Hierarchical Self-Assembly of 3-D Metallic Microstructures for Terahertz Applications: Experiments and Simulation

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The recent advances in miniaturization have succeeded in reducing the size of sensors for remote detection; optical communications require overt optical access, and RF communications require antenna sizes on the order of the wavelength of the RF, typically a few centimeters. We have developed novel self-assembled 3-D structures that have frequency responses in the terahertz frequency range, where antenna sizes are on the order of tens to hundreds of microns. Ultimately, the frequency response will be a characteristic of the structure, and we can program

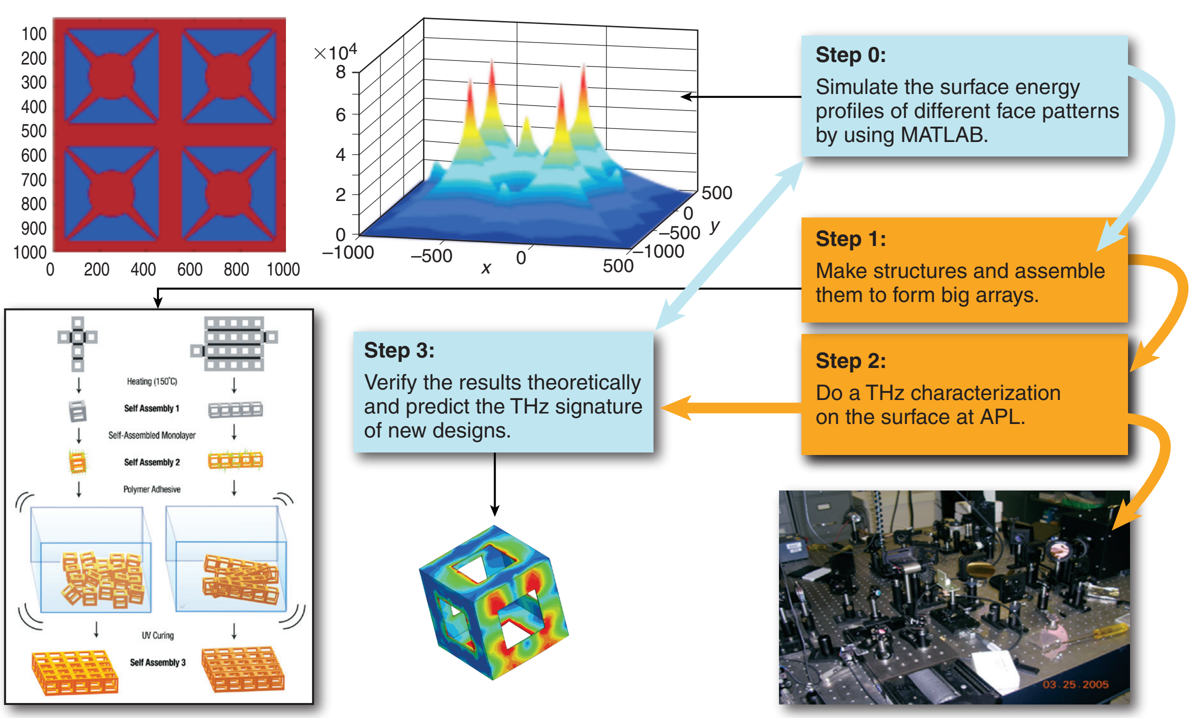

Figure 1. Our approach to creating self-assembled 3-D structures with frequency responses in the terahertz frequency range.

