

Defects, activation and morphological modification by out of equilibrium processes in Si and Ge-based materials

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Nowadays the “More Moore” approach, consisting in extreme miniaturization of semiconductor integrated circuits, regards 70% of the microelectronic industry. Thus, the interest in nanomaterials, such as thin-films, quantum dots and nanowires has rapidly increased in the recent past decades from both technological and theoretical points of view. However, the structural characterization of these unceasing downsizing nanomaterials presents several challenges which semiconductor industry has to face.

In this paper, we report two examples of collaborations with semiconductor factories where the practical use of TEM-related techniques have been paramount for a deep understanding of the chemical and structural properties of their materials of interest.

First, we report the Energy Filtered TEM investigations of Si based nanopowders found as a by-product during the out of equilibrium Inductively Coupled Plasma (ICP) process, usually performed by Tekna Plasma Systems Inc. (Canada) for the industrial production of silicon microspheres. To this purpose, three classes of Si nanostructures have been extensively studied and two different growth processes (oxide and metal assisted growth) have been elucidated. These structures are demonstrated to result from Rayleigh instability due to rapid post-synthesis heating of the SiNWs before their cooling down in the final part of the ICP reactor.

Secondly, we present the study of strain due to atomic Phosphorous located in a defect free and perfectly recrystallized Germanium after Laser Thermal Annealing treatment. For hot topics of nanoscience, such as laser integrated on Si, Ge needs high active doping (above $1e20$) and tensile strain. For this reason, there is leading technological interest for quantifying the contribution of dopants to the strain. We demonstrate that, despite its small atomic radius compared to Ge, substitutional P induces a lattice expansion, putting in evidence that the “electronic contribution” (which is associated to the increased hydrostatic deformation potential in the conduction band of P doped Ge) is larger than the “size mismatch contribution” (associated to the atomic radii).