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Synthesis and Characterization of Ultrathin Unconventional Mixed 2H-HCP/FCC Phase Au Nanowire

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Background incl. aims

Crystal structure engineering enables the cultivation of noble metal nanostructures featuring unique crystal phases, showcasing innovative optical, catalytic, and electronic characteristics. Variations in atomic stacking sequences within these nanostructures are termed polymorphs, often showcasing distinct properties and functionalities despite being of the same material. The crystal structure of nanocrystals is frequently influenced by synthesis conditions such as reaction temperature, surfactants, precursor properties and gas environment. Polytypism, evidenced by the coexistence of several phases within a single nanostructure, defines this phenomenon. Compared to the typical stacking arrangement of "ABC" along the [111] fcc direction in fcc gold, the 4H/2H gold structure exhibits a stacking sequence of "ABCB/AB" along the [001] 4H/2H direction. 1,2

Ultrathin gold nanowires (NWs) with a diameter of approximately 2 nanometers hold significant interest for both nanoscience research and nanotechnology applications. Due to their high surface area and quantum-confined dimensions, these nanowires exhibit fascinating properties such as quantum conductance and ballistic conduction.3 The synthesis of high-quality, single-crystalline ultrathin gold NWs is essential for accurate physical property measurements and further application exploration. Recent reports have surfaced, highlighting successful advancements in the synthesis of these ultrathin gold NWs. However, reports on the synthesis and characterization of ultrathin 2H/4H Au nanowire is still very limited and a detailed structural and optical study of this nanostructure is nedded to be examined closely.1,2,4,5

Methods

In a typical synthesis process, 4.08 mg gold chloride hydrate (HauCl4, H2O) were dissolved into a mixture of 220 µL of oleylamine, 3.54 mL hexane and 250 µL of 1,2-dichloropropane, in a 20 mL glass vial. The solution was shaken for complete dissolution of HauCl4. Next, 80 mL de-ionized water is added into a 500 mL beaker, which was heated to 58°C. The glass vial is kept on the beaker for 16h and after that the solution is centrifuged at 5000 rpm for 2 minutes to filter the residue. The residue was further washed using hexane 3 times. For TEM characterization the Au nanowire solution in hexane was drop-casted on a C coated Cu grid. The HRTEM, selected area diffraction (SAD) were done in an image corrected FEI TECNAI F-30 operated at 300 kV. HRSTEM, energy dispersive X-ray spectroscopy (EDS) were carried out in a probe-corrected FEI TITAN TEM equipped with high-brightness gun and an Oxford Instruments Ultim X-MaxN 100TLE detector for EDS measurements.

Results

We have observed uniform formation of ultrathin Au nanowire. The diameter of the nanowire is between 1.9 nm – 2.3 nm and the length varies between 50nm to 300 nm. The EDS meaurement on them clearly shows the naowires are indeed Au. HRTEM measurement shows formation of 2H-HCP phase mostly on the top of the nanowire and a mixed 2H/HCP and FCC phase in the middle portion as observed form the IFFT image also. A detailed study on the structural evolution of this nanostructure upon electron beam irradiation will be prersented in this work.

Conclusion

We have done successful synthesis of ultrathin Au nanowire consisting of mixed 2H-HCP/FCC phase. Interestingly the nanowire contains bead like structure as observed from the HRSTEM and HRTEM images and they are observed to be very much sensitive to the electron beam.

Graphic:

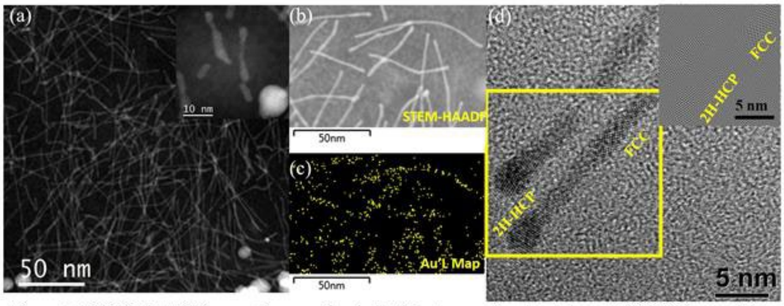

Figure. (a) STEM-HAADF image of uncoventional ultrathin Au nanowire. Inset shows HRSTEM image of two ultrathin nanowire. (b) and (c) shows the HAADF-STEM and Au-L Map of the Au nanowire (d) shows HRTEM image of two ultrathin Au nanowire showing distinct presence of 2H-HCP and FCC region in the nanostructure. Inset shows the inverse fast Fourier transform image of the region marked by yellow square.

Keywords:

Au nanostructure, 4H/2H-HCP Au, Nanowire

Reference:

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