Nanostructured Colors from Colorless Materials

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A recurring theme in our research is the generation of a wide range of colors from materials that are colorless in bulk. Unlike pigments and dyes that have specific colors due to their chemical composition, we generate colors by precise nanopatterning structures using two-photon polymerization (TPL) and electron beam lithography (EBL) into a variety on geometry out of metals,[1-5] semiconductors,[6] stacks of metal/dielectrics,[7] and most recently low refractive-index polymers.[8,9] We introduce a heat-shrinking method to produce 3D-printed photonic crystals with a 5x reduction in lattice constants, achieving sub-100-nm features with a full range of colors. We also demonstrate four-dimensional (4D) printing of shape memory polymer (SMP) that imparts time responsive properties to 3D structures.[10] A new SMP photoresist based on Vero Clear is being used achieving print features at a resolution of~ 300 nm half pitch using TPL. Prints consisting of grids with size-tunable multi-colours enabled the study of shape memory effects to achieve large visual shifts through nanoscale structure deformation. In addition we will discuss fabrication of metasurfaces by EBL.

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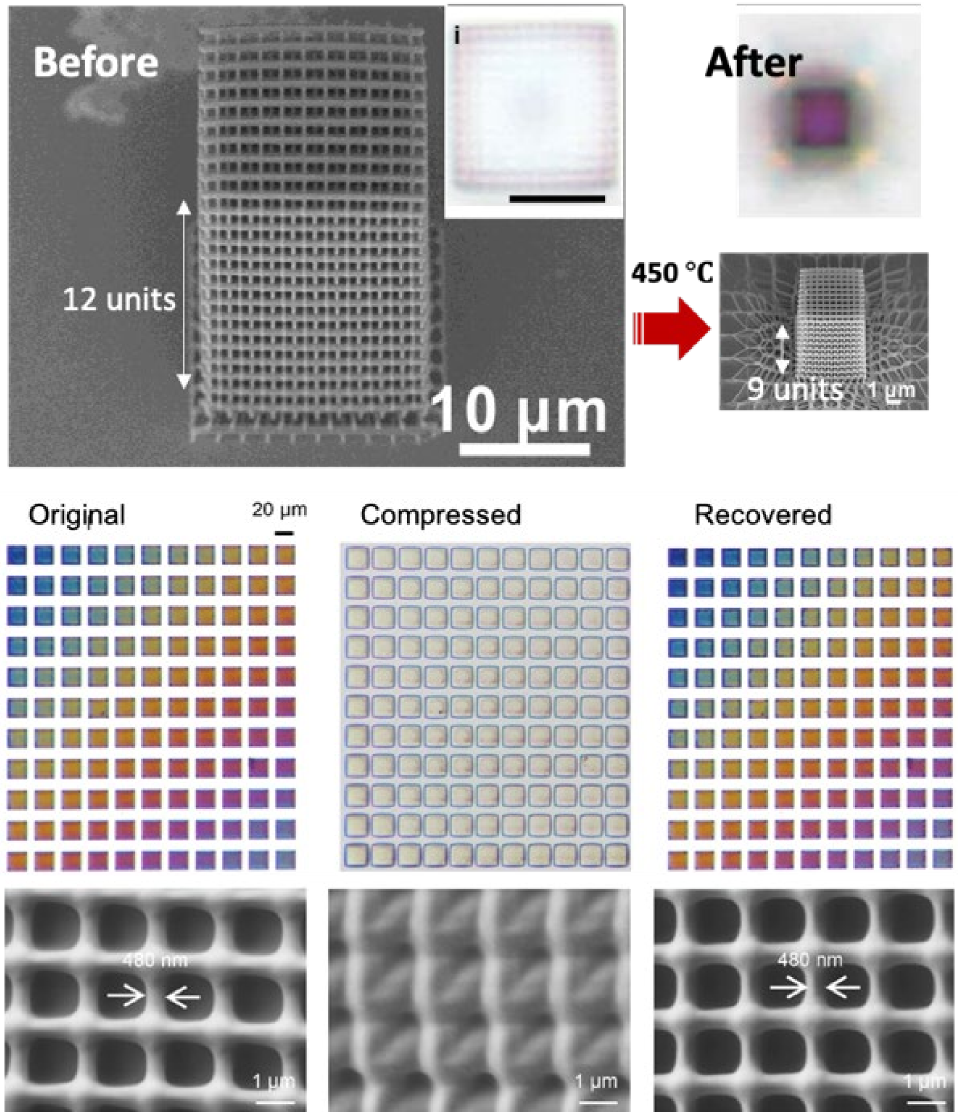

Figure 1: Multifunctional color prints from low refractive-index materials: The top row demonstrates heat-shrinking induced colors of woodpile photonic crystals 3D printed using TPL. Bottom row shows color patches fabricated by two-photon lithography using in-house developed shape memory polymer resin into nanogrid structures of different dimensions. When compressed colors disappear and can be recovered by heat.