Supporting Information

Electrochemical patterning of gold nanoparticles on transparent single-walled carbon nanotube films

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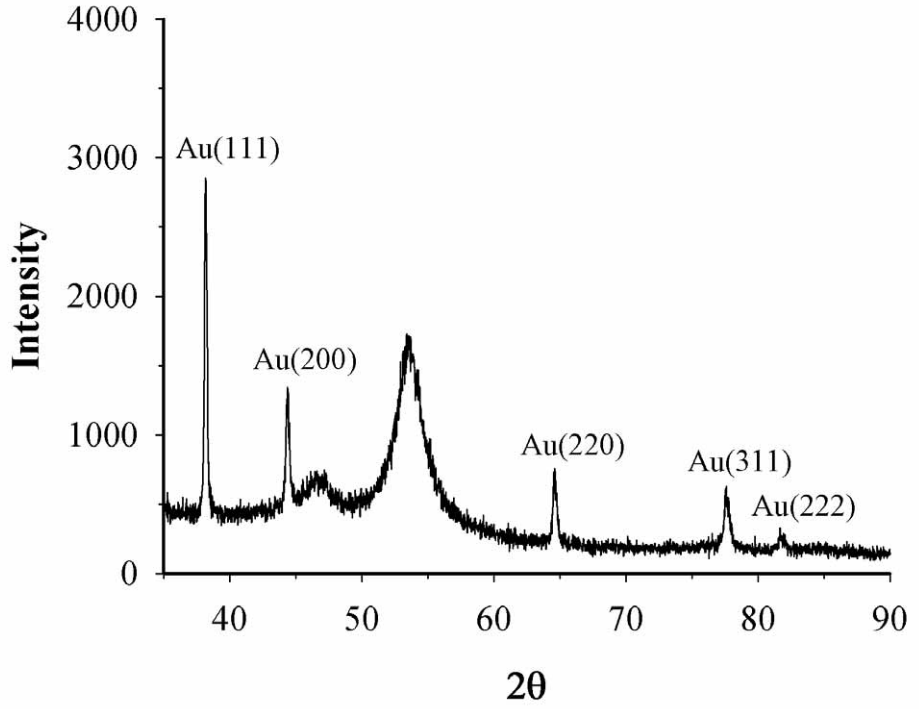

Fig. S1 X-ray diffraction (XRD) of gold nanostructures on the SWCNT thin film.

