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Bragg Surface Diffraction as probe for studying surface/interface defects in opto-electronic devices grown on GaAs(001) substrates

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Abstract – Opto-electronic devices based on embedded nanostructures demand a special attention due the very peculiar features offered by the quantum scale of the inner opto-active structures. Being the encapsulation an essential requirement, non-destructive and penetrating techniques are needed for studying the buried structures. Bragg Surface Diffraction (BSD) is a special 3-beam case of X-ray diffraction that supplies an extremely parallel diffracted beam as well it acts in greater depths compared with grazing incidence techniques. Such odd feature of BSD makes it very suitable for studying surfaces/interfaces of opto-electronic devices based on encapsulated nanostructures as it is shown in this work.

Bragg Surface Diffraction (BSD) is a special case of 3-beam X-ray diffraction where an asymmetric reflection, whose diffracted beam travel nearly parallel to the macroscopic surface of the crystal (Figure 1a), is excited along with a symmetric Bragg reflection [1,2]. Such odd feature of BSD make it very suitable for study systems based on embedded nanostructures which is not possible apply traditional microscopy techniques and also is not accessible by grazing incidence methods due their extremely shallow penetration [3].

Self-organized quantum dots (QDs) grown on top of semiconductor surfaces are the active structures for light-emission/light-detection in many opto-electronic devices. Being the capping of these nanostructures an essential requirement for this type of device, the BSD technique shows up as an excellent candidate to probe information about the structure of such encapsulated devices.

In this work the potential of BSD is exploited for studying InAs QDs on GaAs(001) substrate as well for studying the intermediate stages of the construction of these devices (wafer surface condition, buffer layer, exposed QDs). Two-dimensional intensity profiles of BSD are measured with synchrotron and conventional X-Ray sources which show distinct intensity distributions along the secondary streak (diagonal intensity spread showed in the Figures 1b and 2) in several configurations of samples. Furthermore, changes in the slope of the diagonal streak were observed and it is related to strain in the lattice or even tilt in the cap layer lattice due the presence of the QDs.

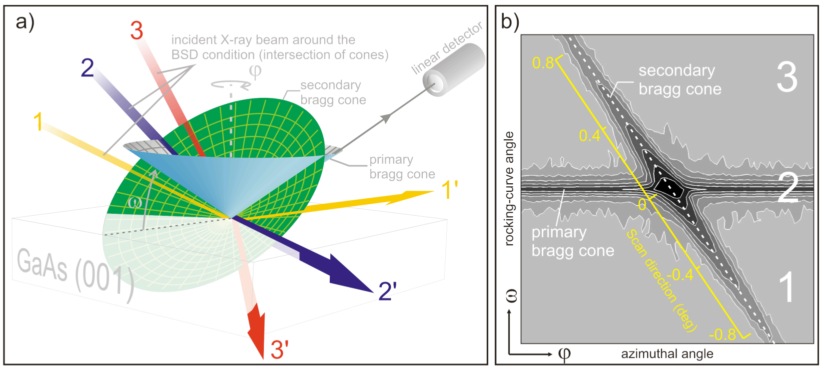

Figure 1: a) In a single crystal undergoing Bragg-surface diffraction (BSD), rescattering processes of the surface beam (1, 2 and 3) are monitored via linear detectors in ordinary diffraction geometries of symmetric Bragg reflections. For incidence angles below (beam 1) and above (beam 3) the primary Bragg cone, the surface beam probes structure above (beam 1') and below (beam 3') the surface, respectively. b) Two-dimensional intensity profile obtained by scanning the intersection of the Bragg cones.

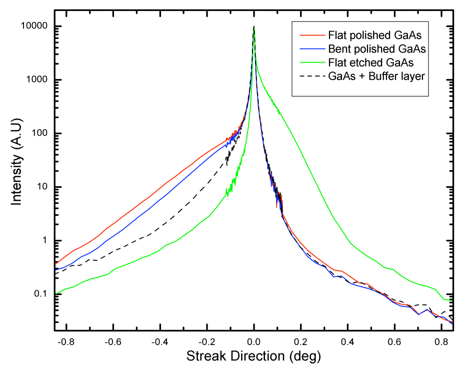

Figure 2: Intensity profiles achieved through scans along the secondary reflection streak: BSD technique shows high sensitivity for presence of defects on the firsts few atomic layers of the sample. Different configurations of samples were analyzed.

References

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