Mechanical properties of Pt atomic chain measured by TEM combined with a frequency-modulation force sensing system

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Metal nano-contacts (NCs) have been studied by many groups since they show unique physical behaviors due to surface effect and quantum confinement. Among them, the atomic chains formation and their physical properties such as electrical conductance have attracted a great deal of interest because they are ultimate one-dimensional material. However, the mechanical property of atomic chains has not been investigated much although it is closely related with the electrical property and very important for novel microelectronics. In this study, for measure the effective spring constant of Pt atomic chain, we employed a transmission electron microscope (TEM) combined with a frequency-modulation force sensing system, which was used for non-contact atomic force microscopy.

We developed a TEM holder equipped with a force sensor of quartz lateral extension resonator (LER) with a high spring constant (k_0) of 7×10^5 N/m and a resonant frequency (f_0) of 1 MHz (Fig. 1). We measured the resonant frequency shift ($\triangle f$) caused by the force acting through the NCs simultaneously with the TEM observation, to evaluate the spring constant (t_{nw}) of the NCs using the equation, $t_{nw} = 4k_0\triangle f/f_0$. The force sensor has the advantage to reduce its oscillation amplitude below 100 pm for the measurement, thus we can observe atomic resolved TEM images under the condition of sensor oscillating. Figure 2 shows a TEM image of the Pt atomic chain. The effective spring constant of Pt atomic chains was pursued from the frequency shift $\triangle f$ measured at the moment of capturing the TEM image.

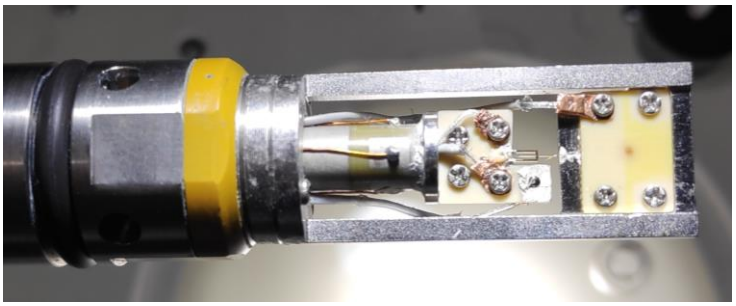

Fig. 1 Photo of our homemade TEM holder combined with the force sensing system.

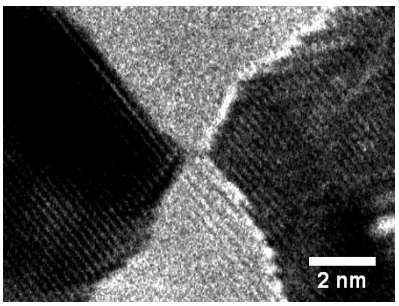

Fig. 2 TEM image of the Pt atomic chain.

[1] Y. Oshima and K. Kurui: Phys. Rev. B 87 (2013) 081404(R).

[2] M. Ternes et al.: Phys. Rev. Lett. 106 (2011) 016802.