ELECTRODEPOSITED PBSE NANOCRYSTALS: SYNTHESIS, ELECTRICAL AND OPTICAL PROPERTIES

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Due to the low effective mass of electrons and holes, lead selenide shows strong quantum confinement when the crystal dimensions are reduced to a few nanometers [1]. This makes PbSe an an attractive material for building nanostructures [2]. In this contribution, we discuss the synthesis of PbSe nanocrystals by electrodeposition on Au(111) and we show that the characteristics of nucleation and growth determine the electrical and optical properties of the nanocrystals.

Electrodeposition of PbSe on flame-annealed Au(111) leads to nanocrystals with edges (parallel to the gold) of 10-25 nm and a height tuneable from 1 to 10 nm (see Fig. 1). Using chronoamperometry, we demonstrate that this geometry is related to a two-dimensional nucleation and growth mechanism. PbSe nanocrystals grow layer by layer on the gold substrate. This makes that the dimensions of the nanocrystals parallel to the gold surface are established shortly after electrodeposition starts and subsequent nanocrystal growth is in the direction perpendicular to the gold surface. Texture analysis by XRD shows that the nanocrystals grow with their (200) planes parallel to the Au(111) surface.

In a semiconductor nanocrystal with edges from 10 to 25 nm and a height of a few nanometer, electrons and holes are confined in one direction only. With scanning tunneling spectroscopy, we demonstrate that these nanocrystals have a staircase-like density of electronic states, in agreement with their dimensions [3].

A layer of PbSe nanocrystals on gold shows a striking color variation when the height of the nanocrystals increases for 2 to 20 nm (see Fig. 2). We have investigated the optical properties of PbSe nanocrystals electrodeposited on gold by spectroscopic ellipsometry. The ellipsometric spectra showed a marked dependence on the height of the PbSe nanocrystals (see Fig. 2). We found that this change was caused not only by a simple increase in layer thickness, but also by a variation of the dielectric constant of PbSe with the height of the nanocrystals. The measured variation of the dielectric constant of PbSe compares favorably with tight-binding calculations of the dielectric constant of thin layers of PbSe. This makes it possible to attribute the observed variation of the dielectric constant to quantum confinement effects along specific directions in the Brillouin zone [4].

References:

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Figures:

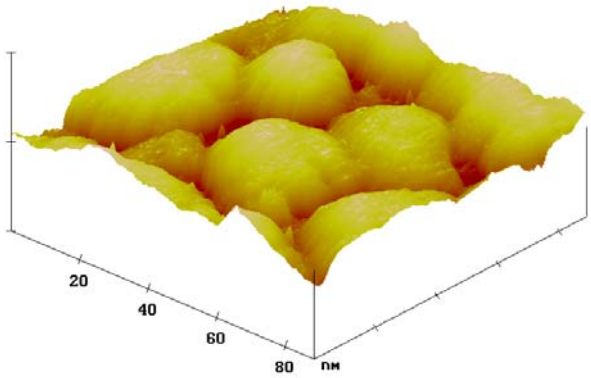

Figure 1: Room temperature STM image of electro-deposited PbSe nanocrystals on flame-annealed gold.

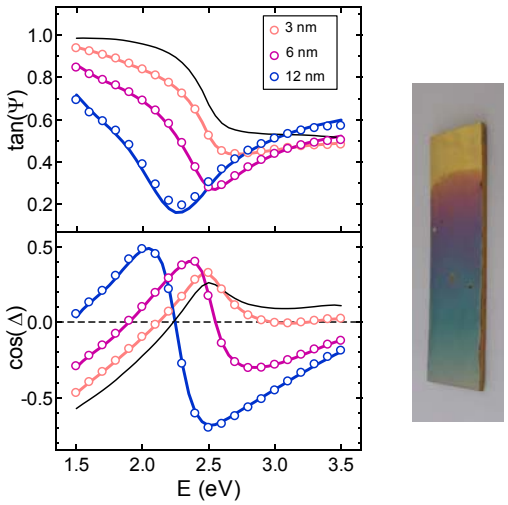

Figure 2: (left) Ellipsometric spectra obtained at a monolayer of PbSe nanocrystals of different height. (right) Image of a monolayer of PbSe nanocrystals on gold. The height of the nanocrystals increases from 2 nm (top) to 20 nm (bottom). A marked color variation occurs along with the variation in height.