Optically directed assembly of mesoscale hybrid structures

Opportunity

Next generation devices will be exceptionally demanding on the properties of the components, and mesoscopic hybrid building blocks that integrate the properties of disparate materials (organic and inorganic) will be required. Conventional self-assembly processes usually rely on attaining an equilibrium state and are mostly limited to assembling one class of materials *i.e.* either organic or inorganic particles. Directed self-assembly and deposition processes are necessary for the fabrication of complex functional devices based on hybrid nanoscopic materials.

Optically directed colloidal synthesis of organic-inorganic hybrid mesoscale structures is a new avenue for hierarchical assembly and patterning of hybrid materials into arbitrary designs.

Meso Challenge

- Controlled synthesis of mesoscopic "user-designed" architectures from colloidal NPs is challenging due to a lack of understanding of the growth mechanisms and parameters
- Can we synthesize a new class of organic-inorganic hybrid materials that can become the sole occupants of long-standing voids in the global materials landscape?
- Establish structure-property relationship in this new class of mesoscale hybrid material

Approach

- Synthesize and assemble nanoscopic building blocks (organic and/or inorganic) into novel mesoscale hybrid structures using optically directed assembly technique
- Characterize and map the atomic scale compositional distribution of this new class of materials
- Theoretical approaches spanning multiple length and timescales, from continuum to classical molecular dynamics to first principles methods to understand the fundamental science of ODA and determine optimum conditions for generating mesoscale materials with desired properties
- Explore materials combination space for key functions with theoretical guidance in nanoparticle selection

Impact

The new class of materials will provide functionality in the form of *porous* and/or *flexible*, high conductivity, robust micro-circuitry pertinent to a broad range of energy, sensory, diagnostic, and communications functions.

The properties of the new materials can be tailored to fit a wide range of functions by simply changing inorganic-organic NP combinations or assembly format.

References: J.T. Bahns, S.K.R.S. Sankaranarayanan, S.K. Gray and L. Chen, "Optically Directed Assembly of Continuous Mesoscale Filaments," Phys. Rev. Lett. **106**, 095501 (2011); J.T. Bahns, S.K.R.S. Sankaranarayanan, N.C. Giebink, H. Xiong and S.K. Gray," Optically Directed Mesoscale Assembly and Patterning of Electrically Conductive Organic-Inorganic Hybrid Structures," Adv Mat *In press* (2012)

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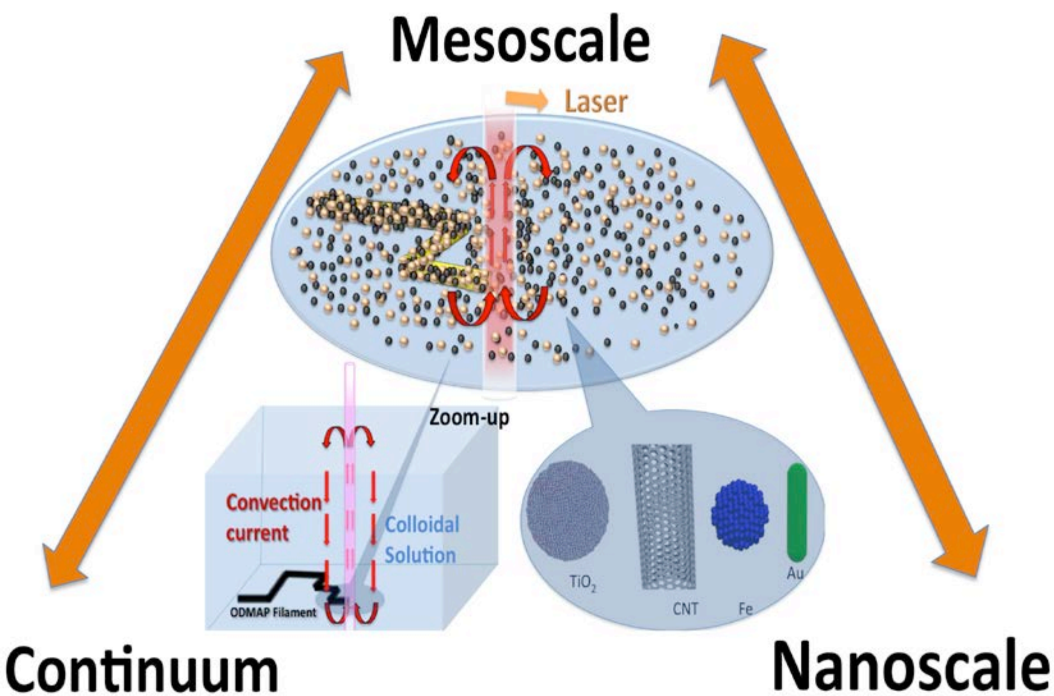
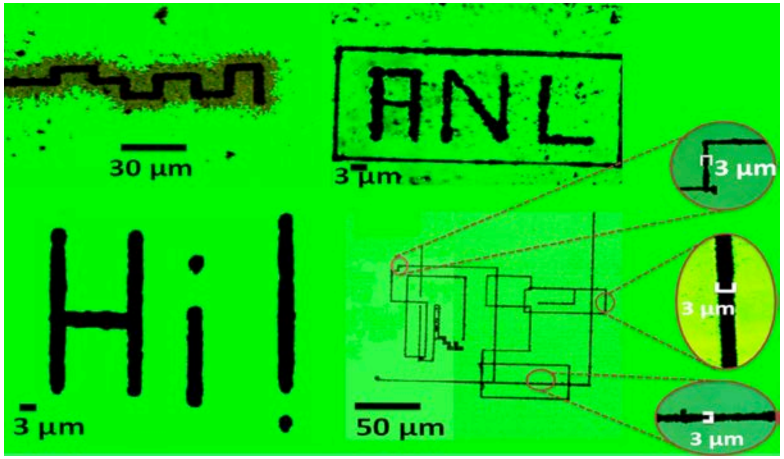
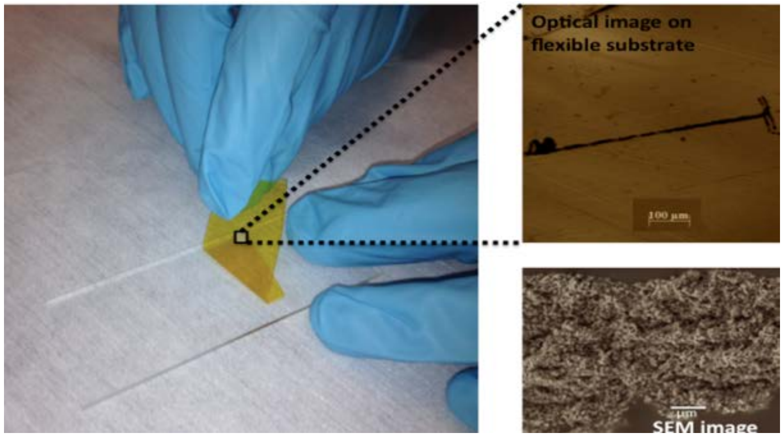


Optically directed mesoscale assembly and patterning (ODMAP) of electrically conductive organic-inorganic hybrid structures on glass substrates



Examples of optically directed patterning of 2-D mesoscale structures comprised of gold and carbon NPs. Such organic-inorganic hybrid structures have relatively high conductivities of ~430 S/cm, significantly better than current devices based on organic structures



ODMAP structures comprised of Si and Au nanoparticles on a flexible substrate