Investigations on Layers of Nanocrystals and on Layered Nanocrystals

A. Eychmüller, N. Gaponik, A. Shavel, D. Dorfs, K. Hoppe, H. Döllefeld, V. Noack, H. Henschel
Institute of Physical Chemistry, University of Hamburg
Bundesstrasse 45, D-20146 Hamburg, Germany

Over the past two decades research on structures in the size regime of nanometers has proven to be one of the most rapidly growing fields of modern science. This sector is being investigated by solid state physicists, inorganic chemists, physical chemists, colloid chemists, material scientists, and recently even biological scientists, medics and engineers. One access to prepare quantum dots by chemical methods is a colloidochemical one. The advantage of this kind of preparations is their versatility: by choosing primary materials and stabilizers, one can produce nearly any semiconductor material as nanometer-sized particles, some of them even in considerable quantities.

The presentation will cover recent advances made in the synthesis and in the characterization including the optical and electrical properties of CdS, CdTe, HgTe, and CdHgTe nanocrystals (NCs) capped with organic surfactants and self-assembled into superstructures (named also “artifical solids”). We will report on the investigation of the correlation between NCs size, chemical nature of the surfactants, inter-NCs separation, inter-NCs dielectric medium, and the choice of the substrate. We will outline our results from studies on compact layers of very small CdS nanocrystals which will be compared to the results from crystalline material together with simple theoretical modelling.

A second topic to be covered will be the charge carrier transport in nanoporous zinc oxide electrodes. By applying a simple phenomenological model in the analysis of transient photocurrents arising in particulate ZnO films, several information are gained concerning the transport of electrons through the nanoporous network. From the results of experiments using electrodes with different thicknesses of the ZnO film, the driving force of the transport is identified as a gradient in the electrochemical potential across the electrode. Furthermore, since no effect of the ambient temperature on the transport dynamics at positive potentials is observed, an tunneling mechanism is proposed for the basic electron exchange between adjacent particles. By changing the average size of the ZnO particles, information about the height and the width of the potential barrier are drawn for the different ensembles of nanoparticles.

A third section of the talk will deal with results on multilayered (also called “onion-like”) nanoheterostructures. Recent progress made in the preparation and characterization of three- and five-layered structures from II-VI semiconductor materials will be shown. We intended to prepare and characterize by high resolution transmission electron microscopy (HRTEM), powder X-ray diffraction (P-XRD) as well as temperature-dependent absorption and fluorescence spectroscopy the structure ZnS/CdS/ZnS. A very demanding experimental endeavour is the attempt to prepare a multiple quantum dot quantum well having two wells in a given particle. The materials combination mercury and cadmium sulfide leads to particles of the composition CdS/HgS/CdS/HgS/CdS. These five-layered nanocrystals have been prepared in several compositions giving rise to quantum dots that contain a double well electronic structure. Both HgS wells are either as thick as a monolayer or as two monolayers. The wells are seperated by a wall of two to three monolayers of CdS which consequently leads to a family of novel particles. Basic theoretical modelling will also be presented.