# Identify the rippled structure of $MoS_2$ film from HRTEM image

◦(D)Lilin Xie and Yoshifumi Oshima

School of Materials Science, Japan Advanced Institute of Science and Technology, Ishikawa 923-1292 Japan

E-mail: s1820416@jaist.ac.jp

When stretching two dimensional (2D) materials, the periodic ripple structure of larger than 30 nm in amplitude were observed to be formed [1]. Such periodical structural modulation seems to have influence on electronic and mechanical properties of 2D materials [2]. Formation of ripple structure in graphene was also observed without stretching. The amplitude was about 1 nm, which is suggested to be intrinsic property due to thermal instability [3]. Such a small amplitude is difficult to be estimated quantitatively. However, here, we demonstrate that the atom-scaled ripple structure of $MoS_2$ nanosheet can be quantitatively identified by high resolution transmission electron microscopy (HRTEM).

First, the amplitude of the ripple structure was examined by HRTEM simulation. The simulation for $MoS_2$ nanosheets was carried out with sinusoidal ripple structure, as shown in Fig.1(a), which amplitudes were range from 0 to 1.5 nm, assuming that the period is 10 nm. In the simulated images, the lattice spacing should be modulated, since the direction of incident electron beam to the surface of the nanosheet was changed. The periodical strain distribution was obtained by applying geometry phase analysis (GPA) method [4] to the simulated HRTEM images. In the obtained strain mapping, we found the relationship between amplitude and apparent strain as showed in Fig.1(b). Roughly, the amplitude of the ripple structure is almost proportional to the strain. It indicates that the amplitude can be estimated by the apparent strain.

We estimated the amplitude of the ripple structure of the suspended $MoS_2$ nanosheet, which image was observed by our home-made TEM holder at accelerating voltage of 200kV, as shown in Fig.1 (c). According to the line profile of the strain distribution, the period, and the value of apparent strain was obtained. An atomic model was proposed based on the experimental and simulated results. The simulated HRTEM image and corresponding strain mapping was shown in Fig.1 (d). By comparing the experimental results with the simulated ones, the amplitude and period of simulated ripples were estimate to be 0.5 nm and 10 nm, respectively.

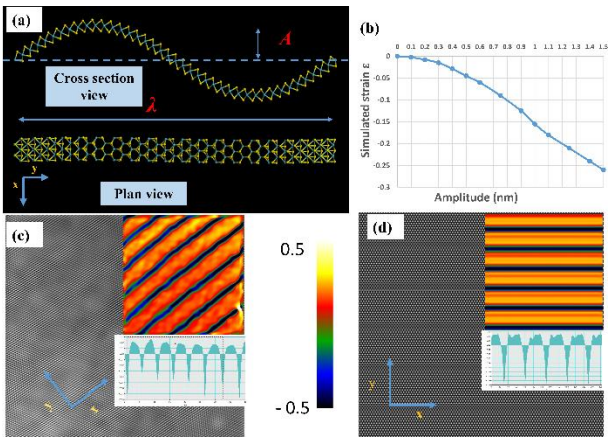


Figure 1. (a) Atomic model of $MoS_2$ ripple. (b) The relation between amplitude and projected strain. (c) Experiment result of $MoS_2$ nanosheet. (d) Simulated results.

Reference

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