Block Copolymer Self Assembly for Design and Vapor-Phase Synthesis of Nanostructured Materials

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Block copolymer thin films have emerged as important patterning materials for defining electronic devices at sub-optical resolution feature sizes because of: their facility in generating uniform, nanometer-scale structures over large areas; their ability to scale to different sizes; and their relative ease of integration with thin-film fabrication methods. These same desirable qualities can provide important benefits for synthesis of macroscopic materials structured uniformly on the nanometer length scale for design of new and/or improved properties.

Here, we describe our efforts to combine block copolymer self assembly with the vapor-phase synthesis methods of atomic layer deposition and physical vapor deposition to produce nanostructured metals and semiconductors. We convert self-assembled patterns of cylindrical- and lamellar phase polystyrene-*b*-poly(methyl methacrylate) (PS-*b*-PMMA) into metal oxides through block-selective infiltration of the PMMA block and organic removal by oxygen plasma (Figure 1). The resulting nanostructured metal oxide layer provides a template for directional growth of metallic and semiconducting nanostructures by physical vapor deposition. This long-known method of oblique angle deposition relies on shadowing of neighboring substrate areas by the metal oxide seeds due to the shallow angle of incident vapor flux (Figure 2, inset).

For example, nanostructured alumina layers formed from cylindrical phase block copolymer patterns can template growth of germanium wires (Figure 2), with average diameter and separation defined by the initial block copolymer film. Varying the polymer total molecular weight between ~48 kg/mol and ~99 kg/mol changes adjusts the average wire diameter between ~15 nm and 25 nm. We will describe examples of macroscopic physical properties imparted to materials structured in this way, including changes to their optical reflectance and hydrophobicity.

Research carried out at the Center for Functional Nanomaterials, Brookhaven National Laboratory, which is supported by the U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. DE-AC02-98CH10886.

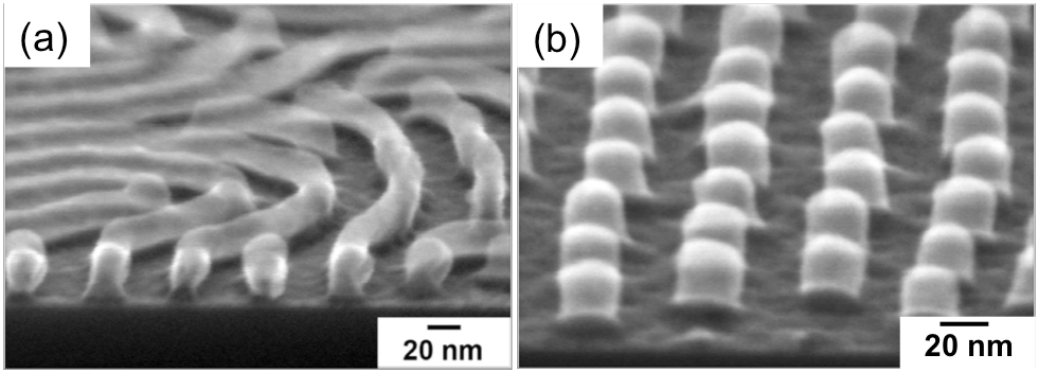

Figure 1. Nanostructured alumina patterns formed by block-selective infiltration of (a) lamellar phase and (b) cylindrical phase PS-*b*-PMMA block copolymer thin films.

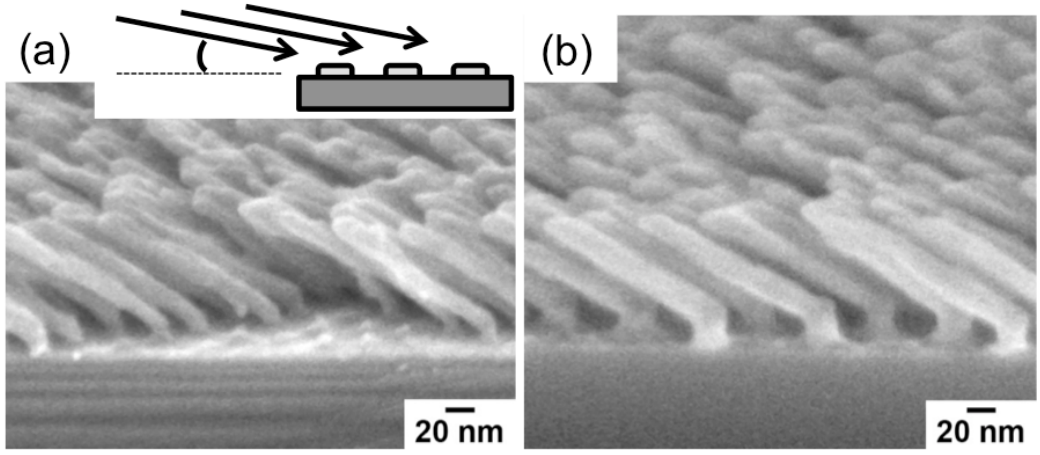

Figure 2. (inset) Schematic oblique angle deposition. Germanium wires grown by physical vapor deposition from alumina seeds templated by (a) 48 kg/mol and (b) 99 kg/mol cylindrical phase block copolymer templates.