Preparation of Graded Materials by Laterally Controlled Template Synthesis

Tali Sehayek, Tat'yana Bendikov, Alexander Vaskevich and Israel Rubinstein

Department of Materials & Interfaces, Weizmann Institute of Science, Rehovot 76100, Israel

Preparation of graded materials displaying gradients of properties (e.g., roughness, composition, reactivity, porosity) is potentially important for obtaining materials of unusual properties, which can be used as sensors, catalysts, or in other applications requiring spatially varying properties of the material. Here we present an approach to the fabrication of graded materials showing structural and compositional gradients, obtained by electrochemical template synthesis in nanoporous alumina membranes (NAMs), created on one side with a thin evaporated gold film used as the working electrode. A lateral gradient of the properties of a material deposited in the insulating membrane is achieved by applying a controlled lateral potential drop on the working electrode during the electrochemical synthesis. The method is demonstrated with three examples: (i) Thickness gradients of a metal (Cu) are obtained by electrodeposition of Cu in the NAM template using a lateral voltage drop on the working electrode. (ii) Thickness gradients of Cu and Au are obtained by electrochemical oxidation of the monomer using a lateral voltage drop. (iii) Compositional gradients are achieved by electrochemical co-deposition of Au and Pd alloy in the membrane template under a lateral voltage drop.

The gradients were characterized by scanning electron microscopy (SEM) imaging of cross-sections along the line of the applied voltage gradient. Local elemental analysis by energy dispersive spectrometry (EDS) imaging of cross-sections along the line of the applied voltage drop. (iv) Compositional gradients are achieved by electrochemical co-deposition of Au and Pd alloy in the membrane template under a lateral voltage drop.

The new method was demonstrated via formation of thickness gradients of CuCu alloy following uniform electrodeposition for 1 h at different potentials (vs. SCE, indicated). (1) SEM image showing the edge sections of a PANi-CuCu filled NAM, filled with PANi (vs. CuCu). The structure was obtained using a lateral potential gradient of +0.72 V to +0.8 V vs. Ag/AgCl for PANi deposition, followed by Cu deposition (+0.1 M AgNO3 and 1.0 M HClO4 solution, at +0.3 V vs. Ag/AgCl for 3 minutes). (2) SEM image showing a cross-section of the PANi-CuCu filled membrane.

Graded materials of different shapes can be obtained by controlling the geometry of the applied potential drop.

Conclusions

- A new approach to the synthesis of graded materials was developed, based on spatial control of electrodeposition (or electrodissolution) in insulating templates.
- The new method was demonstrated via formation of thickness gradients of Cu and polyaniline and compositional (as well as thickness) gradients of Au-Pd alloy, in nanoporous alumina membranes.
- The new method opens various possibilities for obtaining graded materials showing gradients of structural, magnetic, optical, conductive, or catalytic properties on the micrometer scale.

References
