

Ga-catalysed and self-catalysed growth of GaAs nanowires by molecular beam epitaxy.

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Nanowires (NWs) of elemental semiconductors, of III-V and II-VI binary compounds, together with a small number of ternary alloys, have been synthesised in the last years using a variety of growth techniques [1]. Typically the anisotropic growth of the wires is assisted by the presence of a metal particle, commonly called the catalyst.

Catalyst-assisted growth can be in principle exploited to obtain a precise location of the nanowires on the substrate by nano-patterning of the catalyst. However, the diffusion of the catalyst in the nanowire body during the growth may change the electronic characteristics of the semiconductor in an unpredicted way. We have recently demonstrated evidences of Au in ZnSe nanowires [2], as well as indication of diffusion of Mn in Mn-catalysed GaAs NWs [3]. Here we report on Ga catalysed, as well as on catalyst-free growth of GaAs NWs by molecular beam epitaxy.

A number of papers [4] recently reported the growth of III-V NWs obtained by using the group III material of the binary compound as the catalyst. However, our work represents the first success of a completely self-assembled technique for the growth of GaAs NWs without the use of outside catalysts.

The GaAs NWs have been grown on cleaved edges of Si(100) wafers. The wafers were cleaved in air a few minutes before being inserted in the ultra high vacuum (UHV) system. The substrates were then degassed at 300° C in UHV for 30' before being introduced in the MBE chamber. The wires have been grown using Ga and As molecular fluxes corresponding to a two-dimensional GaAs growth rate of 1 µm/h, with a V/III beam equivalent pressure ratio of 15.

For Ga catalysed growth, we have deposited on the substrate an amount of Ga corresponding to a nominal thickness between 2 and 5 Ga monolayer (ML, Ga atomic density on GaAs (100) surface: 1 ML=6.258 E14 atoms/cm²). The deposition has been performed at the selected growth temperature in the 500-650°C range. It is well known that in the absence of group V overpressure Ga tends to form liquid droplets. A 30' long GaAs growth was started immediately after Ga deposition.

Both with and without Ga pre-deposition, one-dimensional nanostructures were obtained on the cleaved edges of Si(100) wafers. In Fig. 1 a scanning electron microscopy (SEM) image of NWs obtained growing GaAs at 600°C after depositing 5 ML of Ga is shown. The NWs are about 5 µm long and have a section diameter in the range of tens of nm. Energy dispersive X-ray spectroscopy (EDS) performed in the SEM demonstrates that the spherical particle found on the top of the NWs is composed of Ga, and confirms that the NW body is GaAs. Very analogous results are obtained by depositing GaAs at 600°C with no Ga pre-deposition. A representative image of the nanowires grown with this latter method is shown in Fig. 2. Also in this case, a spherical particle is observed at the NWs tip, and EDS confirms that it is a Ga particle, suggesting that a Ga induced self-catalysed growth occurred. The NWs density appears to be dependent on the crystallographic orientation of the facets that compose the cleaved edges of the Si-wafers.

As can be seen in Fig. 1 and 2, the growth also produces another type of NWs that generally display a smaller aspect ratio, and have no metallic tip on their top. In those cases EDS demonstrates that the whole nanostructure, including the top part, is composed of GaAs. Work is in progress to understand the growth process and in particular to understand if the

droplet-less NWs grow through a different process or the absence of a Ga droplet could be due to its lost during growth or sample manipulation.

Figures:

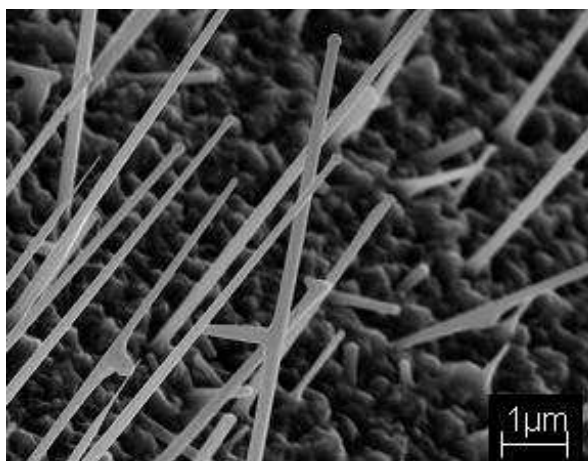


Fig.(1). SEM image of Ga-catalyzed GaAs NWs grown on cleaved edge of Si (100). Ga droplet is clearly visible at the top of NWs and nanorods in the back ground with no droplets at the top.

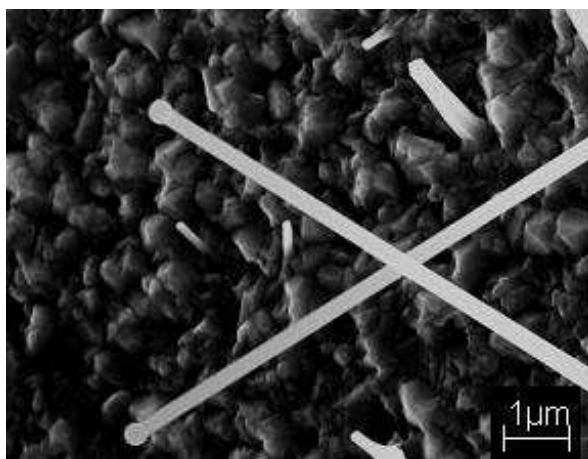


Fig. (2). SEM image of self-catalyzed GaAs grown on cleaved edge of Si (100). NWs have Ga droplet at the top demonstrating self-catalyzed growth and nanorods are also present with no droplet at the top.

References:

- [1] see, e.g., W. Lu and C. M. Leiber, *J. Phys.* **D 39**, (2006) R387 and references therein
- [2] E. Carlino et al., *Phil. Mag. Lett.* **86**, 261 (2006).
- [3] Martelli et al., *Nano Letters* **6**, 2130 (2006).
- [4] see, e.g., Clint J. Novotny and Paul K. L. Yu, *Appl. Phys. Lett.* **87**, 203111 (2005), M. Mattila, et al., *Appl. Phys. Lett.* **89**, 063119 (2006); Bernhard Mandl et al., *Nano Letters* **6** 1817 (2006).

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