Strained induced ripples and structure change in MoS_2 nanosheet

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Molybdenum disulfide (MoS_2) is a promising 2D material in electronic and optoelectronic applications, especially in flexible device owing to their ultra-thin layered structural properties and electronic properties [1]. Such 2D materials have been reported to have periodic ripples owing to thermal fluctuations [2, 3]. Since they could have an influence on electronic and mechanical properties, it is worth investigating the way how to control the ripple structure.

In this work, we investigated the strain dependence of the periodic ripple structure formed in MoS_2 nanosheet of several layers by using *in-situ* stretching transmission electron microscopy (TEM) observation, which holder was developed as shown in Fig.1(a). The structure change of mechanically exfoliated MoS_2 nanosheet were observed at an atomic scale when increasing the strain by stretching uniaxially.

The ripple structure could be identified by the strain mapping which was retrieved from atomic-resolved TEM image of the MoS_2 nanosheet by geometric phase analysis (GPA) method [4]. We also found that contrast of the MoS_2 nanosheet changed periodically along with the zigzag direction as shown in Fig. 1(b). Since the contrast change correlated with the strain mapping, it seems to be caused by the defocus difference. It means that the height is different between the regions showing different contrast and the MoS_2 nanosheet form the ripple structures as illustrated in Fig. 1(c). The strain tensor mappings, ε_{xx} and ε_{yy}, of the MoS_2 nanosheet were obtained before stretching and after stretching by applying the bias voltage of 0.3 and 0.4 V, respectively, to the piezo actuator as shown in Figs. 1(d-i). Before stretching, the ripple structure of the MoS_2 nanosheets was formed one-dimensionally along the armchair direction. After stretching, we found that new two-dimensional strain distribution, corresponding to new two-dimensional ripple structure. By stretching more, the period of the original ripple structure slightly decreased from 10.6 nm to 10.4 nm. One of two independent directions of the new ripple structure was perpendicular to the stretching direction, because the blue area is elongated along the same direction with the stretching direction in the ε_{xx} strain mappings.

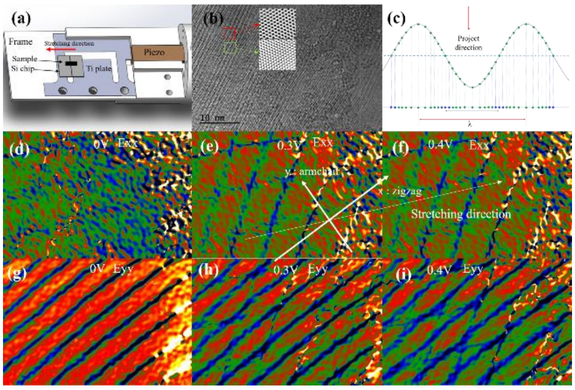

Figure 1. The diagram of the stretching holder, the structural analysis and strain mappings of MoS_2 nanosheet. X and Y direction correspond to zigzag and armchair direction, respectively.

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