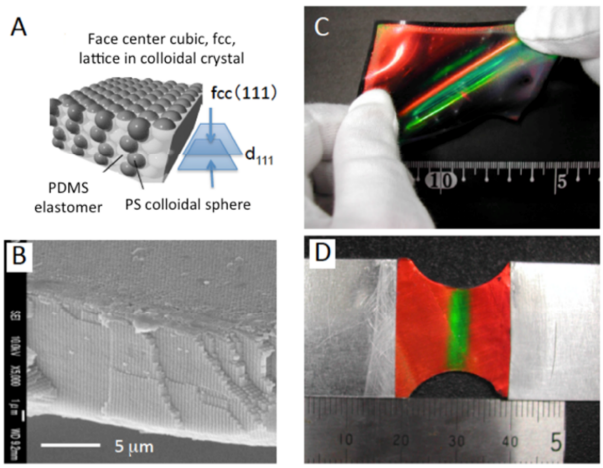

Figure 1. Soft opal photonic crystal films. (A) PS colloidal crystal of fcc (111) planes embedded in PDMS elastomer.(B) SEM image of the soft opal film. (C) Color changing by stretching a rubber sheet. (D) Strain image of deformed aluminium plate.

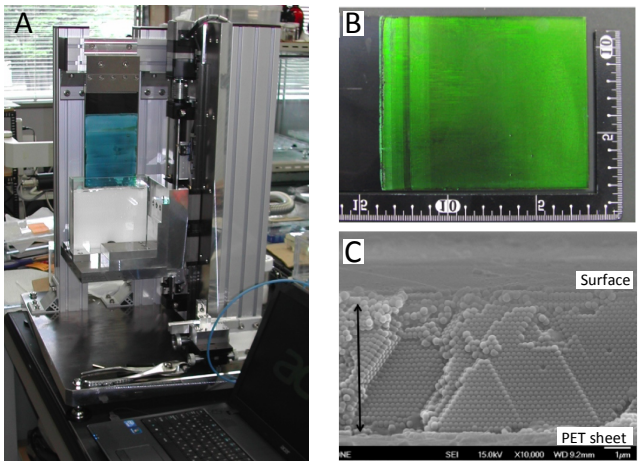

Figure 2. Crystal growth of opal photonic crystal film. (A) Vertical coating equipment based on oil covering method. (B) Optical image of opal photonic crystal film coated on a PET sheet. (C) Cross sectional SEM image of the opal film made of closely packed 200nm-PS colloids.

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