Abs. 89, 204th Meeting, © 2003 The Electrochemical Society, Inc.

Gold nanowire formation of 2-dimensional network structure with electric conductivity

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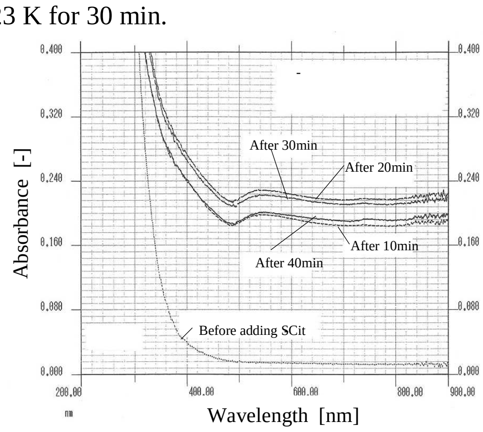
The synthesis of nano-scale inorganic crystals with a specific size and morphology has recently attracted a lot of interest because of the potential to design new materials and devices in various fields.

Gold nanowires with a 2-dimensional network structure were formed by the fusion of gold nanoparticles while controlling the concentration of reductive reagent in the synthetic method for gold nanoparticles. Gold nanoparticles can be produced by reducing 2.52×10^{-4} $kmol/m^3$ sodium chloraurate (C-Au) aqueous solution with 6.76×10^{-4} $kmol/m^3$ tri-sodium citrate (S-Cit) at 353 K for 60 min.[1] We changed the concentration ratio RT=[S-Cit]/[C-Au]. When RT decreased to 0.27 (Figure 1), ultraviolet-visible (UV-vis) spectra showed nanowire patterns, i. e., almost constant absorbance from 500 nm to over 900 nm corresponding to blue color, from reaction time 10 min to 40 min, indicating stable formation of nanowires.

Transmission electron microscopy images clearly showed the formation of a network structure of gold nanowires. (see Figure2) Treatment of water-soluble thiol compound to separate all gold nanomaterials to an individual particle, and the electron diffraction of gold nanowires revealed that gold nanowires were made of fused gold nanoparticles.

Fused gold nanowires should show electric conductivity. The gold nanowires produced in C-Au with S-Cit system were separated as precipitates by centrifugation, dispersed in 2×10^{-3} g/ml gelatin aqueous solution and spread by dip-coating on a hydrophobized glass plate with ferric stearate. The electric resistance of the films was measured as follows. Two electric conductive lines of silver paste were made on the film of gold nanowires. The distance between the two lines was adjusted to 1 cm. The resistance between two lines was measured by digital multimeter. The resistance of the dip-coated gold nanowire films with nanosize thickness after removing gelatin by calcinations was around 1 ohm/cm as shown in Figure 3. The network structure was nicely maintained after calcinations at 623 K for 30 min. However, the network structure of gold nanowires was destroyed and changed to gold nanoparticles after calcinations at 723 K for 30 min. The electric resistance of gold films calcined at 723 K for 30 min became one order magnitude higher than that calcined at 623 K for 30 min.



RT=[S-Cit]/[C-Au]=0.27

Figure 1. UV-vis spectra of gold nano-materials under the conditions of [C-Au]= 2.52×10^{-4} $kmol/m^3$, 353 K.

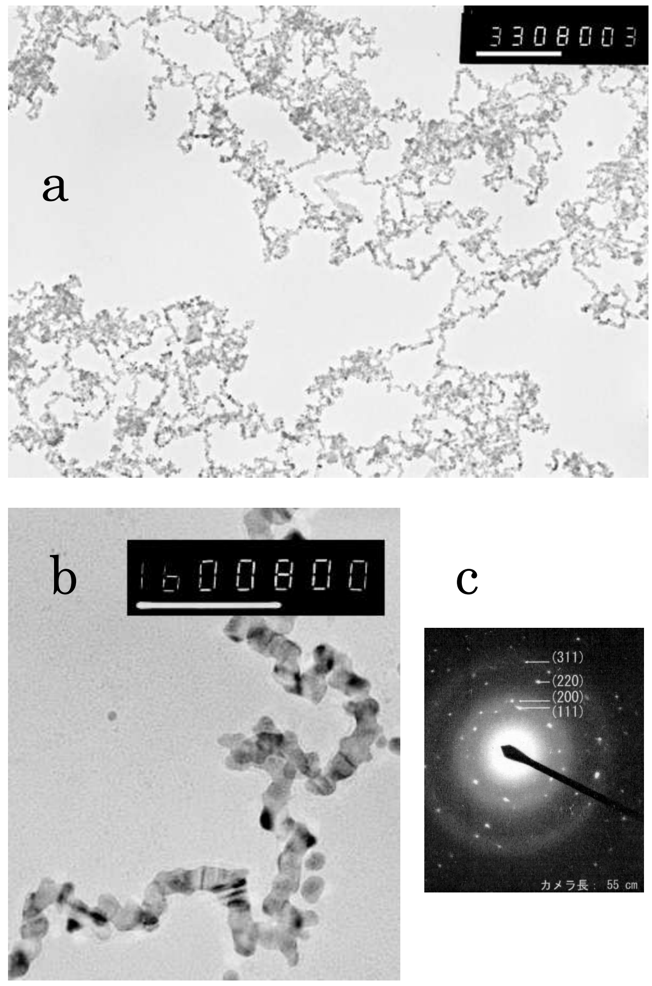


Figure 2. TEM images of the sample obtained at RT=0.27. a) Reaction time was 30 min. (bar: 303nm) b) A magnified view of Figure 2a. (bar: 62.5nm) c) Electron diffraction of the gold nanowire

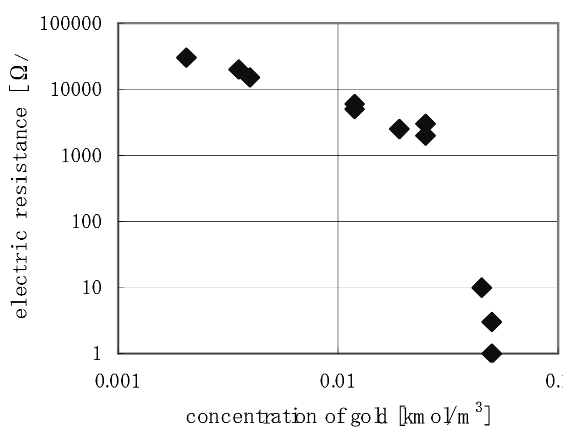


Figure 3. Variation in the resistance of the thin film made of gold nanowires with increase in the concentration of gold in the source gelatin solutions.

The gold density on the glass plate was less than 0.1 mg/cm^2. The electric resistance of commercially available transparent electric conductive glass was measured by the same method and was around 10 ohm/cm. Therefore the gold nanowires produced in this experiment were very useful for making an electric conductive 2-dimensional film of a nanosize thickness.

References

1. Frens, G. Nature Physical Science, 1973, 241, 20-22