Novel crystalline behaviors of self-catalyst GaAs nanowires on GaAs(001) substrates with thin film masks by molecular beam epitaxy

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One-Dimensional (1D) semiconductors have been developed over the last two decades into a large field and they are believed to be building blocks for wide range of applications. III-V group semiconductors are well-known materials with high electron mobility and conductivity that are important for future high-speed and low-power nanoelectronics [1]. Here we present in detail of self-catalyst GaAs nanowire (NW) growth on hydrogen silsesquioxane (HSQ)-coated GaAs(001) substrate using molecular beam epitaxy (MBE).

After coating and annealing of HSQ in the air, substrate surfaces were uniformly covered with 20-nm-thick SiO_x which could open pin-holes at the beginning of the growth [2]. Surface treatment is particularly important for NW growth and usually follows complicated procedures. In this work, Ga exposure in 20 s on HSQ-coated substrates without As flux was performed to create NW nucleation sites i.e. Ga nanoparticles. The typical growth condition is as follows; Ga beam equivalent pressure (BEP) of 5.4×10^{-8} Torr (growth rate of 0.04 ML/s on planar), As BEP of 1.0×10^{-6} Torr (V/III ratio of 18.5), and growth temperature of 620 ^{o}C.

Figure 1(a) shows top-view scanning electron microscope (SEM) image of NWs after 4-hour growth. To remove Ga nanoparticles at top of NWs, the NWs were kept in As flux of 2.0×10^{-6} Torr at 500 ^{o}C for 1 hour without Ga flux. The obtained NWs were found to project on substrate to form approximately 35^{o} and 73^{o} with their own projections <1$\bar{1}$0> and <110>, as shown in Figs. 1(b) and 1(c). We also observe that the NWs' cross sections of the all directions show hexagonal shape indicating <111> orientations. 35^{o} NWs along <1$\bar{1}$0> are observed to be predominant and attributed to <1$\bar{1}$1>B orientations. 35^{o} NWs pointing along <110> is also evaluated to be <1$\bar{1}$1>B derived from inverse polarity of crystal through thin and non-polar native oxide layer on substrate. 73^{o} NWs were observed to be <1$\bar{1}$1>B which are formed through on-substrate rotation of <1$\bar{1}$1>B by 60^{o} around <111>A. The tendency for 60^{o} rotation around <111> on single NW was observed through TEM analysis which enables twin plane formation.

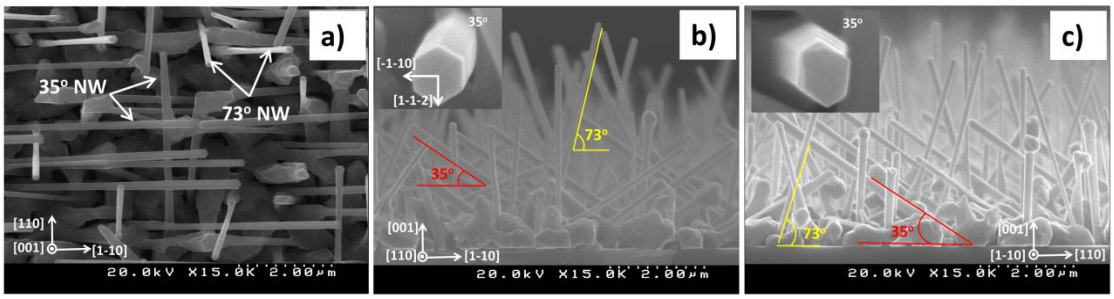

Figure 1: GaAs NWs grown by MBE, a) plane view SEM image, b) cross view of (1$\bar{1}$0) plane, c) cross view of (110) plane. The insets of b) and c) show hexagonal cross sections of 35^{o} NWs pointing along <1$\bar{1}$0> and <110> respectively.

Reference

1) R. Chau et al., Nat Mater **6** (2007) 810.

2) T. Rieger et al., J. Crystal Growth **353** (2012) 39.