Inorganic Photoresist Materials for Direct Fabrication of 3D Photonic Crystals Using Phase Mask Lithography

M.C. George, E.C. Nelson, D.G. Cahill, J.A. Rogers, P.V. Braun
Materials Science and Engineering, University of Illinois, Urbana, Illinois.

R. Dror, B. Sfez
Applied Materials Group, Soreq Nuclear Research Institute, Yavne, Israel.

Direct fabrication of two- and three-dimensional inorganic photonic crystals has been achieved by using conformable phase mask elements to generate high contrast, 3D periodic interference patterns[1] within two markedly different inorganic photoresists. Photonic crystals of varying lattice parameter and complexity were fabricated by varying the phase mask pitch and exposure wavelength and by utilizing both linear and 2-photon absorption[2]. Photonic crystal structures were characterized via SEM and compared to the phase mask interference pattern predicted by RCWA and the Abbe Theory of image formation. Normal incidence reflectance measurements were also taken and compared to the spectra predicted by FDTD modeling. The two inorganic photoresists, one oxide based and the other a chalcogenide glass, have competing strengths. The chemically amplified oxide resist is based on the acid catalyzed condensation of poly(methyl silsesquioxane) end groups. After calcination, the silsesquioxane is thermally stable, allowing for infiltration with high index of refraction materials. We have used this oxide resist and silicon CVD to form high index 3D photonic crystals. We have also demonstrated the oxide resist's compatibility with nanoimprint interference lithography where the surface of the photoresist film is embossed to form the phase shifting element. The chalcogenide glass based photoresist is composed of As_2S_3. This material already has a high index of refraction, making further template infiltration and removal processing steps unnecessary. As_2S_3 is also highly nonlinear and shows excellent sensitivity to pulsed near-IR radiation, allowing us to directly pattern high quality photonic crystals from this chalcogenide glass using multiphoton interference lithography. We measure and compare the 2-photon sensitivity and resist contrast of the oxide and chalcogenide glass materials and show that both are compatible with the large area fabrication of photonic crystals via phase mask lithography.

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[1] S. Jeon, J-U. Park, R. Cirelli, S. Yang, C.E. Heitzman, P.V. Braun, P.J.A. Kenis, and J.A. Rogers, PNAS 101, 12428-33 (2004).

[2] S. Jeon, V. Malyarchuk, G.P. Wiederrecht, and J.A. Rogers, Optics Express 14, No. 6, 2300-08 (2006).

