Movement of Au-Si Catalyst Droplets at High Temperatures

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ABSTRACT

Semiconductor nanowires are potential candidates of nanoscale devices of electronics[1] and optoelectronics which concern size- and dimensionality-dependent physical properties. For the growth of well-controlled silicon nanowires, catalysts play the key role because of their influence on the growth rates, orientations and even wire shapes. Au-Si eutectic droplets are conventionally chosen as catalysts for Si nanowire growth of vapor-liquid-solid (VLS) mode because of the high diffusivity for silicon in gold at or even below the eutectic temperature and good adhesion of gold to the substrate. However, years of study have not actually unveiled all aspects on the mechanism of the catalyst such as: Au-Si droplet migration behavior[2] before and during the nanowire growth. The evolution of Au-Si droplets with temperature and chemical environment is a complex yet important issue from both fundamental research and application points of view, since it involves nanoscale phase diagram[3] and liquid-solid interaction, as well as the control of nanowire growth. For this issue, studies on the behavior of Au-Si droplets at temperatures lower the nanowire growth temperature are urged, since the evolution at a lower temperature will become much slower, which allows us to make observation at time scale of seconds or minutes.

In this work, the transport behavior of Au-Si droplets on silicon surface with increasing temperature in argon atmosphere is investigated. The sample was prepared by depositing a uniform Au layer on Si substrate via sputtering. For the as-grown sample, a smooth SiO_2 layer was formed with a thickness of 3 nm on the Au layer due to exposure of the sample to air, which was observed previously by others. At the temperature of 700℃ the Au layer began to aggregate and Au-Si droplets were formed, making the surface SiO_2 layer protrude. At the temperature of 900℃ the Au-Si droplets were found to penetrate into the silicon substrate with SiO_2 islands formed on the tops of the droplets. Such a vertical movement of the Au-Si droplets and therewith the formation of SiO_2 islands can be explained by the Au-catalyzed oxidation of Si in argon atmosphere with inevitable residual oxygen. More interestingly, at the temperature as high as 1100℃, the Au-Si droplets were found to move laterally along the smooth interface between the surface SiO_2 layer and Si substrate just like self-propelled motion[4] of liquid droplets on solid surface with different surface tensions. The driving force is attributed to the symmetry breaking of droplet surface tension along the contact line due to the oxygen concentration gradient at the interface, which is supposed to be caused by the Au-catalyzed Si oxidation process.

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KEYWORDS

Au-Si droplet, oxidation, catalyst, catalyst droplet movement