Using intruded gold nanoclusters as highly active catalysts to fabricate silicon nano-stalactite structures

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The amount of attention focused on catalysts based on metal nanoparticles (NPs) and nanoclusters has increased dramatically in recent years because of their applicability in wide fields of modern science and technology, including physics, chemistry, engineering, and biomedicine [1]. Use of metal catalyst to prepare nanostructures on semiconductor materials has attracted much attention because of the improved devices performance. In most cases, the metal catalysts were positioned on the substrate and the 1D nanostructures subsequently constructed through growing (bottom-up) or etching (top-down) processes [2].

In this study, we employed the intruded Au nanocluster (INC) technique to prepare highly uniform, "atomic-scale" (ca. 3 nm) Au nanoclusters as highly active catalysts within Si wafers. Employing the Au nanoclusters as highly active catalysts allowed us to readily and rapidly prepare, at room temperature, unique Si nano-stalactite (SNS) structures of ultrahigh density and very narrow diameter (ca. 10 nm). We used high-resolution transmission electron microscopy (HRTEM) to analyze the distribution of the Au nanoclusters that had intruded beneath the Si surface. Figure 1 (a) presents a cross-sectional HRTEM image of the Si substrate obtained after using the INC method. An ultrathin layer (thickness: ca. 3 nm) of metal clusters was clearly evident underneath the substrate's surface. In the next step, we performed etching in a mixture of HF, H_2O_2, and DI water. Figures 1 (b–d) reveal the surface morphology of the Si substrate, analyzed using SEM, after etching for 1.5 min. These SNS structures possessed superior light trapping capability relative to corresponding structures prepared using electroless metal deposition (EMD) methods; in addition, the etching duration was much shorter. Figure 2a reveals that the reflected light had a decreased intensity (down to ca. 2%) for the SNS structure having an average depth of ca. 250 nm and an average pore size of ca. 20 nm. Figure 2b reveals that the reflected light had a decreased intensity (down to ca.17%) for the Si nanowires fabricated by EMD method having an average depth of ca. 250 nm and an average pore size of ca. 150 nm. Detailed fabrication methods and results of optical and field emission will be reported in the conference.

[1] M. S. Chen and D. W. Goodman, Science **306**, 252-255 (2004).
[2] Peidong Yang, Ruoxue Yan and Melissa Fardy, Nano Lett. **10**, 1529-1536 (2010)

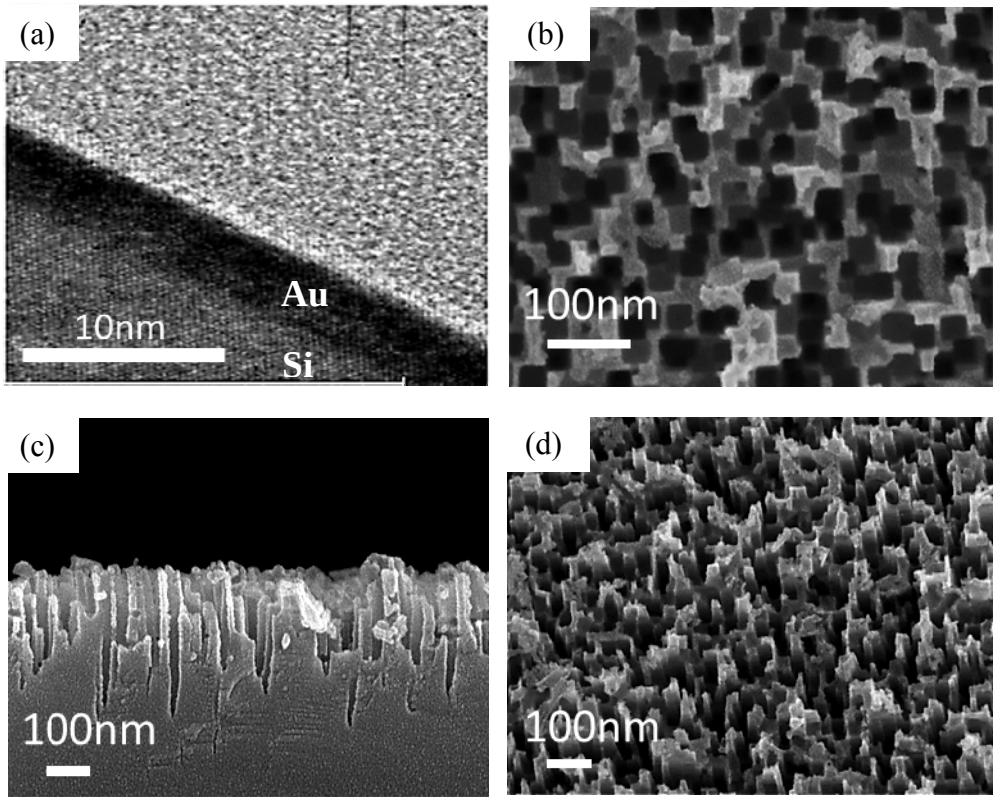

Figure 1: (a) Cross-sectional HRTEM image of the Si substrate after using the INC method. An ultrathin layer (thickness: ca. 3 nm) of Au clusters clearly remained beneath the substrate surface. (b) Top-view, (c) cross-sectional, and (d) slightly tilted (10°) top-view SEM images of the structure obtained after etching for 1.5 min in the INC process.

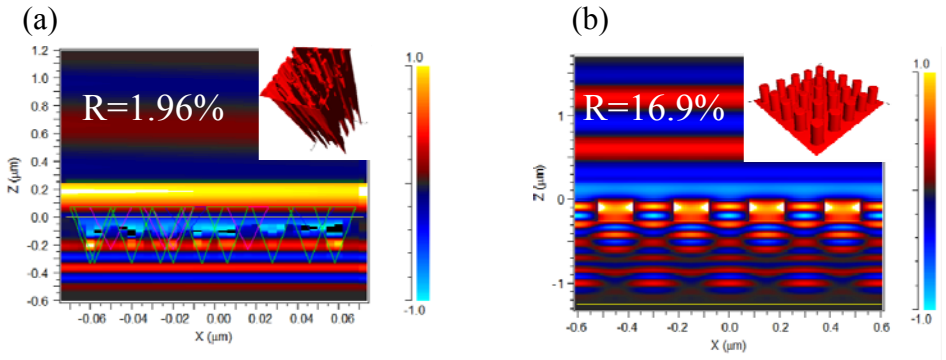

Figure 2: Optical simulations of antireflection nanostructures. Simulated (3D-FDTD method) reflection properties of various surfaces. A plane wave (wavelength: 600 nm) was propagated from 0.25 µm above the air–nanostructure interface to the substrate in the presence of nanostructures (a) SNS (b) Si nanowires