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Lateral inhomogeneities in engineered Schottky barriers

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The band alignment across heterostructures - e.g. the Schottky barrier height or the heterojunction band offsets - determines carrier injection and confinement in devices ranging from MESFETs to lasers, and several authors have attempted to tune such parameters through local modifications of the interface. For example, large changes in the Schottky barrier height have been observed in Al/n-GaAs(001) diodes following the fabrication of Si interface layers two monolayers thick under an excess flux of group V or group III atoms. The application of such heterostructures in practical devices hinge on the lateral homogeneity of the engineered interfaces. Such interfaces, however, include pseudomorphic and highly strained (approximately 4% in-plane mismatch) interface layers fabricated by MBE in nonequilibrium conditions. A driving force toward three-dimensional nucleation is clearly present during the growth of highly strained systems, and may affect these interfaces.

We measured the Schottky barrier height of Al/Si/GaAs(001) heterostructures using the SPELEEM (Spectroscopic Photo Emission and Low Energy Electron Microscope) at ELETTRA. It combines a LEEM with an imaging band pass filter, and has been operating successfully since the end of 1996 at the undulator beamline 6.2. The high brightness of ELETTRA together with an optimized instrument setting result in a spatial resolution of 22 nm and an energy resolution better than 0.5 eV in XPEEM mode, which is the highest lateral resolution ever reported for a spectromicroscope. The search for compositional and structural inhomogeneities which correlate with inhomogeneities in the electronic parameters (Schottky barriers) is ideally suited to the potential of the SPELEEM.

All epilayers were grown by solid-source MBE at the TASC-INFM. In detail, n-GaAs buffer layers 500 nm thick were initially grown at 600°C on n^+-GaAs(001) wafers. Under the growth conditions employed, the GaAs exhibited a 2x4 surface reconstruction. After growth of the buffer, the samples were cooled to 300°C. Si epilayers 0-3ML thick were subsequently grown under an As flux of 4×10^{-6} torr. The typical Si growth rate was 20 Å/h. The heterostructures were then protected by an amorphous As cap layer during transfer in air from the MBE facility to the beamline.

As-grown samples with a Si interlayer thickness of 0.5 and 3 monolayers appeared homogeneous within the spatial resolution of the SPELEEM (22 nm), suggesting that Schottky barrier engineering leads to interfaces with lateral homogeneity comparable to that of 'natural' metal-semiconductor interfaces. Annealing an Al / Si(As) / GaAs(001) heterostructure for 10 min at 500°C, however, caused inhomogeneous As out-diffusion which is correlated with a local As 3d core level shift of 0.3 eV. We suggest that the reported degradation of such engineered Schottky barriers might be correlated with laterally inhomogeneous As out-diffusion upon annealing.