Flow Programmed Mesoscale Assembly of Nanoengineered Materials and Net Shape Components

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In a continuing effort from FY2007, we demonstrated the ability of our mesoscale assembly system to synthesize porous polymer layers with varying density profiles and packing structures. The system is currently capable of integrating highly dissimilar materials and producing features with critical dimensions in the submicron range. This system enables nm-scale precision synthesis of mm- to cm-scale materials and parts in a simple, low-cost system.

We perform this synthesis by computer-controlled electrophoretic deposition in a miniature aqueous deposition cell interfaced to computer-controlled automated fluidics. Nanoparticle solutions are available in a wide and ever-growing variety of material compositions, morphologies, and surface chemistry states. We introduce mixtures of various precursor solutions into the deposition cell, and deposit nm- to µm-scale layers by the pulsed-field electrophoretic deposition of particles onto substrates. We use post-deposition sintering to achieve densification of these films.

The high degree of control and wide range of heterogeneous materials made accessible by this approach brings powerful, low-cost capabilities to the fabrication of density- and composition-varying layers. The highly conformal nature of the deposition allows the fabrication of near-net shape high precision parts. The lack of need for vacuum conditions allows high-speed and low-cost nanomaterial synthesis in a simple benchtop system.

The system is available for follow-on work to capitalize on the broader capabilities it makes accessible, including the programmed synthesis of parts incorporating dissimilar and custom materials, the *in-situ* fabrication of hemispherical and other net-shape parts, and

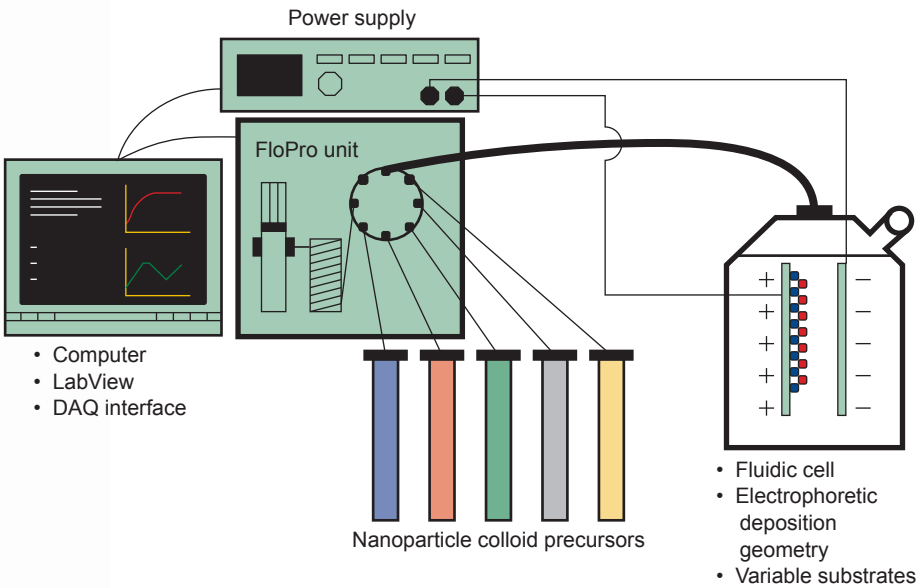

Figure 1. Schematic of the mesoscale assembly system. A FloPro unit provides automated valving and pumping to move particle solutions through the deposition cell. The power supply provides either constant voltage or constant current across the particle-laden fluid. The fluidics and the power supply are controlled via LabView software for full automation.

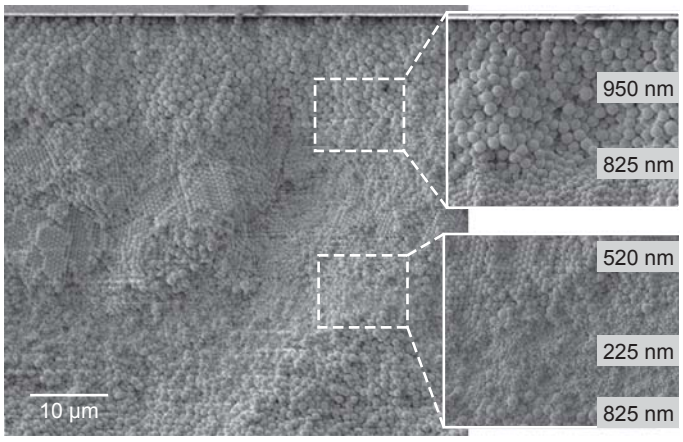

Figure 2. Example of a five-layer film deposited using polystyrene particles as the precursor material. The particles range in size from 225 to 950 nm in diameter. The total film thickness for this example is approximately 100 µm.

