Heterogeneous nucleation of CBE grown catalyst-free InAs nanowires on silicon

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Monolithic integration of III-V nanowires on silicon substrates has gained considerable research interest because of its significant potential for future electronic and opto-electronic devices. The common way to grow NWs is the vapor liquid solid (VLS) mechanism in which foreign metal nanoparticles deposited on the silicon substrate catalyse the growth. Catalyst-free growth techniques are however intensely explored driven by the need to avoid metal contamination and favour its full compatibility with the present silicon technology[1,2].

Direct growth of III-V NWs, in particular InAs on silicon, does have critical issues. InAs NW growth is usually accompanied by unwanted parasitic island formation and both continue to nucleate even after long growth times, causing neighbouring nanocrystals to coalesce. For most practical purposes, it is desirable to suppress the coalescence process by reducing the initial nucleation density as well as inhibiting new nucleation. However, there are very few reports on density-control methodologies for InAs NWs on silicon [3,4]. Therefore, there is an urgent need for understanding the nucleation mechanisms of NWs and islands deposited on silicon to achieve control on their density.

In this contribution, we present a new approach to prepare Si (111) surfaces for the controlled growth of InAs NWs by chemical beam epitaxy (CBE). We show that controlled sputtering of the surface of Si (111) enhances the nucleation of InAs crystals (NWs and islands) while no nucleation occurs on non-sputtered Si (111) surfaces under identical growth conditions. We argue that this stems from the formation of surface defects associated to the sputtering process that serve as preferential physical nucleation sites. Furthermore, we show that the silicon surface can be modified by in situ growth and ex situ sputtering parameters allowing to control the density of InAs NWs over a wide range. We show that the yield of NWs with respect to islands can be maximized by choosing an optimum growth window obtaining InAs NW densities in the range of ~1-30 NWs/μm^2 with a yield of ~50%. [5]

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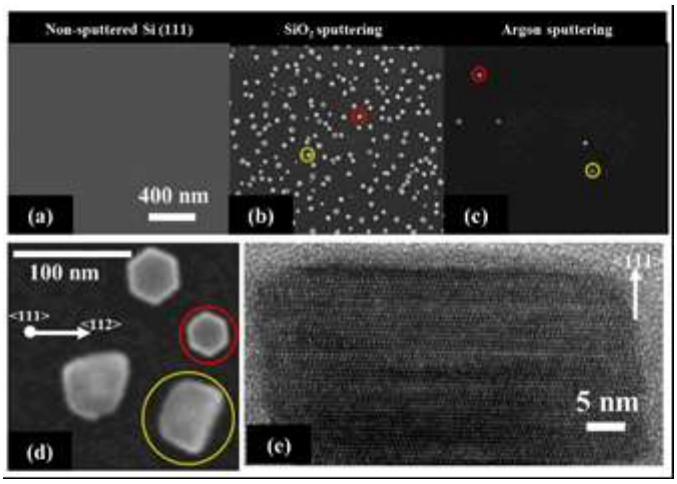

Plan-view SEM micrographs of InAs crystals grown under identical conditions on (a) non-sputtered, (b) SiO_2 sputtered, and (c) ICP Argon sputtered silicon substrates. (d) Plan-view SEM micrograph of InAs NWs and islands from the sample shown in (b). The coloured markers are used to identify islands (yellow) and NWs (red). (e) High-resolution TEM image of an individual InAs NW from the sample shown in (b) taken in the Si <110> zone axis.