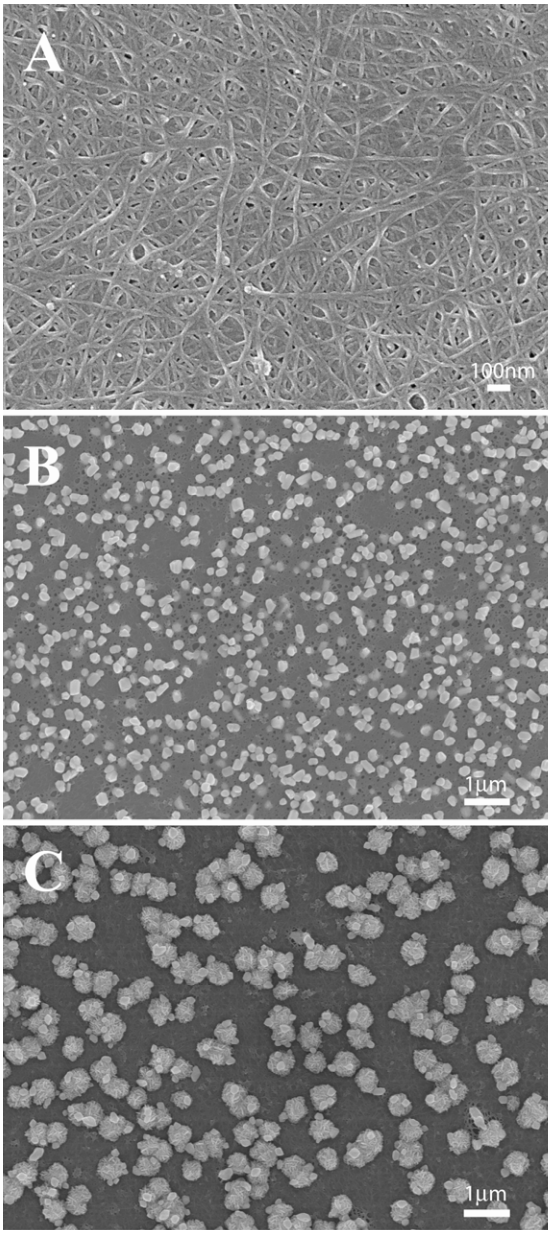

Fig. S2 FE-SEM images of SWCNT films: (A) bare SWCNT film, (B) gold nanoparticle-patterned SWCNT film, (C) gold nanoparticle-patterned SWCNT film after silver staining with a silver enhancement kit (Eppendorf, Hamburg, Germany).

Silver particles were fabricated through silver staining by the gold nanoparticles on the SWCNT films, and then the SERS activity was investigated.[1,2] The silver staining was performed by incubation of the gold nanoparticle-patterned SWCNT films for 5 min in a silver enhancement solution, which was a 1:1 vol combination of the two solutions: Silverquant A, which contained the silver salt, and Silverquant B, which contained the hydroquinone. The size of the silver particles was around 500 nm in diameter.

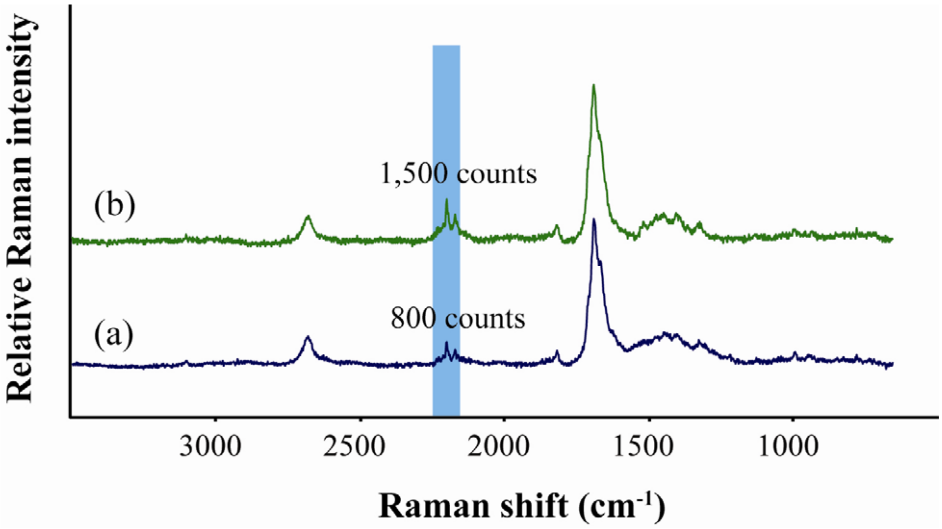

Fig. S3 Typical surface-enhanced Raman spectra of (a) 1 mg/ml, and (b) 10 mg/ml of $K_3[Fe(CN)_6]$ absorbed onto gold nanoparticle-patterned SWCNT films after silver staining.

The SERS signal enhancement seen with the silver particles was 20 times lower than that seen with the gold nanoparticles. We believe that this is because nanoparticle spacings are too large to generate a large electromagnetic field enhancement, which means that the number of “hot-zone” is greatly reduced by the particle aggregations through silver staining.

