In-plane oriented InAs nanowire formation by selective area molecular beam epitaxy on GaAs (211)B substrates

Masashi Akabori, Tatsuya Murakami, Syoji Yamada
Japan Advanced Institute of Science and Technology (JAIST), Nomi, Ishikawa, Japan

III-V compound semiconductor nanowires (NWs) have received much attention as base components of nanodevices. Especially, InAs NWs are very promising to realize high-performance electronic and spintronic nanodevices because of their high electron mobility and large spin-splitting. For the nanodevice applications, it is desirable that the NWs are synthesized with controlling their positions as well as orientations. Catalyst-free selective area epitaxy on partially masked (111)B substrates is one of the suitable methods to synthesize vertically-oriented InAs NWs [1]. However, in-plane-oriented NWs are more suitable for the nanodevice fabrication by using conventional lithography. To this end, selective area molecular beam epitaxy (SA-MBE) on (110) has been carried out [2]. However, since there are two <111>B directions in (110) plane, there is a difficulty in the orientation control. In this paper, we demonstrate in-plane oriented InAs NW formation by SA-MBE on GaAs (211)B substrates. Since (211)B has one <111>B direction in plane, it can be more suitable for in-plane oriented NW formation than (110).

We coated n-type GaAs (211)B substrates with hydrogen slisesquioxane (HSQ), and patterned them with a hole array by using electron-beam lithography and reactive ion etching. The initial opening holes were designed with a triangular shape. We treated the substrates by H_2SO_4 and de-ionized water followed by loading them into a conventional solid-source MBE system. The beam equivalent pressures of In and As were fixed to 1.0×10^{-7} and 1.0×10^{-6} Torr, respectively. The substrates were heated up to 590°C once under As ambient for the thermal cleaning, and then they were cooled down to 510°C for the growth. The growth time was fixed to 3 hours.

Figure 1 shows a scanning electron microscope (SEM) image of InAs NWs grown on (211)B. Almost all InAs growth started from the opening holes, and a few polycrystalline deposition on HSQ mask area was observed. Therefore, SA-MBE under the growth condition was almost succeeded. We can see three in-plane oriented NWs and one out-of-plane oriented NW in the image, which are <111>B oriented. The yield of in-plane oriented NW formation is roughly estimated to be ~15 %, which is almost similar to that on (110) [2]. Figures 2(a) and 2(b) show an atomic force microscope (AFM) image and a current image taken by a conductive AFM cantilever, respectively. Since current flowing through InAs NW and n-GaAs substrate was confirmed, the InAs NWs are conductive without any intentional doping.

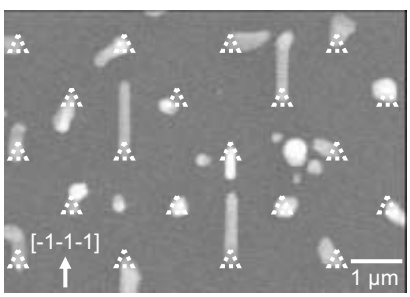

Fig. 1 Top-view of InAs SA-MBE on a GaAs (211)B substrate. Triangular marks represent position of initial opening holes.

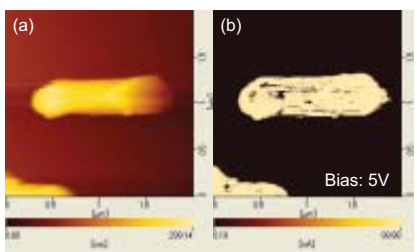

Fig. 2 AFM image (a) and current image (b) of InAs NWs.

[1] M. Akabori *et al.*, J. Crystal Growth, **311**, 3183 (2009).
[2] M. Akabori *et al.*, J. Crystal Growth, **345**, 22 (2012).