INVESTIGATION OF MORPHOLOGY AND CHEMICAL COMPOSITION OF SELF-ORGANIZED SEMICONDUCTOR QUANTUM DOTS BY X-RAY SCATTERING

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Self-organization phenomena during epitaxial growth of semiconductor hetero-structures represent a promising route for a fabrication of semiconductor nanostructures such as quantum wires and dots in large volumes. Important parameters limiting the electronic and optical performance of self-assembled quantum dots are their size, chemical composition and structural homogeneity of the whole dot ensemble. These properties can be studied non-destructively by means of x-ray scattering.

In principle, small angle x-ray scattering is sensitive to the chemical contrast, i.e. to the variation of local electron density and it is completely insensitive to the deformation of the sample. Therefore, this method can yield information on the dot shapes and on the distribution of the dots not only at the sample surface but also at buried interfaces. For grazing angles of incidence of the primary x-ray beam, the information depth in the sample (the depth where the scattered radiation comes from) is very sensitive to this angle. Therefore, grazing-incidence small angle x-ray scattering (GISAXS) is suitable for depth-resolved studies.

Wide-angle x-ray scattering (x-ray diffraction) is mainly sensitive to the strain fields induced in the host crystal matrix by the elastic forces at the dot-matrix interface. These strains depend on the lattice mismatch, and consequently on the chemical composition of the dot lattice. From the comparison of the experimental diffraction data with the results of numerical simulations and using the dot shape obtained from the small-angle scattering measurements, it is possible to determine the chemical composition of the dot lattice. Since, in the first approximation, the intensity of the diffracted radiation is proportional to the dot volume, in a usual coplanar diffraction geometry the signal from the dots is much weaker than that of the host crystal. In the grazing-incidence diffraction arrangement (GID) the substrate signal is suppressed, and similarly to GISAXS, the diffraction process is depth selective.

We have used the GISAXS and GID methods for the investigation of the structure of SiGe self-organized dots at the interfaces of SiGe/Si superlattices [1], Ge dots in Si/SiC/Ge multilayers [2] and PbSe dots in PbSe/PbEuTe superlattices [3]. The dot parameters have been compared with those obtained by transmission electron microscopy and atomic force microscopy.

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