Why silicon dioxide is needed to grow GaAs nanowires on Si(111) by Vapor-Liquid-Solid method using Ga as catalyst

Fouquat Louise[1], X. Guan[1], M. Vettori, J. Penuelas[1], G. Grenet[1]

[1]*Institut des Nanotechnologies de Lyon (INL), Ecole Centrale de Lyon, Ecully, France*

louise.fouquat@doctorant.ec-lyon.fr

To obtain good optoelectronic performances, Ga (instead of Au) must be used as catalyst to grow GaAs nanowires (NWs) on silicon by Vapor-Liquid-Solid (VLS) method [1]. Typically, this self-catalyzed growth is performed directly on epi-ready Si substrates rather than on clean Si substrates [2-4]. The VLS process is complex because the substrate temperature must be such that the catalyst sticks on the substrate and forms liquid droplets. These droplets are thought to etch the SiO_2 overlayer and reach the substrate from which well-crystallized and well-epitaxied nanowires can grow. However, despite a strong technological concern, the nature of the chemical interaction between the metal and the substrate for the Ga/SiO_x/Si system is not yet fully understood.

In this work, we present a photoemission study focusing on the early stages of the self-catalyzed growth of GaAs nanowires on epi-ready Si substrates. The interaction of Gallium droplets with silica is investigated by in-situ X-ray Photoemission Spectroscopy right after the Ga deposition in the MBE reactor. The initial configuration of the Ga droplets is controlled by the deposition temperature, which is of special interest as it determines NWs dimensions and repartition.

Confronting XPS spectra with Atomic Force Microscopy (AFM) images gives clear evidence that Gallium, under precise deposition conditions, locally interacts with the silicon native oxide to produce the volatile compounds SiO and Ga_2O. This oxydo-reduction reaction leads to nano-holes in the SiO_2 overlayer, which allow contact between liquid Gallium nano-droplets with the cleaned crystalline silicon and thus the epitaxial growth of nanowires.

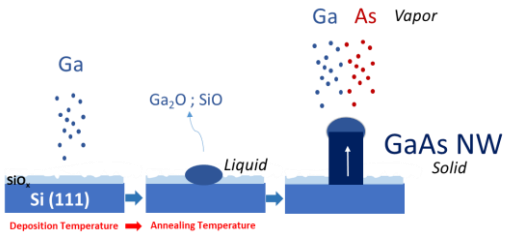

Fig. 1: Vapor-Liquid-Solid (VLS) mechanism for growing GaAs nanowires on Si by Molecular Beam Epitaxy (MBE).

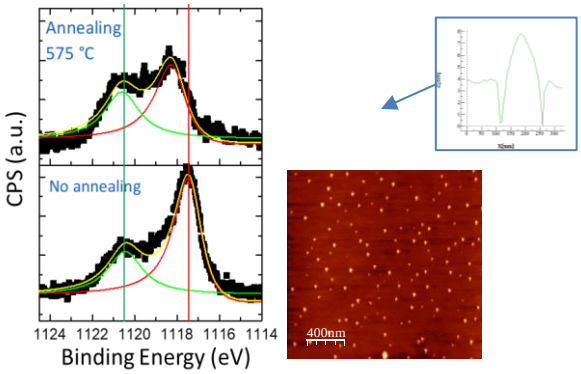

Fig. 2: Ga2$p_{3/2}$ core level Photoemission spectra and AFM pictures of Gallium nano-droplets before and after annealing showing the presence of nano-holes.

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