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Aberration Corrected Microscopy and Spectroscopy for Pico-meter Characterization of Device Materials --- Coductance Quantization of Metal Nanowire and AtomicChain-----

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1. Introduction

As the device scale decreases to the order of the mean-free-path length of electrons, conductance quantization plays a dominant role in the transport of carriers. The conductance is given in the unit of the conductance quantum 2e2/h, independent of the length of nanowires. The conductance quantization of nanowires has been studied by quantum point contacts (QPCs) of various materials. The studies by *in-situ* electron microscopy fitted with STM give how quantization holds for metal nanowires of various thicknesses.

2. Aberration Corrected Electron Microscopy

Modern electron microscopy is achieving the resolving power of 50pm by use of an aberration correction technique[1]. This enables us to detect directly light elements such as oxygen and/or carbons, in particular dopants buried in nanowires and oxide films at the interfaces. An aberration corrected *in-situ* electron microscopy/spectroscopy is under developing, which will become common usage for materials analysis and characterization shortly. *In-situ* capability then allows us to detect electronic behavior of nanowires and contacts, opt-electronic behavior of nano-devices.

3. Conductance Quantization

The conductance of gold nanowires was measured while thinning a nanowire. A contact between two electrodes was stretched by piezo drive till breaking. Hundreds of the thinning expriments gave conductance histogram (Fig.1) which tells most probable conductance values and the corresponding thickness [2,3]. Conductance is quantized not only atomic wires but also thick wires with diameters of a few nanometer. As shown in Fig.2 of a time dependent conductance change while the stretching, the conductance was kept constant unless the cross-sectional

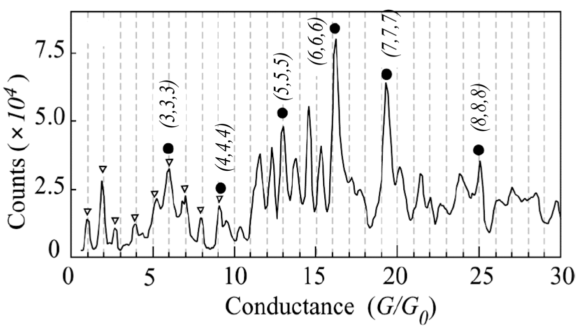

Fig.1 Conductance histogram for gold nanowires. G_0 = 1/12.7kΩ is the conductance quantum. Peaks corresponds for the nanowires of stable structures, and those marked by (n,n,n) are the nanowires with hexagonal cross-sections.

area did not change. A slight change in the conductance (see, a dip between B and C in Fig.2(a)), however, was driven through some change at the contact between the nanowire and the electrodes. The nanowires having their cross section denoted by (6 5 5) and (5 5 5) in Fig.2 take the quantized conductance values of $14G_0$ and $13G_0$, respectively, where $G_0=2e^2/h=1/12.7\text{k}\Omega$. The conductance per atomic row for each wire is 14/21 and 13/19. It is noteworthy that the single atomic chain has the unit conductance of G_0.

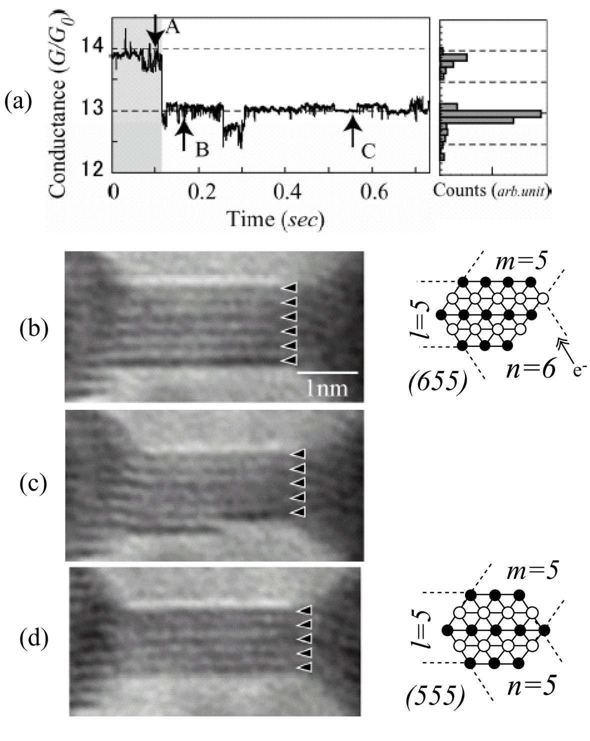

Fig.2 (a) Time dependent conductance change while thinning a gold <110> nanowire. Note that the conductance stays constant during stretching of the nanowire. (b) (c) (d)Transmission electron microscope image of the gold nanowire photographed at the time A, B, and C in (a), respectively. The cross-section structure is shown in the right hand side of the image. Open and solid circles illustrate the atomic rows running vertically to the sheet of paper.

4. Conclusion

Conductance of metal nanowires are quantized well in the unit of conductance quantum, 1/12.9kΩ, for the conductance values less than 10. For thick nanowires, conductance value deviates from integral multiple of the quantum, because of electron de-channeling from the conductance channel. For thick nanowires, conductance changes proportionally to the area of their cross section, being independent of their length.

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