In Situ Growth of Si Nanowires Using Transmission Electron Microscopy

Yi-Chia Chou
Department of Electrophysics, National Chiao Tung University, Hsinchu, Taiwan

The growth of semiconductor nanowires by the vapor-liquid-solid (VLS) and vapor-solid-solid (VSS) mechanisms takes place when the growth material, supplied from a gas phase species such as a chemical vapor deposition (CVD) precursor, dissolves into catalyst particles (liquid or solid, respectively) and precipitates at the catalyst/substrate interface. In order to gain a detailed understanding of this process at the atomic level, we examined Si nanowire growth in situ, to provide a direct view as growth takes place.

We discuss observations made in two different instruments, an ultra high vacuum (UHV) TEM and an aberration-corrected environmental TEM (ETEM), by introducing an environmental friendly catalyst system which opens up the opportunity for nanowire growth in UHV and non-UHV systems. The UHV TEM allows us to introduce low pressures (below 10-5 Torr) of a precursor gas such as disilane to a heated Si sample decorated with Au or other metal catalysts. With UHVTEM we can achieve oxide-free surfaces and well-controlled growth kinetics. However, in conventional CVD reactors, Si nanowires grow at higher pressures, over 10-3 Torr, rather than under UHV conditions. ETEM allows us to explore Si nanowire growth kinetics at these pressures, and to compare the results with those from UHV TEM. In ETEM we can observe details of the Si/catalyst interface, defects and epitaxy. We will describe the addition of Si bilayers during VLS growth in ETEM, and the addition of bunched steps consisting of three Si bilayers during VSS growth with AuAg catalysts. However, we find that the details of growth dynamics in ETEM are different compared to UHV, in particular, the structure and dynamics at the trijunction. Even though the samples appear clean at the start of growth, we find that an amorphous layer of SiO_2 builds up under the beam. We speculate that this layer arises from beam-induced reactions between disilane and residual water vapor in the microscope. This layer pins the liquid at the original trijunction location, changing the local kinetics of the process. ETEM is therefore extremely valuable for understanding growth, but we need to consider effects arising from the combination of non-UHV conditions with the electron beam for a quantitative interpretation of the results.