3D nano-manufacturing processes for nanophotonic devices and systems

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Nanophotonics is an emerging field at the intersection of photonics and nanotechnology. The University of Colorado Nanoscale Interdisciplinary Research Team (CU-NIRT) is advancing this new discipline by bringing together a team of investigators coming from different backgrounds and disciplines with a new generation of graduate students and postdoctoral researchers.

Nanolayer deposition

The CU-NIRT has developed a new process for metal shell growth. In this method, gold nanoparticles are first embedded in silica particles to form silica cores with some degree of affinity to gold nanoparticles. The subsequent gold shell growth process has been carefully studied and optimized to produce continuous and uniform gold shells with controlled thickness. These shells were further coated with silica for subsequent self-assembly. The formation of metal-dielectric opals was verified by SEM micrographs (Fig. 1). These metal-dielectric opals are expected to exhibit wide and robust 3D photonic bandgaps and will therefore serve as an excellent platform for 3D nanophotonic devices and systems.

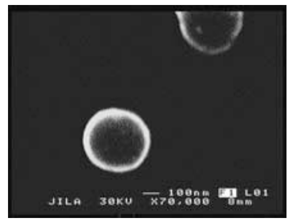
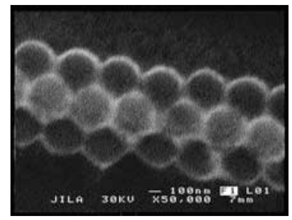

Figure 1: (a) SEM image of silica-gold core-shell particles (core diameter: 365 nm, shell thickness: 20 nm). (b) The self-assembled structure of core-shell.

Another promising technique developed by the group for the creation of nanolayers is atomic layer deposition (ALD). ALD grows conformal films of a wide variety of materials. ALD is a subset of chemical vapor deposition (CVD). Unlike conventional CVD, the substrate is only exposed to one reactant at a time. This temporal separation eliminates gas phase reactions and allows every available surface site to react under an excess of the precursor. After every available site has reacted with the first precursor, the reaction stops in a self-limiting fashion. The precursor can then be purged from the reactor and the next precursor can be exposed to the new surface sites on the substrate. The CU-NIRT used aluminum oxide to investigate ALD film formation in the voids of synthetic opals.

Ultrafast nanomachining of dielectrics and composites

Ultrashort light pulses are used to concentrate energy in a time interval of a few optical cycles and produce extremely high peak powers with moderate pulse energies. In this project, tightly focused femtosecond pulses were used to modify the physical properties of dielectric materials on a sub-micron scale and in three-dimensions.

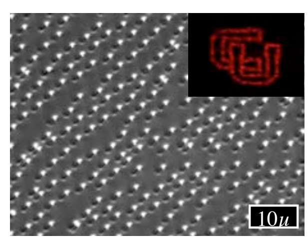

Figure 2: 3D aperiodic modulated grating for the generation of prescribed diffraction patterns. The insert shows the far-field diffraction pattern of the structure.

The CU-NIRT demonstrated the lowest pulse-energy modifications using unamplified pulses. The team created 3D waveguides and demonstrated their use in high speed optical interconnects, as required for future chip-to-chip and on-chip communication.

The CU-NIRT has also demonstrated for the first time 3D computer- generated aperiodic modulated gratings for the generation of diffraction patterns (see Fig. 2).

* For further information link to http://ece.colorado.edu/~piestun/CU-NIRT.htm or email piestun@colorado.edu