

In-situ UHV-Electron Microscopy with Scanning Tunneling Microscope

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Ultra-high-vacuum (UHV) electron microscopy has been used for analyses of thin film growths, surface structures, and monolayer adsorbates, in the last two decades. In recent years, a miniaturized scanning tunneling microscope (STM) has been built at the specimen stage of an UHV electron microscope, which allows us to study not only the structures but also electronic states of nanomaterials simultaneously. We present here the construction of a newly developed STM-combined-UHV-TEM, and the observations on quantized conductance of the gold nanowire that is formed between the gold electrodes.

Figure 1(a) and (b) shows a new STM holder developed specially for the FE-UHV-TEM (JEOL-2000FV). The STM holder is transferred to the gap of the objective pole piece of the FE-UHV-TEM which was developed for the “particle surface” project of ERATO program at JST[1]. The STM holder head has two electrodes (see Fig.1(b)), one of which can be moved in three directions by a piezo driver. The electrode can further be moved by an inchworm as long as 5mm to make contact between the two electrodes. Once the two gold electrodes have a contact, they are slowly retracted by piezo drives so that the contact extends to form a gold nanowire. The electronic current that passes through the gold nanowire is measured in correlation with the TEM images, in order to obtain one-to-one correspondence between the structure and the conductance of the nanowire[2].

The new STM combined FE-UHV-TEM was confirmed the previous experiments [3,4,5] : As shown in Figs 2 and 3, the gold nanowires change their structure from the six-prism[3] to the helical multi-shell (HMS) tubular structure[4]. The prism structure changes into the HMS tubular structure for diameters smaller than 2nm. The HMS structure in Fig.3 is the finest one found in the previous studies, and has the diameter of 0.56nm. The HMS gold tubes are designated by the number of gold atomic rows which composes the outer tube and that of the inner tube as n-n'-n" HMS. For the 7-1 HMS in Fig.3, the outer tube has 7 atomic rows and the inner tube (it is not a tube, in this case) has 1 atomic row. In addition the new STM system has succeeded to measure the conductance of the 11-4, 14-7-1, and 15-8-1 gold HMS tubes[6]. In the previous conductance measurements of the gold point contact [5], the gold nanowires formed at the contact were too short to have the HMS tubular structure

UHV-TEM thus has an advantage to study nanowires, and thus, nanostructures without any attack from reactive residual gases. If any attack on nanostructures might cause unexpected change in electronic properties. UHV environment is the way to analyze their properties reliable. UHV condition is also reduces specimen contamination, and inevitably needed for nano-probe experiments. In this connection “super nano-probe UHV electron microscopy” which is the most powerful instrument for NANO-analysis [7] should only work at UHV condition.

References

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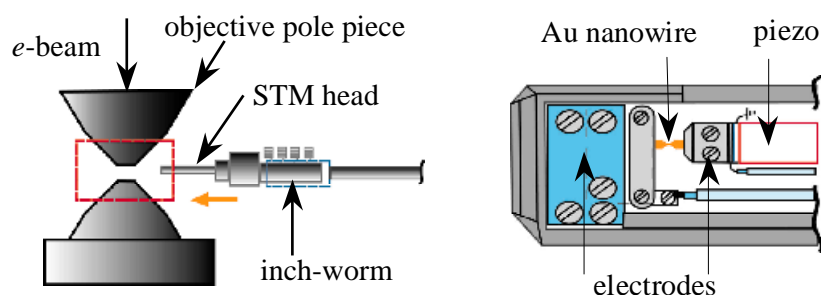


FIG. 1 Design of STM holder at the specimen stage of the UHV electron microscope. (a) Side view of the STM holder and objective pole piece. (b) onstruction of the STM head.

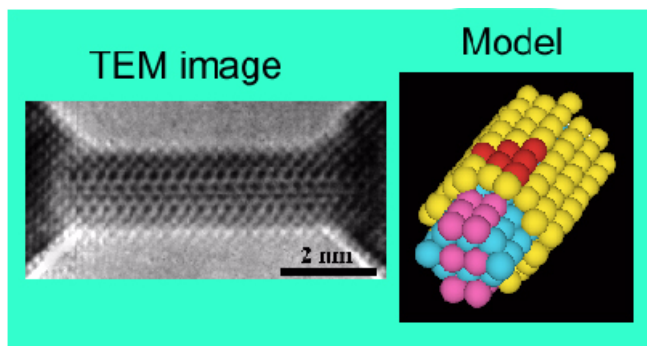


FIG 2 six-prism structure of gold nanowire. The surface has been reconstructed to (111) like 23x1 structure. The axis of the nanowire has the [110] atomic row of the gold face centered cubic crystal.

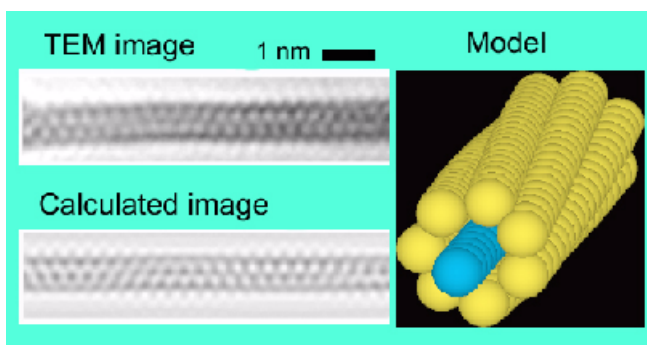


FIG 3 The 7-1 helical multi-shell (HMS) gold nanotube. The outer tube has seven atomic rows which coil the axis of the tube axis. The observed and calculated images (multi-slice method) agree well with each other.