Strain In Semiconductor Nanowires And Device Integration

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One-dimensional nanowires (NWs) are promising materials for future nanodevices owing to their small dimensions and novel properties. After ten years of materials optimization [1], it is now possible with the help of X-rays and synchrotron radiation to draw some preliminary conclusions about the structural requirements necessary to tune the physical properties of demanding devices in terms of strain control and size distribution. The frontiers of information given by diffraction experiments performed at the European Synchrotron Facility will be illustrated by III-V and IV-IV semiconductor devices.

Quantitative structural information about epitaxial arrays of Au-catalyzed NWs will be reported for InAs/InP longitudinal [2] and core/shell [3] heterostructures grown by MOCVD on InAs $(111)_B$ substrates (see Fig. 1 (a-b)). *Grazing incidence X-ray diffraction* (GIXRD) and *crystal truncation rod* measurements allow separating the NW contribution from the substrate overgrowth and give averaged information about crystallographic phases, epitaxial relationships with orientation distribution, and strain. Wrap gate InAs NWs have been also studied after HfO_2 dielectric coating and Cr metallic deposition necessary for transistor integration. X-ray diffraction allows determining the strain tensor and shows a longitudinal contraction increasing with HfO_2 and Cr shell depositions. The measurement of grazing incidence X-ray scattering [2, 3] for different azimuths with respect to the nanowire edges has shown the signature of the initial hexagonal shape and of the coating thicknesses of the wires.
Longitudinal InP/InAs/InSb NW heterostructures with different InAs insertion thicknesses will be also presented. *Anomalous scattering* measurements and *reciprocal space mapping* close to the As and Sb absorption edges (11.8 and 30.5 keV) allows estimating the InAs interdiffusion inside the wires and separating the structural and chemical part of the strain relaxation occurring in complex heterostructures.

Mechanical relaxations of strained Silicon On Insulator (sSOI) nanostructures will be discussed from the point of view of isolation and implantation processes used in transistor technology (see Fig. 1 (c)). The strain in long etched sSOI lines of different widths and 2D sSi samples implanted by As/Xe ions with the same stripe geometry (the gate stack acting as an implantation mask) is measured by GIXRD [4]. Then, Fully Depleted Silicon-On-Insulator (FDSOI) n and pMOSFETs (Metal-Oxide-Semiconductor-Field-Effect-Transistors) integrated with a TiN/HfO_2 gate stack on 1.55 GPa strained SOI (sSOI) and 2.1 GPa eXtremely strained SOI (XsSOI) substrates will be analyzed. The performance improvement in terms of effective mobility as well as the threshold voltage has been systematically extracted as a function of the gate width and the channel orientation for long and narrow n and pMOSFETs and correlated to strain properties [5].

Recent results corresponding to the use of micro-beam *coherent Bragg diffraction* on single and buried wires will also be presented. Size requirement (sample and beam) and reconstruction of strain distribution in single wires will be illustrated with the previous samples (see Fig. 1 (d)).

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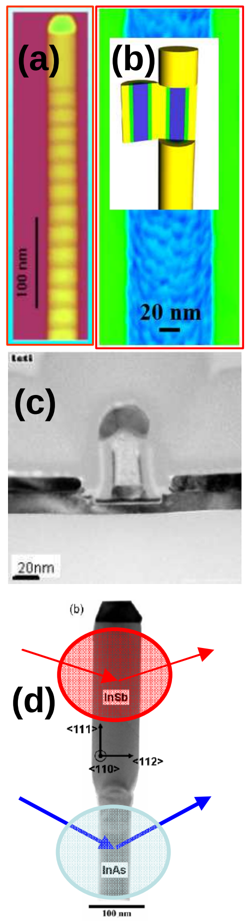

Figure 1. Examples of NWs studied by X-ray: (a) assembly of longitudinal InAs/InP NWs, (b) Core/shell Cr/HfO_2/InAs assembly, (c) Si active layer in n-MOSFET on SOI (arrays of transistors), (d) single InSb/InAs NW with a micro-beam.