Surfactant mediated Selective Area Growth of Germanium nanowires

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Site-selective integration of semiconductor nanowires directly on a Si substrate is a prerequisite for the scalability of nanowire-based devices. This work reports the selective area growth by metalorganic vapor phase epitaxy (MOVPE) of in-plane Ge nanowires and their networks on patterned Si (001) substrates. Here, the growth of the semiconductor material is limited to openings made in a SiO_2 mask using electron beam lithography and dry etching techniques [1].

Nanowire growths are carried out at 30 mb in a N_2 atmosphere using isobutyl germane (IBuGe) as the Ge precursor and arsine (AsH_3) as a probable source of H^+ for substrate surface treatment prior to growth. The patterned substrates are first deoxidized at 820°C under AsH_3, then cooled down and stabilized at 750. Before IBuGe is introduced to initiate the Ge epitaxy, we allow an arsine-free N_2 purge of variable duration. This step is found to modify the aspect ratio and surface coverage of the germanium islands formed during the initial stages of nanowire growth.

We understand this behavior as the result of a time-dependent memory effect of AsH_3 which provides a variable As coverage on the growth surface. This modifies the growth kinetics of Ge since As was reported to act as a surfactant during the growth of Ge [2]. A purge step of 4 minutes resulted in a uniform surface coverage of Ge islands, and the resulting nanowires exhibited the best crystal quality. Transmission electron microscopy studies of the fully-grown Ge nanowires showed the creation of periodically arranged misfit dislocations at the interface between the Ge nanowire and the Si substrate as the primary strain relaxation mechanism.

To demonstrate the high quality of the nanowire networks, the electrical properties were investigated. For this, temperature-dependent Hall effect measurements were performed on the fully-grown Ge nanowire networks to evaluate the charge carrier mobility and crystal quality of the nanowires. The nanowires were found to be p-doped for the whole temperature range of measurement (300 K to 2 K), suggesting a low background incorporation of arsenic during the nanowire growth. Finally, the temperature-dependent hole mobility was analyzed to understand the charge scattering mechanism.

References

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