Iridescent Structural Color from Ultra-low Refractive Index Aerogel as Optical Cavity Dielectric

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Iridescent color-shift pigments have been used in many industrial applications, e.g. for cosmetics and packaging, due to its distinct color change at varied viewing angles. To achieve a vibrant and lasting color, thin-film interference is used to generate structural colors [1]. By tuning the refractive index, thickness, and geometry of the component films, a wide range of vivid and iridescent colors can be produced. By maximizing the refractive index (RI) difference between the thin films (i.e. using an ultralow RI film), super-iridescent structural color can be produced. However, the lowest refractive index of a naturally occurring solid dielectric is close to 1.37 (i.e., MgF_2). To address this, we developed a high-refractive index/low-refractive index/absorber (HLA) [2] trilayer structural color using a solution-processed SiO_2 aerogel film as the low-RI dielectric, whose ultralow refractive index arises from artificial structural engineering towards high porosity (Figure 1c) and demonstrated its superior iridescent performance in a $TiO_2/SiO_2/Si$ system. The ultra-low refractive index of aerogel is close to that of air (n~1.06), enabling structural color capable of tracing a near-closed loop in CIE color space upon angle variation (Figure 1a).

This work is the first to employ an ultra-low RI aerogel dielectric in an optical cavity-based structural color. Through spectroscopic ellipsometry, the spin-on aerogel film's porosity and refractive index can be characterized and confirmed through SEM and TEM. By tuning the refractive index, thickness, and geometry of the aerogel layer, we control the reflection dip's shape, thereby producing highly iridescent reflective structural color.

[1] D. Wang, Z. Y. Liu, H. Wang, M. Li, L. J. Guo, C. Zhang, "Structural color generation: from layered thin films to optical metasurfaces," *Nanophotonics,* 2023, doi.org/10.1515/nanoph-2022-0063

[2] W. J. Feng, Y. Cheng, L. J. Guo, "Temporal Coupled Mode Analysis of Chromaticity in Trilayer Subtractive Structural Colors," *ACS Photonics* 10, 2784-2792, 2023

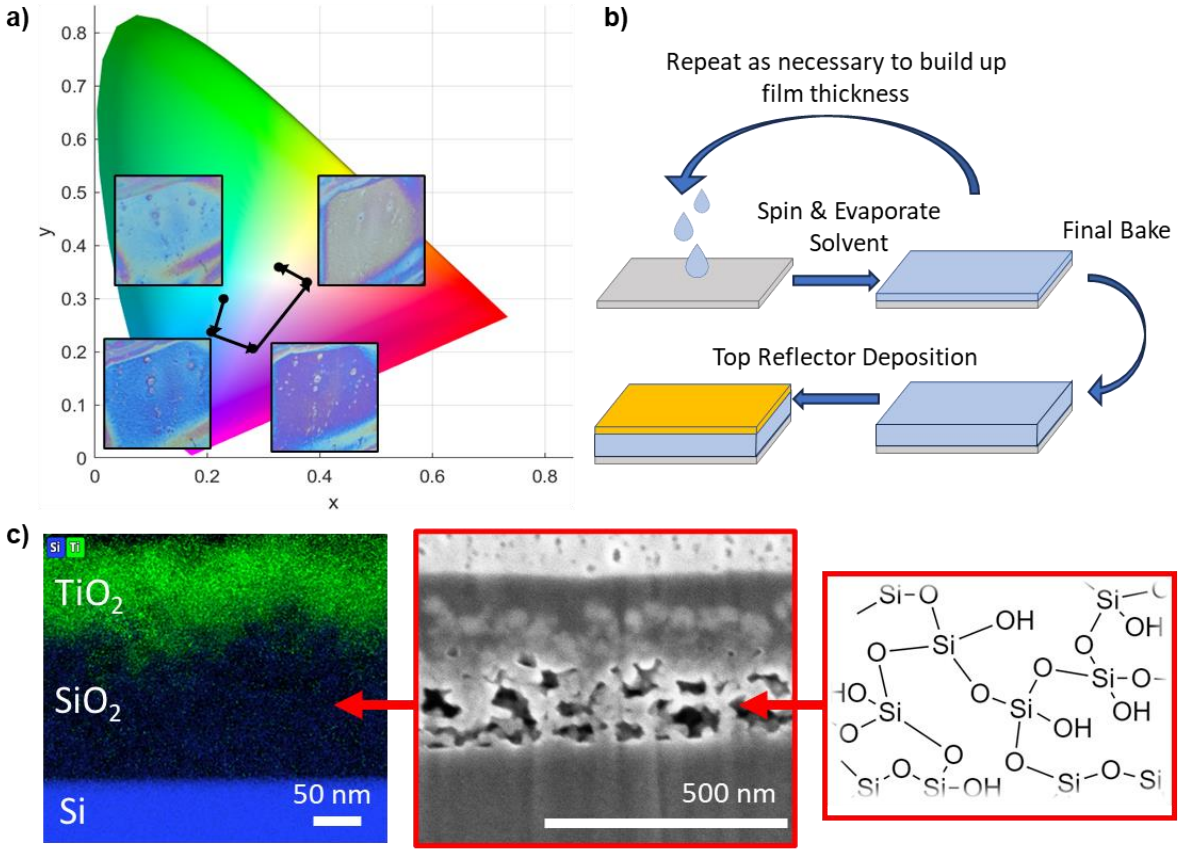

Figure 1. a) 38 nm TiO_2/aerogel/Si HLA structural colors at various viewing angles and corresponding locations on CIE coordinate. Photos were captured outdoors in sunlight. b) Schematic of aerogel HLA fabrication. c) Cross-sectional elemental mapping of HLA, cross-sectional SEM, and schematic depicting SiO_2 network.