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Elemental Distributions in Individual Ge/Si/Ge Core-Double Shell Nanowires Investigated by Atom Probe Tomography

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Introduction

Over the past decade, core/shell semiconductor nanowires (NWs), as potential building blocks for electronic and photonic devices, have attracted considerable attention due to its unique electronic properties caused by the one-dimensional quantum confinement effect [1]. The core/shell NWs' electronic properties are directly affected by their atomic composition and the dopant distributions. Therefore it is highly desirable to know the elemental distributions in individual core/shell NWs.

Atom probe tomography (APT) has been proved to be a powerful instrument to obtain three dimensional dopant distributions with nearly atomic-scale resolution. It had been reported that APT can be applied to study single NWs. The single NWs were grown on the top of a micropost vertically for APT analysis [2]. However, unlike single NWs, the core/shell NWs get collapsed during growth. So this method is not suitable for core/shell NWs. Hence, in this study, we employed an appropriate way to prepare the specific individual Ge/Si/Ge core-double shell NWs for APT.

Experiment details

Ge/Si/Ge core-double shell NWs were grown on SiO_2 substrate by chemical vapor deposition (CVD), with gold nanocolloid particles as the seeds for vapor-liquid-solid (VLS) growth. The B atoms were only doped during the Si shell formation [3]. The NWs were then transferred to a TEM grid for further processing. Individual Ge/Si/Ge core-double shell NW specimens for APT observations were prepared by focused ion beam, with FIB-SEM dual-beam system. As the Ge/Si/Ge core-double shell NWs were too fine to pick up directly by the conventional lift-out probe, a two-step pick-up method was employed. First we pick up a long Si NW, next use this Si NW to pick up the Ge/Si/Ge core-double shell NWs (Fig. 1(a)), and then mount it to the micropost vertically. Finally the Si NW is cut by Ga ion beam to release the lift-out probe (Fig. 1(b)). The Ge/Si/Ge core-double shell NWs were analyzed by a local-electrode type atom probe (LEAP4000X-HR, AMETEK).

Results and discussion

Figure 1(c) shows an example of a 3D map of Ge/Si/Ge core-double shell NW. In the APT map, only the Si and Ge double shells were observed, but the Ge core did not appear. One of the possible reasons is that the Ge core expected to be located too deep while the analysis region is only the apex, as explained in schematic in Fig. 1(d). What's more, the B atoms were also observed, which were mainly distributed in the Si shell. In this presentation, the details of sample preparation and more analysis data will be shown.

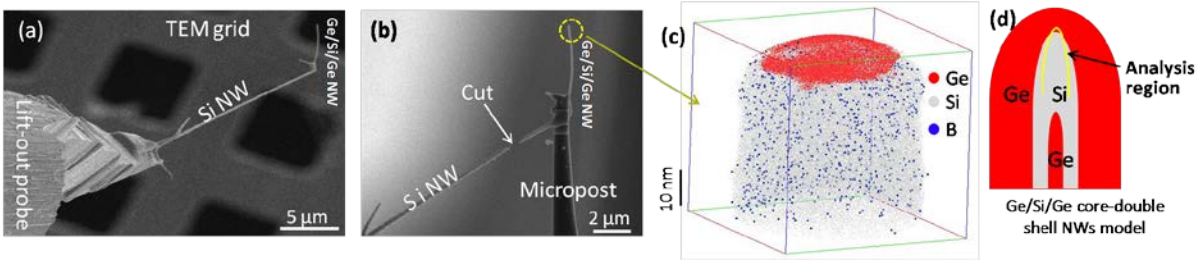

Figure 1. (a) and (b) SEM images showing the process of individual Ge/Si/Ge core-double shell NWs preparation for APT. (c) 3D APT map of Ge/Si/Ge core-double shell NWs. Ge, Si and B atoms are rendered as red, gray and blue dots, respectively. (d) Expected schematic of analyzed volume in Ge/Si/Ge core-double shell NWs.

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Reference:

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