Comment on “Gold nanowires from silicon nanowire templates” [Appl. Phys. Lett.84, 407 (2004)]

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Gold nanowires from silicon nanowire templates
One-dimensional nanowires of both metal and semiconductor find potential applications in nanotechnology. Attempts have often been made to form interconnect between semiconductor and metal nanostructures using metal silicides. A recent letter by Wong et al. is dedicated to a convenient method for the formation of Au nanowires (AuNWs) embedded in silicon nanowire (SiNW) templates. Enhanced indiffusion of Au and outward motion of the Si–SiO$_2$ interface to minimize the surface energy at an elevated temperature are modeled for the formation of AuNWs in the core of oxidized SiNW. The authors negate the possibility for the formation silicide phase at elevated temperatures. A high-resolution transmission electron microscopy (TEM) image of the annealed sample, showing interlayer spacing corresponding to [111] plane for Au, is provided as the only evidence for the formation of Au in the core. Unfortunately, in this particular case, the evidence of interlayer spacing with no information of crystalline orientation may not be sufficient to prove the core structure as metallic gold as the information regarding the formation of gold silicide only in the low-temperature range 370–500 °C is not at all true.

Since the advent of microelectronics, Au–Si is most well studied system for its possible applications as an interconnect. Despite the early setback of interconnect with Au in Si, as the device property is degraded by a high diffusion rate of Au in Si, it still has numerous advantages in bipolar and rf-power transistor and other microelectronic applications. Metastable phases of gold silicides, in the composition ranges from Au$_5$Si to Au$_7$Si with different structural and electronic properties, are reported. With the Au–Si system being a simple eutectic at 363 °C about 19 at.% Si and large interdiffusion of Au in Si, various gold silicide phases are, in fact, reported at temperatures up to ~1000 °C. There is no reason why the silicidation should not occur at annealing temperatures of 500–880 °C, reported in the letter. Subjected to an annealing temperature of 500 °C, the authors observed a change in the shapes of as-grown nanocrystallites on SiNWs but no attempt is made to identify the crystalline structures of these nanocrystallites. As a matter of fact, the interlayer spacing of 0.235 nm for the sample annealed at 880 °C may also closely match with 0.236 nm spacing for [311] planes corresponding to cubic Au$_5$Si, 0.237 nm spacing corresponding to cubic Au$_2$Si, and 0.239 nm spacing for both [220] planes corresponding to cubic Au$_5$Si phase and [114] planes corresponding to orthorhombic Au$_7$Si. An analysis of interlayer spacing, without a proper analysis of the selected area electron diffraction (SAED) pattern may not be conclusive enough to ascertain the true phase of the core structure reported in the letter. Astonishingly, no attempt is made by Wong et al. to analyze the crystalline orientation using the SAED pattern of the nanostructures at any stage of growth and obtain complete structural information, which is well within the purview of TEM analysis.

Moreover, the formation of AuNW in the core SiNW, as claimed by Wong et al. also seems to be incorrect. A careful look at Fig. 3(a) in the letter shows that a grainy structure of the core and nanostructures with a similar dark contrast are also present radial to the core structure all along the wire. It is true that the density of nanostructures with a dark contrast is considerably high in the core forming a wirelike structure, but the study is not conclusive enough to either prove that it is a nanowire or its correct phase. The core structure may be a simple agglomeration of silicide nanoclusters. However, it is difficult to predict which silicide phase will be most stable at the core of nanostructure reported in the letter. Oxygen acts as an impurity in Si and impedes its diffusion in the Au–Si system. In the presence of oxygen during annealing at 10 Torr, as reported by Wong et al., the gold silicide phase with a high content of Au in the unit cell is likely to be stable.

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