[SS-05]

Electrical Conduction through Atomic/Nano Wires on Silicon

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Since the establishment of surface conductivity measurement techniques by microscopic four-point probes (M4PP) [1-4] with four-tip scanning tunneling microscope (STM) and monolithic four-point probes, electron transport through single-atomic layers on semiconductor crystals has attracted considerable interests. The electrical conduction through atomic or nano wires, which are self-organized on semiconductors, can also be measured by the method. Interesting transport properties of such atomic-scale structures have been revealed in my Laboratory. Especially, it has been revealed that the instability and atomic-scale defects intrinsic to such nano-scale wire structures play decisive roles in transport. I will introduce and summarize the following several topics in the talk.

(1) Ametal-insulatortransitioninIndiumatomicwires.

The conductivity of a Si(111)-4x1-In surface, which is composed of massive and periodic arrays of parallel metallic In atomic chains, has been measured by a temperature-variable M4PP method combined with *in-situ RHEED* [5]. We have succeeded, for the first time, in detecting directly a surface metal-insulator transition around 130 K as a dramatic change of electrical conductivity through the atomic wires, which corresponds to a Peierls transition previously reported [6]. An energy gap of ~ 300 meV at the low-temperature phase, influences of defects and phase locking between the neighboring charge-density-wave chains were elucidated from the temperature dependence of conductivity.

(2) Anisotropyinconductivityintheatomic-wirearray.

As for the Si(111)-4x1-In surface, we have succeeded in measuring the conductivity along the In atomic wires ($\sigma//$) and that across the wires ($\sigma\perp$) separately, by use of a 'microscopic square four-point probe' method [1]. The $\sigma//$ is approx. 60 times higher than $\sigma\perp$, and is consistently described by Boltzmann picture of metallic band conduction. The

$\sigma\perp$, on the other hand, turns out to be mainly via the Si substrate.

(3) Non-metallicconductoinofmetallicAuwires.

Another example is Si(557)-Au surface, composed of a periodic array of Au chains, having a quasi-1D metallic band structure. By the square-four-pint probe method [1], the conductivities parallel to the Au chains ($\sigma//$) and perpendicular to that ($\sigma\perp$), were obtained separately; $\sigma\perp$ was about 1/3 of

$\sigma//$. The $\sigma//$ value is much smaller than that expected from the Boltzmann picture with the known electronic band structure. The temperature dependence of the surface conductivity showed a semiconductive character below RT with an activation energy of ~ 55 meV. Then we can say that the transport along the Au chains is not metallic band conduction, probably because of adatoms adsorbed on the chains, which break up the chain into metallic segments the conduction is a kind of hopping conduction [7]. Thus, even if photoemission spectroscopy shows metallic surface-state bands, the transport is not necessarily metallic. Atomic scale defects/impurity are decisive for transport through atomic chains.

(4) Conductanceofindividualsilicidenano-wires.

It is known that Co, Dy, Fe, Er depositions on Si crystal surfaces form wire structures of nano-meter scale. We have measured the conductance of the individual wires as a function of length by two-point probe method with the four-tip STM. The resistivity of wires is almost the same as the bulk values of silicides. The contact between the wires and underlying substrate turns out to be a Schottky contact.

(5) Conductanceofindividualcarbonnanotube.

The conductance of individual multi-walled carbon nanotubes (CNTs) of 0.8-5 'm longwas measured by the 4-tip STM. The conductance was proportional to the cross section divided by the length of CNTs, meaning diffusive transport [8].

[References]

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