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

Japan Adv. Inst. Sci. & Technol.[1], Kanazawa Univ.[2], ◦Jiaqi Zhang[1], Yuki Kobori[1], Keisuke Ishizuka[1], Masahiko Tomitori[1], Toyoko Arai[2], Yoshifumi Oshima[1]

E-mail: s1820021@jaist.ac.jp

Metal nano-contacts (NCs) have attracted much interest, since they show unique physical behaviors due to surface effect and quantum confinement. Recently, much efforts have been devoted to mechanical property of NCs, because nanoelectronic devices require atomic-size conductors for wiring [1]. The mechanical properties of Au and Cu NCs were studied as a start. On the other hand, one of Pt NCs was not studied, although it seems to give a clue for understanding of the catalysis phenomenon which appear at Pt nano-material, but not at Au one. For measuring the mechanical properties of metal NCs, silicon cantilever force sensors have been often used [2]. However, using them, it is difficult to precisely estimate the amount of distortion of NCs during loading force because of small size. In this study, for estimation of Young's modulus of Pt NC, 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, 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 typical TEM image of the Pt NC. When the NC was mechanically being extended narrower, the change in Young's modulus of Pt NC was pursued from the spring constant evaluated from $\triangle f$ and the shape of NC observed in the TEM images.

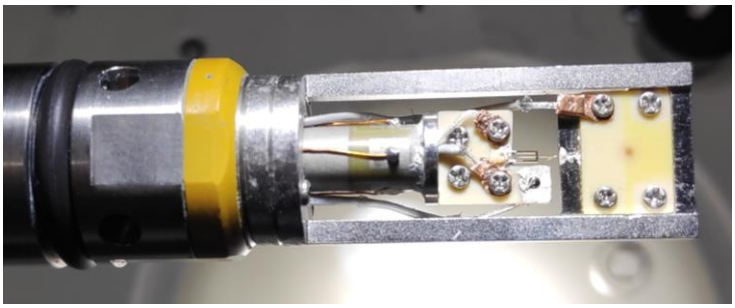

Fig. 1 Photo of our homemade TEM holder combined with the force sensing system.

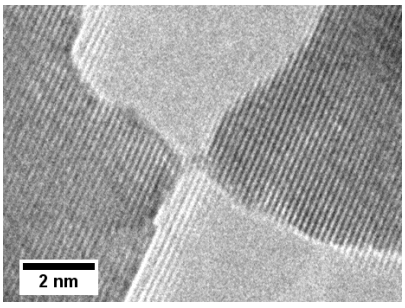

Fig. 2 TEM image of the Pt NC.

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

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