Fabrication of Multilayer 3D Micron-Scale Metamaterials

D. B. Burckel[1], J. R. Wendt[1], J. C. Ginn[1,2], I. Brener[1,2], and M. B. Sinclair[1]
1 Sandia National Laboratories, ABQ, NM, 87123 MS 1082
2 Center for Integrated Nanotechnologies, Sandia National Labs, ABQ, NM, 87123

Recently, we have demonstrated several variants of membrane projection lithography (MPL), a metamaterial fabrication technique capable of creating a layer of micron scale metamaterial unit cells with resonators oriented arbitrarily with respect to the surface normal[1,2]. These single layer MPL structures include the smallest published instances of cubic unit-cell metamaterials with split ring resonators oriented along each of the principle coordinate axes. Here we present our recent progress in creating optically thick metamaterials by stacking multiple layers using the MPL process flow.

Figure 1A contains a schematic of the basic MPL process flow – after creating a patterned membrane suspended over the unit cell, directional evaporation is used to deposit metallic/dielectric replicas of the pattern on the interior faces of the cavity. Figure 1B and 1C show scanning electron micrographs (SEMs) of a single cubic unit cell and an array of unit cells, respectively. During the formation of these single layer structures, the unit cell array must be backfilled and planarized with a sacrificial material in order to deposit the membrane material and then dissolve out the cavity. This step of backfill and planarization represents perhaps the most critical elements of a layer-by-layer MPL-based stacking approach.

Figure 2A contains a schematic of a multi-layer MPL process flow where the completed first layer is backfilled and planarized with a permanent structural material rather than a sacrificial material. The standard MPL process flow is then repeated on the newly-planarized first layer, and fabrication proceeds, building up the material a layer at a time. Figure 2B shows an SEM of an example planarized first layer, while the SEM in Figure 2C shows the second layer of SU-8 unit cells created with standard contact lithography on top of the first layer.

This paper will present detailed fabrication steps and optical characterization data of these materials.

Supported by the Laboratory Directed Research and Development program at Sandia National Laboratories. This work was performed, in part, at the Center for Integrated Nanotechnologies, a U.S. Department of Energy, Office of Basic Energy Sciences user facility Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.

1. D. B. Burckel, J. R. Wendt, G. A. Ten Eyck, A. R. Ellis, I. Brener and M. B. Sinclair, Adv. Mater. **22**, pp. 3171-3174 (2010).
2. D. B. Burckel, J. R. Wendt, J. C. Ginn, G. A. Ten Eyck, I. Brener and M. B. Sinclair, Adv. Mater. **22**, pp. 5053-5057 (2010).

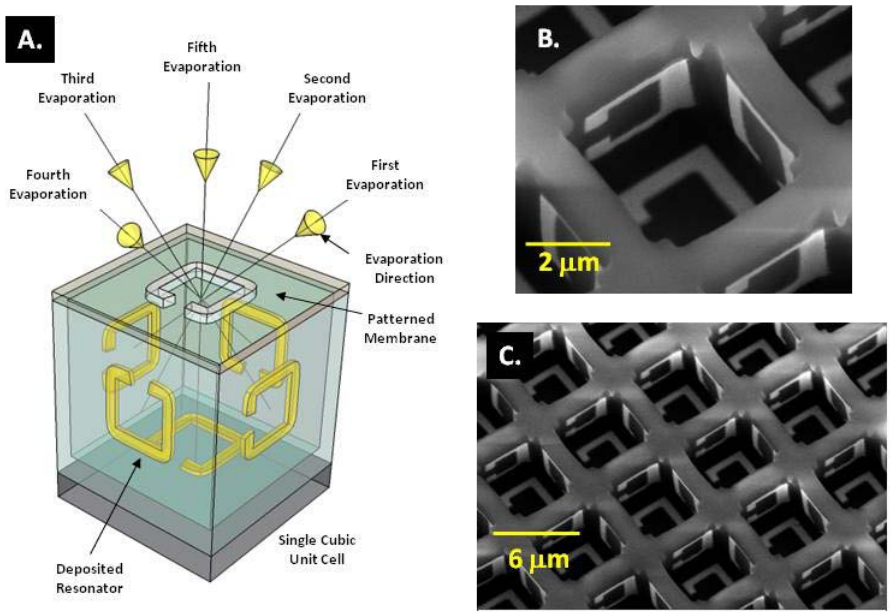

Figure 1. (A.) Schematic of MPL process. (B.) SEM image of gold patterns deposited in a cubic unit cell. (C.) SEM image of array of cubic unit cells.

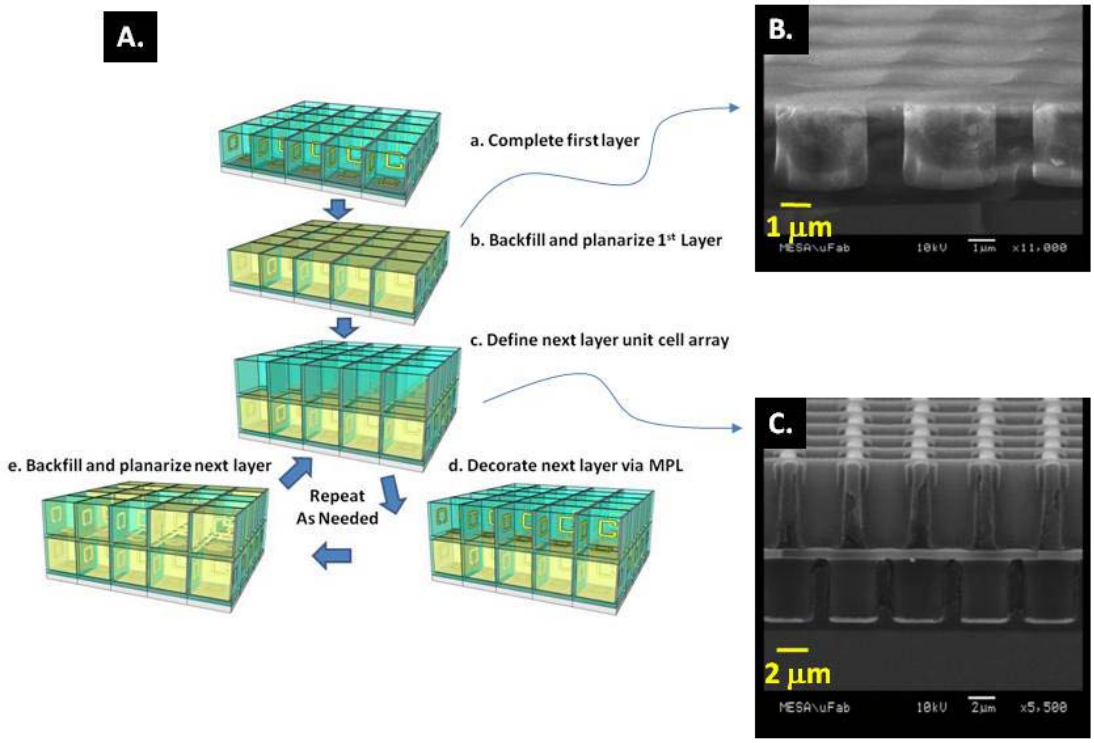

Figure 2. (A.) Schematic of multi-layer MPL process. (B.) Scanning electron micrograph backfilled and planarized single MPL layer. (C.) Second undecorated MPL layer positioned on top of planarized first layer