Critical shear stress of gold nanocontact measured by TEM combined with a quartz resonator

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Critical shear stress (CSS), which is defined as a necessary stress at which dislocations begin to move on the slip plane or the slip is caused, is one of important parameters to understand the strength of NCs. Metal nanocontacts (NCs) with several nm in diameter are in a state close to a perfect crystal with almost no defects so that near-ideal CSS are expected to be measured.

A method for measuring the CSS of metal NCs by in-situ transmission electron microscopy (TEM) observation was proposed [1]. In this method, a quartz length-extension resonator (LER) was equipped in a home-made TEM holder as a force sensor. The Au NC was suspended between a movable Au wire attached to the edge of the LER and a fixed Au wire attached to a counter plate. The LER was oscillated controllably, so that the resonance frequency, the LER amplitude and the excitation voltage was recorded in computer. Thereby the equivalent spring constant of a metal NC can be evaluated from the shift in resonance frequency of LER by frequency modulation (FM) method [2,3]. The slip dissipation for Au NCs was estimated from the increment of excitation voltage [4]. In the experiments, the LER amplitude dependence of the spring constant and the slip dissipation for Au NCs with a few nm in diameter for two different axes of <110> and <111> orientations were investigated. The CSS of Au NCs corresponding to the slip along the [112] direction on the $(11\bar{1})$ plane was determined to be 0.94±0.1 GPa regardless of the orientation of Au NCs.

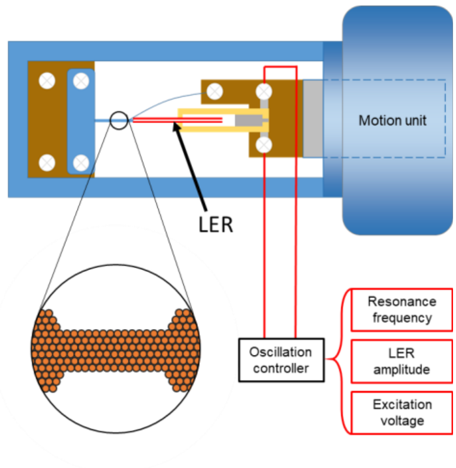

Fig. 1: Schematic illustration of the home-made TEM. The Au NC was suspended between the edge of the LER and a counter plate. The LER was managed by an oscillation controller.

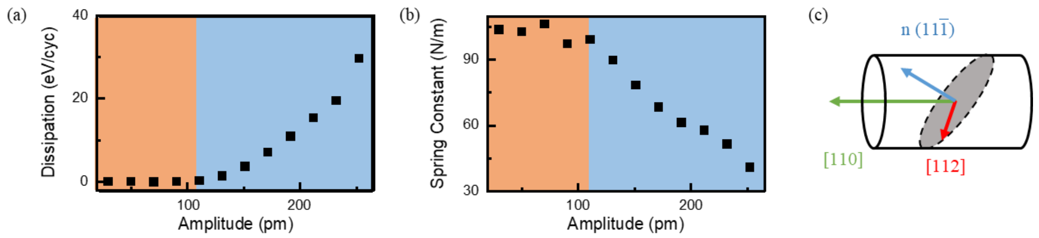

Fig. 2: (a) From the dissipation of the LER, the deformation of Au NC could be divided into elastic deformation (orange) and plastic deformation (blue). (b) The spring constant of the NC. (c) An illustration of slip system for <110> NCs.

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