Helical Gold Nanowire

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One-dimensional nano-materials attract strong interests in fundamental and applied sciences and engineering. One-dimensional materials such as carbon nanotubes (CNTs), peptide tubes, and DNA often present helical structures. In recent years, metal nanowires of atomic dimensions have studied intensively, since the electronic conductance of metal nanowires were found to display quantization in the unit of $2e^2/h$, where e is electron charge and h, Planck constant. Although the conductance quantization had already been investigated deeply in cases of quantum point contacts (QPCs) of the two dimensional electron gas systems (GaAs/GaAlAs) and of metal QPCs with mesoscopic dimensions, conductance quantization even at room temperature is only possible for thin metal nanowires of atomic dimension.

More recently, efforts have been done to visualize metal nanowires of atomic dimension by transmission electron microscopy (TEM). Ohnishi and Kondo (1,2) showed TEM images of a suspended gold atomic chain that is free-standing between the electrodes (gold chain is not deposited on a substrate surface). The gold atomic chain was fabricated by STM tip that is installed inside an UHV(ultara-high-vacuum) TEM: The gold STM tip was dipped into a gold substrate, and then it was retracted from the substrate to form a thin gold nanowire between the STM tip and the substrate. Such STM-TEM combined techniques are used by several research groups (Ugarte, Kizuka, Olin, Iijima).

Metal nanowires allow to have different structures from the bulk, as carbon nanotubes. Tosatti had proposed a critical diameter, below which metal nanowires can take weird structure. Kondo(2) showed experimentally that gold nanowires take helical multi-shell structure (HMS) when their diameter become less than 2nm. The HMS has the geometry of multi-wall co-axial tubes. The geometry is similar to the multi-wall CNTs, but nature of gold HMS differs from CNT apparently. Also the gold co-axial tubes has a definite magic number between the diameters of inner and outer tube, because of weak inter-tube interaction: Seven is the magic number, which is the number difference of gold atomic rows that make helix.

We review TEM-STM works on metal nanowires, and conductance quantization of metal QPCs. Emphasized is the gold HMS nanowires, since the reason why metal atoms can form helix has not been answered yet. In future, we need to develop any technique that allow us to synthesize long metal quantum nanowires with nano-meter scale diameter for our use.

1 Quantized conductance through individual rows of suspended gold atoms, Hideaki Ohnishi, Yukihito Kondo, Kunio Takayanagi, *Nature*, **395**, 780-783 (1998)

2 Synthesis and Characterization of Helical Gold Nanowire, K.Kondo and K. Takayanagi, *Science*, **289**, August 28, 606-609(2000)

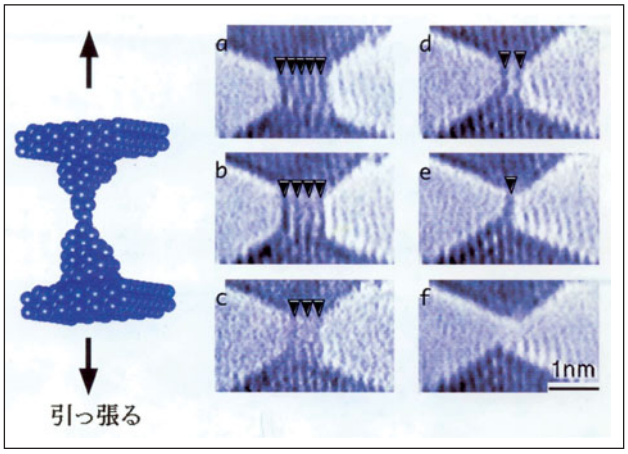

Figure1
(left) TEM-STM experiment of gold QPC. The dark vertical lines are images of gold atomic sheet. The gold short nanowire is formed between the gold substrate (above) and a gold STM tip (below). (After ref.1)

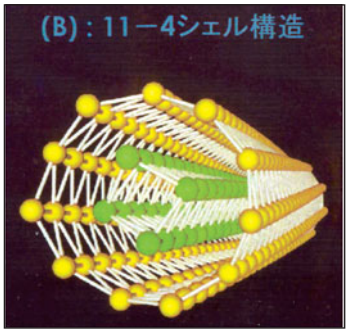

Figure 2
(right) Model of the helical multi-shell (HMS) gold nanowire. The outer tube has 11 atomic rows (shown by yellow balls), while the inner tube has 4 atomic rows (shown by green balls). (After ref.2)