Synthesis and Applications of Metallic and Hybrid Nanoarchitectures

Research Advisor: Dr. George Chumanov

Metal nanoparticles exhibit a number of unique optical properties due to the excitation of collective oscillations of the electron density or plasmon resonances. Various nanoparticle assemblies are of particular interest because they have the potential to exhibit a range of novel phenomena due to the coherent interaction of their plasmon resonances. These phenomena are very promising for applications in a new generation of optical, photonic and sensing devices. The project involves the development of new methods for the preparation of uniform metal (Ag, Au, Cu, Pd, Ni) and hybrid nanoparticles, assembling them in various 1D, 2D, and 3D architectures, and their comprehensive characterization using optical, electron, and scanning probe microscopy (SPM), as well as different spectroscopic techniques. Hybrid structures will be synthesized using sol-gel methods, by coating metal nanoparticles with different metal oxides, semiconductors (SiO_2, TiO_2, $In(Sn)O_n$, etc.), and polymeric layers to produce novel nanocomposite materials with unique optical and electronic properties. The nanoparticles will be self-assembled on chemically modified and patterned surfaces. Patterning methods will include nanolithography with atomic force and scanning tunneling microscopes, "soft lithography", and electron-beam lithography. The results of these studies will provide fundamental information about near- and far-field interactions between metal nanoparticles under visible irradiation. This information will be used to design new optical, photonic, and optoelectronic devices as well as chemical sensors for various analytical, bioanalytical, and environmental applications. The latter requires the immobilization of biologically active molecules on the surface of nanoparticles. We have developed novel chemical procedures allowing covalent attachment of various proteins including antibodies and oligonucleotides to metallic nanoparticles encapsulated in dielectric protective shells. The same procedures were adapted for pattering of biologically important molecules of macroscopic flat surfaces that will be used for the development of multianalyte assays.

Due to its nature, the research program consists of many small projects comprising diverse methods and techniques which can be easily accomplished in a few weeks. REU participants will have the opportunity to choose from relatively simple projects related to synthesis and surface modification of nanoparticles to more sophisticated techniques such as nanolithography and electron beam lithography. The program provides various levels of complexity that will satisfy abilities and needs of different students.