Colloquium

Department of Physics, Temple University

The Electronic Structure of Artificial Atoms (Quantum Dots): An Exercise in Applied Quantum Mechanics

Robert W. Meulenberg
Department of Physics and Astronomy and Laboratory for Surface Science and Technology, University of Maine, Orono ME 04469 USA

Abstract

Generally speaking, the properties of bulk materials do not depend on the number of atoms contained in some unit volume. For instance, the light absorption properties of a silicon wafer will not vary due to the physical dimensions of the wafer. Over 150 years ago, however, Michael Faraday discovered that certain forms of gold could exist as a red solution which he correctly attributed to a nanoscopic form of gold and thus providing evidence that the number of atoms can control the properties of a material. When considering this from a chemical perspective, however, this result is not entirely surprising, as the optical properties of □-conjugated carbon systems (i.e. benzene vs. naphthalene vs. anthracene) are drastically different. In physics, we utilize the periodic nature of solids to aid in the description of the electronic structure of materials. At some point, however, the application of Bloch's theorem will fail. It is at this intersection of physics and chemistry where the rich electronic structure of semiconductor quantum dots (QDs), so called "artificial atoms", exists.

In this presentation, I will discuss our group's efforts on using x-ray absorption spectroscopy (XAS), photoelectron spectroscopy (PES), and *ab initio* modeling of the experimental spectra to probe the electronic structure of QDs, including both elemental and binary semiconductor systems. XAS offers an ideal means with which to investigate the electronic structure of nanocrystalline materials because the technique provides an element specific and angular momentum resolved probe of the unoccupied density of states. Due to the constraints of the □$l = \pm 1$ dipole selection rule, we can choose appropriate absorption edges that will correspond to electron transitions from a localized initial state into the unoccupied states that are near or at the bottom of the conduction band. In certain cases, some of these vacant states are associated with the surface atoms and, therefore, these absorption edges are also well-suited for the investigation of doping and ligand-induced changes in the electronic structure of QDs. With XAS and PES, we probe the size dependent evolution of the electronic structure of QDs which agrees well with quantum confinement theory, which is an example of a simple problem in introductory quantum mechanics: solving the Schrödinger equation for a quantum particle in a finite well. I will also discuss how changing the chemical environment of the surface can have an impact on the electronic structure and lead to interesting new physics, such as induced magnetism.

Monday, February 25, 2019 at 3:00 pm
SERC, Room 116
Refreshments will be served at 2:45 pm