# Mechanical properties of Pt atomic chains measured by TEM coupled with a quartz resonator

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Monatomic chains have shown unique physical and chemical properties, which draws a different picture from their bulk counterparts. It has been reported that the electrical or magnetic properties can be tuned by controlling the length of the atomic chains, which indicate that the mechanical properties is very important for their applications. However, the mechanical properties of atomic chains have not been clarified experimentally. To solve this problem, we developed an in-situ TEM holder equipped with a quartz resonator as force sensor (Fig. 1a) [1] to measure the mechanical properties of atomic chains when observing their atomic configurations.

A quartz length-extension resonator (LER) was used to measure the stiffness of platinum (Pt) monatomic chains from its frequency shift. Because the stiffness of the atomic chain suspended between the edge of LER and the fixed counter base can be measure precisely with very small oscillation amplitude (about 30 pm). The atomic resolution TEM images (Fig. 1b) and videos were captured simultaneously with measuring the conductance and stiffness by our developed TEM holder.

The stiffness of atomic chains with 2-5 atoms were obtained (Fig. 1c). By subtracting the stiffness of the electrodes supporting the monatomic chain from the measured stiffness, we found that the stiffness of a Pt monatomic chain varied with the number of the constitute atoms in the chain. We investigated the stiffness of about 150 Pt monatomic chains for reproducibility and confirmed that the middle bond stiffness (25N/m) in the chain was slightly higher than that of the bond connect to the suspending tip (23N/m). In addition, the maximum elastic strain of individual bond in the chain was as large as 24% [2]. These values were obviously different from the bulk counterpart. Such peculiar values could be briefly explained by the concept of “string tension”.

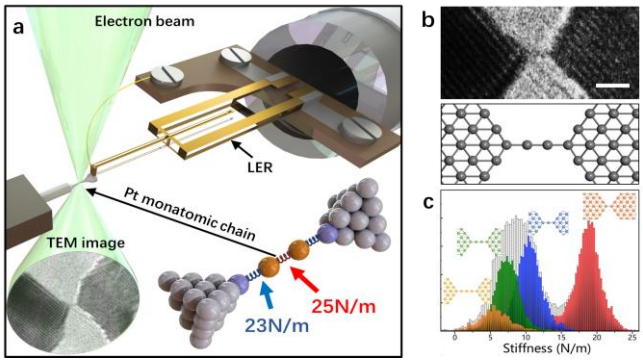


Fig. 1. (a) Schematic illustration of the experimental setup. (b) TEM image of at atomic chain with 4 atoms and corresponding atomic configurations of the chain. (c) Stiffness histograms of the Pt monatomic chains.

[1] J. Zhang et al, Nanotechnology. 31 (2020) 205706.

[2] J. Zhang et al, Nano letters. 21 (2021) 3922-3928.