Selective Area Epitaxy and Doping of Catalyst-Free GaAs Nanowires on Silicon

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III-V semiconductor nanowires (NW) have gained a lot of interest for their ability to be integrated on silicon due to their small footprint and therefore efficient strain relaxation mechanism. With molecular beam epitaxy (MBE), a lot of research has been focusing on catalyzed growth of NWs in the vapor-liquid-solid (VLS) growth mode using either metallic, most prominently gold, or group III element droplets.

For the realization of optoelectronic devices like solar cells, LEDs or electrically pumped lasers using NWs, control of the doping profiles is key and directly affects performance when designing the necessary pn- or pin-junctions. Even though aspect ratios for VLS grown NWs are typically superior to NWs grown using selective area epitaxy (SAE), doping these structures directly proofed difficult due to non-uniform incorporation of dopants during growth [1] and the reservoir effect that is caused by the droplet catalyst [2]. Particularly in GaAs, while n-type doping using the amphoteric dopant silicon is well established for growth directly from the vapor phase in planar samples, only p-type material could be realized so far for VLS NWs. Literature from liquid phase epitaxy (LPE) suggests that the preferential incorporation on Ga lattice sites only occurs for temperatures beyond 860°C [3], which are inaccessible in the usual MBE VLS growth.

To date, most investigations of SAE growth of catalyst-free GaAs NW arrays have focused on the nucleation and growth kinetics during chemical, i.e., MOCVD-based processes. In contrast, growth kinetics studies have not yet been performed for physical, i.e., MBE-based processes, where differences in the surface reactivities, incorporation and adsorption/desorption kinetics are expected.

In this contribution, we present our recent advances in establishing the selective area epitaxy of completely catalyst-free GaAs NWs on silicon (fig. 1). We achieve this by applying a special surface treatment to our SiO_2 masked nanoscale apertures before growth, which transforms the usual 7x7 silicon surface to a 1x1-As terminated surface reconstruction. We explore the effects of mask opening diameter, pitch, V/III flux ratio and growth temperature with respect to growth rate and morphology. In addition, we probe the microstructure of our nanowires using TEM.

Furthermore, we show preliminary results of the influence of silicon doping on the growth kinetics and morphology.

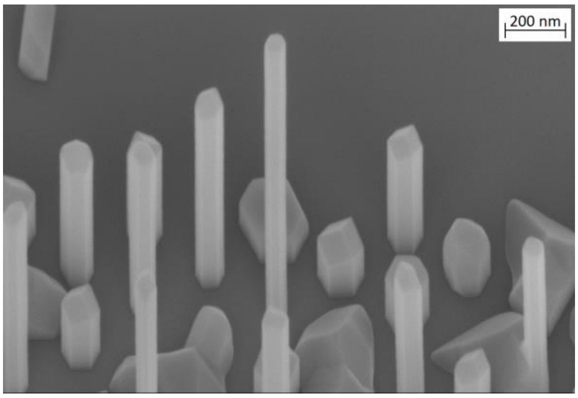

Fig. 1: GaAs nanowires with high aspect ratios grown on silicon without a catalyst.

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