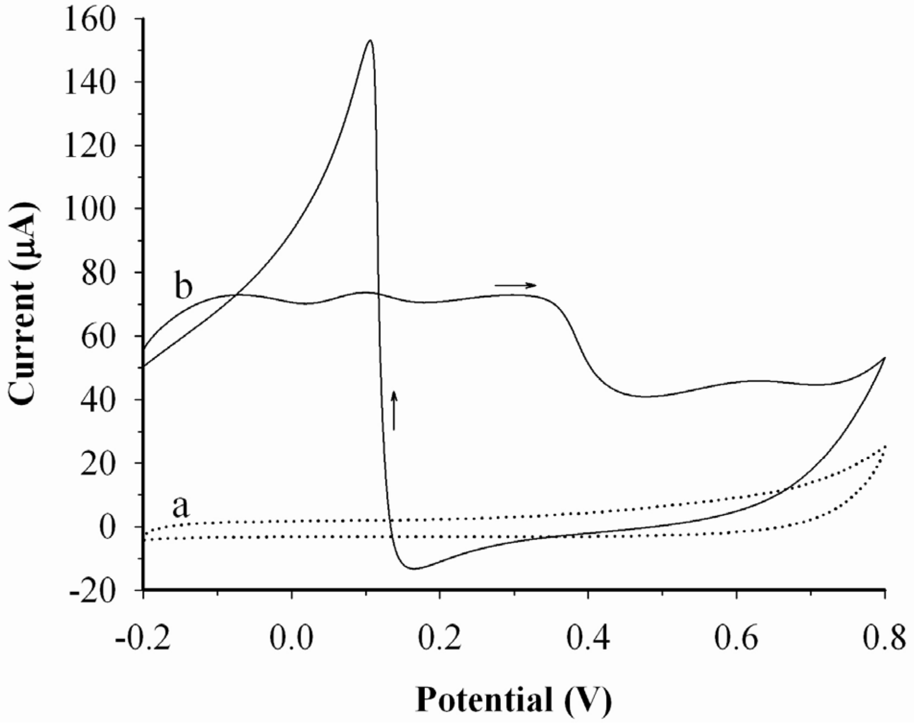

Fig. S4 Cyclic voltammetries for the oxidation of 5 mM glucose on (a) bare SWCNT electrodes and (b) gold nanoparticle-patterned SWCNT electrodes in 50 mM of phosphate buffer including 0.1 M of NaOH at a scan rate of 50 mV/s.

The procedures for fabricating the glucose sensor

The homogeneous SWCNT films were fabricated by a vacuum filtration method. Briefly, the SWCNT mixture (Topnanosys co., South Korea) was sonicated for 1 h, and then centrifuged at 14,000 rpm for 10 min. The pre-suspended solution was further diluted by a factor of 50 with deionized water and filtered through an anodic aluminum oxide membrane of 0.2 μm pore size.

The alumina membrane under the SWCNT thin-layer was easily removed in 3 M NaOH solution and the SWCNT thin layer was then transferred to a flexible PET film directly after adjusting the solution to neutral pH using deionized water.

Gold nanoparticles on the SWCNT films were patterned using a standard photolithography method and the electrochemical deposition. A positive photoresist polymer (AZ4620) was spin-coated onto the produced SWCNT films at 1,500 rpm for 1 min, followed by exposure to UV light (~365 nm) through a designed mask and development with AZ400K solution. Gold nanoparticles for glucose detection were electrochemically deposited on the SWCNT films pre-patterned with photoresist polymer at 0.6 V (vs Ag/AgCl) in the 1 mM $HAuCl_4$ solution using chronocoulommetry technique. The density of the gold nanoparticles was controlled by adjusting the charge deposited onto the SWCNT working electrode (the exposed area was 0.25 cm^2). Clean platinum wire and Ag/AgCl (saturated in 3 M NaCl) were used as counter and reference electrodes, respectively. The SWCNT films were then immersed in the tetrahydrofuran solution to completely remove the photoresist polymer from the SWCNT films. This was followed by washing with ethanol and deionized water, and drying under nitrogen gas.

Cyclic voltammogram behavior of glucose at gold nanoparticle-patterned SWCNT film

Fig. S4 compares the cyclic volyammograms of 5 mM glucose at a bare SWCNT electrode and a gold nanoparticle-patterned SWCNT electrode in 50 mM of phosphate buffer including 0.1 M of NaOH. No redox peaks are observed at the bare SWCNT electrode. However, the gold nanoparticle-patterned SWCNT electrode exhibits multiple oxidation peaks in the potential region from -0.1 V to +0.3 V. The peaks present a mechanistically complex oxidation process (i.e. electrosorption of glucose on the electrode surface, formation of glucose intermediates layer, oxidation of glucose intermediates).[3,4] Above a potential of +0.4 V, the decrease of current occurs due to the formation of gold oxide, which competes for surface adsorption sites with glucose, also inhibiting the direct electro-oxidation of glucose. In the negative-potential scan, with the reduction of the surface gold oxide, enough surface active sites are available for the direct oxidation of glucose, resulting in large peak at around 0.1 V.

References

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