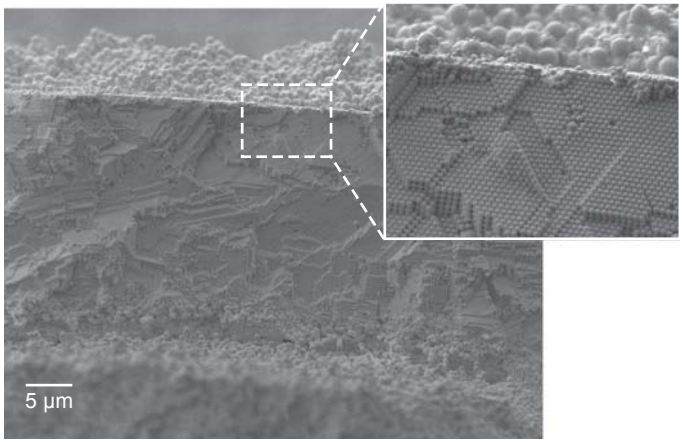

Figure 3. Example of the ordered packing structure achievable with the appropriate deposition parameters. The particles are 525-nm-diameter polystyrene.

ultimately the electronically-controlled assembly of nanostructured composite and functional materials.

Project Goals

The goals in the second year of this project were to: 1) optimize the control scheme for operating the deposition system based on basic transport models; and 2) demonstrate the synthesis of porous polymer layers with pre-defined, smoothly varying density profiles.

Relevance to LLNL Mission

This project was part of a new, integrated, mutually supporting, and dynamic multi-project portfolio in novel nanomaterial synthesis capabilities for mesoscale manufacturing. This portfolio is directed to LLNL application areas in target materials and structures, sensor materials, and biodetection devices. The short-term payoff is the creation of new nanoscale target structures. The proposed technology is ideal for combining novel nanomaterial components such as engineered nanoparticles, carbon nanotubes, and others into complex materials and structures. Future applications of this approach could include transparent ceramic optics for new high-powered lasers, ceramic armor, and new structures for radiation and IR detectors.

FY2008 Accomplishments and Results

We have accomplished the second year goals of this project using the prototype system assembled in FY2007 (Fig. 1). Specific results and accomplishments include the following.

1. fabricated four- and five-layer polystyrene films of different particle sizes with sharp transitions between each layer (Fig. 2);
2. demonstrated the ability to deposit polystyrene particle layers with ordered packing structures (Fig. 3);
3. demonstrated the deposition and drying of a relatively thick (> 375 µm) multilayer polymer film with smooth transitions between regions of different density (Fig. 4); and
4. deposited polydisperse 200-nm YAG particles to create a 6-mm-thick part which sintered translucent. Total deposition time was 5 min.

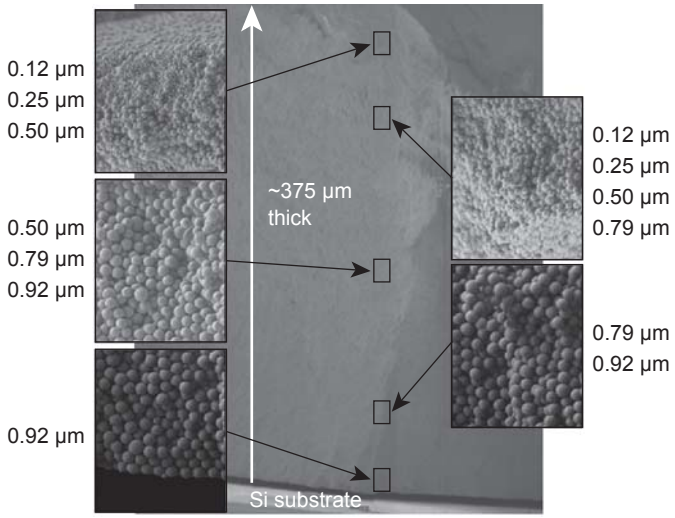

Figure 4. Cross-section of a multilayer polystyrene film with smooth transitions between each region. The smooth transitions reduce film stresses between the layers and eliminate cracking and peeling.