PHOTOELECTRON SPECTROSCOPY FROM INDIVIDUAL HETEROEPITAXIAL NANOCRYSTALS ON GaAs(001)

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In the last decade, semiconductor systems with reduced dimensionality have attracted great interest regarding their basic physical properties as well as possible electronic and optoelectronic device applications. Growth in the Stranski-Krastanov mode is widely used to fabricate self-organized nano-scale quantum dots without the need for expensive lithography processes.

However, while the quantum dot concept sounds very promising, there are some serious problems that limit its possibilities. Applications will clearly depend on the control of the quality, composition, size, and uniformity of the dots. For example, size fluctuations lead to large inhomogeneous broadening of the photoluminescence spectra of ensembles of dots. To overcome this problem, nano-scale spectroscopic techniques have been developed which permit the study of the properties of individual quantum dots.

We measured core level spectra of individual heteroepitaxial InAs nanocrystals on a Se-terminated GaAs-substrate with the spectroscopic photoemission and low energy electron microscope (SPELEEM) at ELETTRA which allows laterally resolved photoemission spectroscopy. The nanocrystals were obtained by depositing nominally 2 and 4 monolayers (ML) of InAs on a Se-terminated GaAs surface. The Se-termination of GaAs(001) results in the formation of a 2-3 ML-thick film of Ga_2Se_3 on top of GaAs(001). During heteroepitaxy the InAs reacts with the Ga_2Se_3. A phase separation takes place on the anion sublattice, while an alloying takes place on the cation sublattice. During the initial stages of growth, a submonolayer-thick wetting layer of $In_xGa_{1-x}As$ is formed which is capped by $(In_yGa_{1-y})_2Se_3$. $(In_yGa_{1-y})_2Se_3$ covered InAs nanocrystals are formed on this surface. The implication of our results is that significant mass transport has occurred from the Se-terminated GaAs surface to the nanocrystals.

This is confirmed by differences in valence band structure and work function between the nanocrystals and the Se-terminated GaAs substrate which we measured with the SPELEEM. The samples showed differences in the valence band edge position and work function both between nanocrystals and substrate as well as between 2 ML and 4 ML. We suggest that a Se-termination of the InAs nanocrystals caused by the $(In_yGa_{1-y})_2Se_3$ surface layer is the reason for these differences.