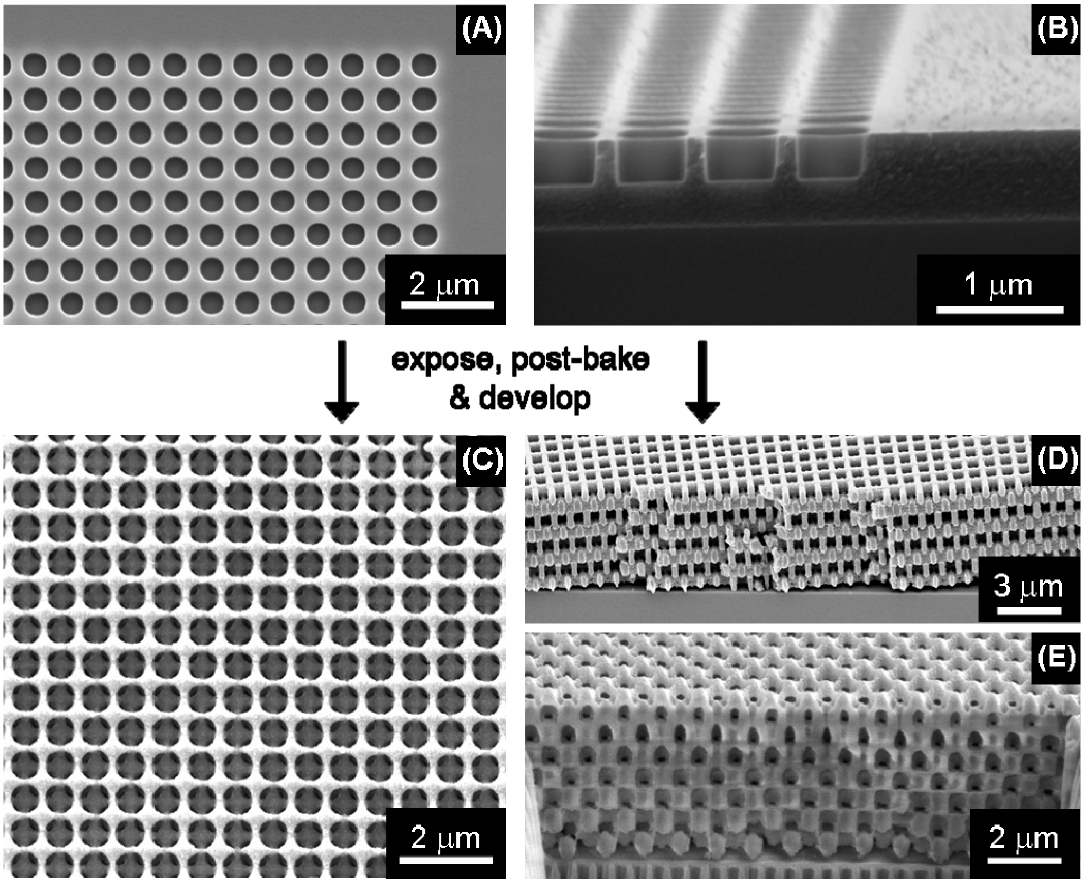

Fig. 1: Embossed poly(methyl silsesquioxane) resist surface (A) and cross-section (B) after imprinting with 740nm pitch PDMS phase mask. The resist surface acts as the diffractive optical element allowing for its own 3D patterning: photonic crystal (001) plan view (C), cleaved (100) cross section (D), and Focused Ion Beam (110) cross section (E).

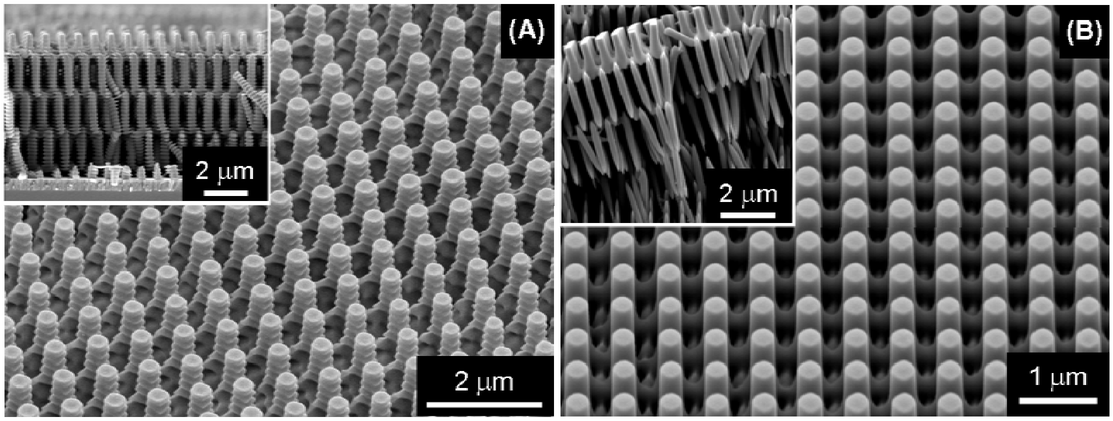

Fig. 2: 3D chalcogenide photonic crystals patterned using conformal PDMS phase masks and radiation from a pulsed 800nm laser (A) and a continuous wave 532nm laser (B). The anti-reflection coating was optimized for the 532nm case, but absorption gives a density graded 3D structure in (B) (see inset).