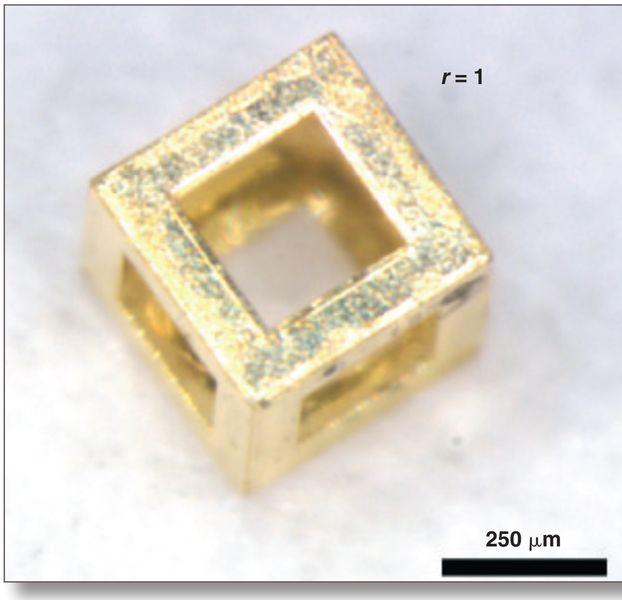

Figure 2. Building block for self-assembly.

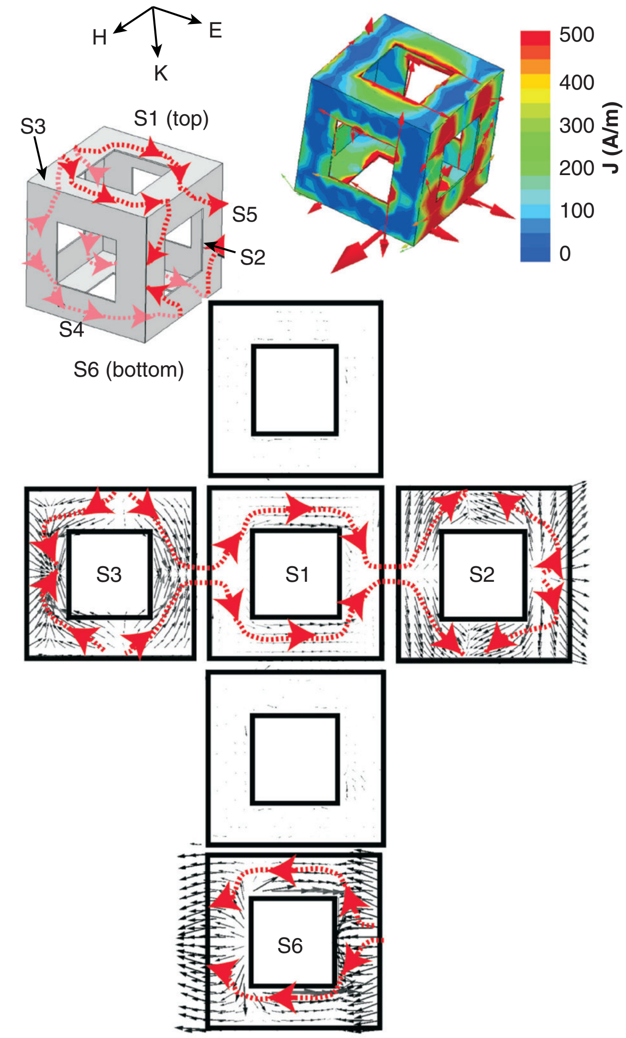

Figure 3. Simulated behavior of the electromagnetic fields within a 3-D cube.

the responses in the design. Further, the frequency responses could be modulated, for example, by conductivity changes due to environmental effects (imagine a sensor that changes its response on exposure to explosives) or stress changes in the structure, and the reflection efficiency should be optimized (e.g., a terahertz retro-reflector). These structures have the capability to be covert because of their small size and the option to embed them in or under a dielectric. They can be custom designed and can act as retro-reflectors in the terahertz frequency range without the quality requirements of their optical counterparts. In a future development, these structures can be designed for active response, e.g., as a sensor that transmits via frequency changes as a function of external environment.

The hierarchical self-assembly of lithographically patterned 3-D polyhedral metallic microstructures for terahertz applications is described below. Specifically, we have assembled cubic and parallelepiped-shaped building blocks from 2-D lithographically patterned templates (Fig. 1). These building blocks were functionalized with self-assembled molecules and hydrophobic polymers and assembled into 3-D periodic structures (Fig. 2). The structures show strong terahertz signatures that depend on geometric factors within the microstructure as well as their orientation with respect to the polarization of the field (Fig. 3). Our strategy enables a straightforward paradigm to construct 3-D periodic metallic microstructures with precisely lithographically patterned features in a parallel and cost-effective manner.

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