NANO HIGHLIGHT
Development of Mesoporous, Ultra Low Dielectric Constant, Patterned Films by 3-D Replication of Structured Organic Templates: A University/Industry/National Laboratory Collaboration

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Ordered metal oxide films containing well defined pores in the size range of 3-50 nm are of enormous interest for applications in catalysis, separations, photonics, electronics, sensing and detection devices. One unresolved challenge has been the fabrication of robust films with cylindrical pores aligned perpendicular to the plane of the substrate. Such an arrangement renders the pore structure accessible for the intended application. Over the course of our NIRT program, we have developed approaches to hierarchical porous silicate films for applications in microelectronic devices. An important by-product of this work has been the development of a rapid and efficient route to nanochannel arrays of prescribed orientation.

Our approach involves the three-dimensional replication of organic templates, namely polymers, into functional inorganic materials, namely metal oxides. We accomplish this by first preparing a polymer template that contains the desired structural elements and then conducting regio-specific reactions within specified sub-domains of the template in the presence of a compressed gas carrier. The carrier dilates the template, allowing efficient delivery of the reagents without disrupting the architecture of the polymer. The template is then removed by heating to yield the metal oxide. In this manner the structural details of the block copolymer template are transferred to the metal oxide network with high fidelity. The templates we employ are block copolymers, which are molecules that contain long segments of repeating chemical functionality that are tethered together at one or more junction points. When the block copolymers are cast from solution they can spontaneously self assemble into periodic structures containing spherical, cylindrical, bi-continuous or lamellar domains in which the dimensions of the repeating units range between 3 and 50 nm. It is these structures, imparted simply and rapidly in the block copolymer during template formation, that carry over into the metal oxide structure. Fig.1 shows a silica (SiO_2) glass film containing cylindrical pores oriented perpendicular to the surface prepared using a sacrificial polymer template of the same geometry.

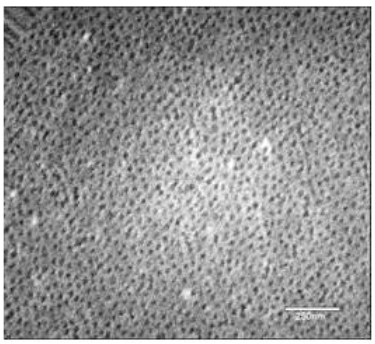

Figure 1. SEM micrograph of a mesoporous silica film with 20 nm channels. Perpendicular channels are enabling for applications in magnetic data storage, sensor and detection arrays, catalysis and separations.

1. For further information about this project email watkins@ecs.umass.edu
2. Pai et al., Science 2004, 303, 507.
3. Nagarajan, S.; Li, M.-Q.; Pai, R.A.; Weinman, C.; Ober, C.K.; Russell, T.P.; Watkins, J.J., in preparation.