Molecular Beam Epitaxy of Self-Organized PbSe Quantum Dot Superlattices

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Self-assembly of Stranski-Krastanow islands in lattice-mismatched heteroepitaxy has recently evolved as a novel tool for the fabrication of low-dimensional semiconductor nanostructures. In self-assembled quantum dots *superlattices*, the elastic interactions between the growing dots on the surface and those buried within the previous layers often lead to the formation of long range correlations within the dot ensembles. This can lead to a lateral ordering and size homogenization as well, which is of crucial importance for device applications. In contrast to other material systems, in IV-VI semiconductor quantum dot superlattices grown along the (111) growth directions, dot correlations *inclined* to the growth direction are observed. This leads to a unique *fcc*-like *ABCABC*... dot stacking sequence and a nearly perfect lateral ordering within the growth plane, and to the formation of *trigonal* self-organized 3D lattices of dots [1]. As shown by our previous work, this special type of ordering can be explained by taking into account the elastic anisotropy of the various materials systems [2].

In the present work, we have investigated how finite size effects affect the self-organization processes during PbSe superlattice growth. For this purpose we have fabricated several series of superlattice samples with (1) a variation of the thickness of the $Pb_{1-x}Eu_xTe$ spacer layers between the dots, and (2) with a variation of the PbSe dot sizes by adjustment of the PbSe thickness as well as the growth temperature. From cross sectional TEM as well as x-ray diffraction studies we find the occurrence of several different ordered dot phases due to abrupt changes in the type of vertical dot correlation at certain spacer thicknesses and dot sizes. For small spacer thicknesses and/or large dot sizes, the dots are vertically aligned with a weak hexagonal ordering in the lateral direction. For intermediate spacer thicknesses and/or medium sized dots, a well defined *fcc*-stacking is observed; and for large spacer thicknesses and/or small dot sizes no dot correlations are observed. For the different 3D dot arrangements, a qualitatively different scaling behavior of the lateral dot spacings versus spacer layer thickness is observed [3]. In addition, the different vertical correlations also result in a completely different evolution of dot sizes and shapes as a function of the number of superlattice periods. From finite element calculations it is shown that the different dot correlations are due to finite size effects, and the calculated spacer thicknesses for the transitions between the different dot phases are in good agreement with the experiments.

References:

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