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NIRT: Total Chemical Synthesis, Modeling and Property Studies of Nanoparticle/Polymer Hybrid Materials

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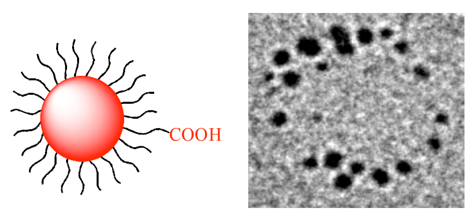
Introduction and Objectives

In the bottom-up approach towards nanomaterial development, two very important aspects need to be addressed: one is the synthesis of nanobuilding blocks and the other one is how to assemble the nanobuilding blocks together into materials or devices with ideal structures, properties and functions. The property of a nanomaterial is not only dependent on the individual nanobuilding blocks, but is also affected dramatically by the architectural organization of the nanobuilding blocks and their interactions. Our research team addresses important and challenging issues in nanoparticle research such as the size and chemical functionality control of nanoparticles, chemical assembling of nanoparticles into well-defined architectures and particle/polymer hybrid materials, as well as the property-structure relation of the hybrid materials.

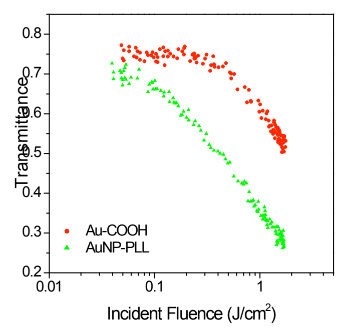
Our work encompasses three principal tasks. The first task is the synthesis and characterization of monofunctional gold nanoparticles and nanoparticle/polymer hybrid materials. The second task is the testing of the properties of the nanoparticle/polymer hybrid materials. The third task is to develop mathematical models for the growth of gold nanoparticle and study of methods to control the dispersity of the product of wet-chemical synthesis of gold nanoparticles.

Research Findings: Synthesis and characterization of gold nanoparticle/polymer hybrid materials. Members of the team lead by Dr. Huo have introduced a solid phase method for production of monofunctional gold nanoparticles [1,2]. The monofunctional nanoparticles were then subsequently used as molecular nanobuilding blocks to construct sophisticated nanoparticle assemblies and nanoparticle/polymer hybrid materials [3,4]. Nanoparticles were chemically linked to polymer backbones (polylysine, carboxyl-group protected polylysine, and a generation 5 PAMAM dendrimer) to produce nanoparticle/polymer hybrid materials in the form of nanoneclaces, nanochains, and nanoclusters respectively. This is the first time that it has been shown that different nanoarchetectures can be produced from monfunctional gold nanoparticles using simple chemical reactions.



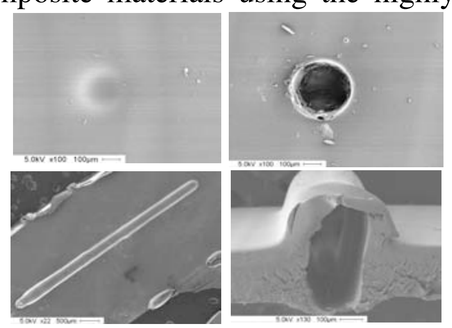
Research Findings: Property study of hybrid materials.

Optical and electronic properties of nanoparticle assemblies are dependent not only upon the size and characteristics of individual nanoparticles but also are strongly dependent upon the assembly geometry. Members of the team lead by Dr. Sun [5] have studied the effect of interparticle interaction and aggregation of gold nanoparticles on the optical limiting effect of nanoparticles. It was found from these studies a nanoparticle necklace structure



exhibits enhanced nonlinear optical property compared to individual nanoparticles. The enhanced optical limiting effect was attributed to the electromagnetic interactions between nanoparticles in a specially-defined geometry. In another study, the aggregation of gold nanoparticles induced by electrolytes was observed to significantly enhance optical limiting and enhance the polarizability of the nanoparticles. These studies lead to important understandings on the structure-property relation of nanoparticle and hybrid materials and provide valuable guidance for the development of optical limiting materials for eye protection against laser blinding weapons.

Research Findings: Application of gold nanoparticles for microfabrication
Another significant result from our research is the development of a direct laser-writing technique for the fabrication of microstructures on nanocomposite materials using the highly efficient photon-thermal energy conversion properties of gold nanoparticles [6]. By mixing gold nanoparticles with poly(methyl methacrylate) in solution, we fabricated nanocomposite thin film materials. By subjecting the nanocomposite thin film to laser irradiation at 532 nm using a CW Nd:YAG laser, microstructures included enclosed reservoirs, holes, and tunnels were created on the nanocomposite films. The microstructure formation is believed to be due to the thermal decomposition of polymers upon absorption of the thermal energy released by gold nanoparticles. This development will expand the capability of laser writing techniques for microprocessing and microfabrication.



Research Findings: Mathematical modeling of nanoparticle growth and size control
In order to use nanomaterials for future manufacturing, the size of nanoparticles must be better controlled. Different from traditional chemicals, the size and chemical structures of nanoparticles are often widely dispersed from the wet chemical synthesis process. Such processes are often complicated and require a much better understanding. Members of the team lead jointly by Dr. Brennan and Dr. Huo have begun to develop mathematical models to study nanoparticle growth in wet-chemical processes [7,8]. From the comparison of different models, further understanding on different stages of nanoparticle growth was revealed.

References
[1] For further information about this project email qhuo@mail.ucf.edu
[2] Liu, X.; Worden,J.; Dai, Q.; Zou, J.; Wang, J. ; Huo, Q., *Solid phase synthesis of monofunctional gold nanoparticles using noncovalent interactions,* Small **2**(2006) 891.
[3] Dai, Q.; Worden, J.; Trullinger, J.; Huo, Q. *A nanonecklace synthesized from monofunctionalized gold nanoparticles*. J. Am. Chem. Soc. **127**(2005) 8008.
[4] Worden, J.; Dai, Q., Huo, Q., *Nanoparticle-dendrimer conjugate prepared from a one-step chemical coupling of monofunctional nanoparticles with a dendrimer,* Chem. Comm. (2006) 1536.
[5] Sun, W; Dai, Q,; Worden, J. Huo, Q., *Optical limiting of a covalently bonded nanoparticle/polymer hybrid material,* J. Phys. Chem. B **109**(2005) 20854. *(for further information, email: wenfang.sun@ndsu.edu)*
[6] Chen, H.; Liu, X.; Muthuraman, H.; Zou, J.; Wang, J.; Dai, Q.; Huo,Q., *Direct laser-writing of microtunnels and reservoirs on nanocomposite materials,* Adv. Mater. 2006, published online
[7] Liu, X.; Worden, J.; Huo, Q.; Brennan, J., *A kinetic modeling study of gold nanopartical growth in solution,* J. Nanosci. Nanotech. **6**(2006) 1054.
[8] Brennan, J.; Liu, X.;Dai, Q.; Worden, J.; Huo, Q., *Stochastic model analysis of nanoparticle size polydispersity,* J. Comput. Theor. Nanosci. **3**(2006) 417