Abstract
by
Eredzhep Menumerov

Materials with nanoscale dimensions allow for the exploitation of a set of unique and often extraordinary properties originating from finite size effects. The devices that are built using these nanomaterials are, therefore, capable of deriving new or enhanced functionalities based on the remarkable optical, chemical, thermal, magnetic, and transport properties accessible. Nanomaterial fabrication involves various methods and strategies for synthesizing, manufacturing, and assembling nanostructured surfaces and nanostructures. Over the last two decades there has been tremendous progress in the development of a variety of nanofabrication techniques able to meet the demands of nanotechnology and fundamental research. These nanofabrication techniques have already found their applications in numerous electronic, sensing, medicine, renewable energy, photovoltaics, construction, automotive, chemical, and catalysis applications. There, however, often remains a considerable gap between the demonstration of nanostructure synthesis and nanofabrication methods and their commercial implementation.
This dissertation serves to address these challenges by demonstrating the possibility to exploit several novel nanofabrication techniques such as the: (i) formation of stable metal nanoparticles using just a reducing agent, (ii) thermal dewetting, and (iii) fabrication of nanogaps using a single-step bending deformation. These nanofabrication techniques were applied to the catalytic reduction of 4-nitrophenol, hydrogen gas sensing, and thermal management in electronics.

A novel approach for synthesizing and stabilizing colloidal nanoparticles using only sodium borohydride (a common reducing agent) was used to investigate the role of dissolved oxygen in determining the induction time during the catalytic reduction of the anthropogenic water pollutant 4-nitrophenol. The same approach was then utilized to fabricate highly catalytic nanostructures using a single-step procedure that led to extraordinary catalytic activity with turnover frequencies as high as 65000 h\(^{-1}\) when reducing 4-nitrophenol.

Thermal dewetting is one of a number of unconventional methods for fabricating substrate-based nanomaterials and it was used to study the leaching of metal nanostructures through oxidative etching and its influence on the catalytic reduction of 4-nitrophenol. A modified thermal dewetting nanofabrication technique, devised and patented by the Neretina group, utilizes a sacrificial layer of Sb to exert control over the dewetting process. It was exploited to address the challenges of thermal management in electronic devices. Demonstrated are significant thermal conductance enhancements across metal-semiconductor interfaces using engineered nanostructures derived from this modified dewetting process.
A completely new strategy for fabricating nanogaps using a new approach reliant on a single step bending deformation was invented and it was further implemented into the fabrication of a hydrogen gas sensor with characteristics which include room temperature detection, a high sensitivity and selectivity towards H₂, low-cost lithography-free fabrication, and recyclability.