Research Highlights

[Vol. 15]
Revealing the "Scotch-tape" technique mechanism

Previous Index Next

27 Jun, 2014

First In-Tandem Experimental and Theoretical Modeling of a Famous “Scotch-Tape” Technique for Making Two-Dimensional Graphene-like Nanosheets.

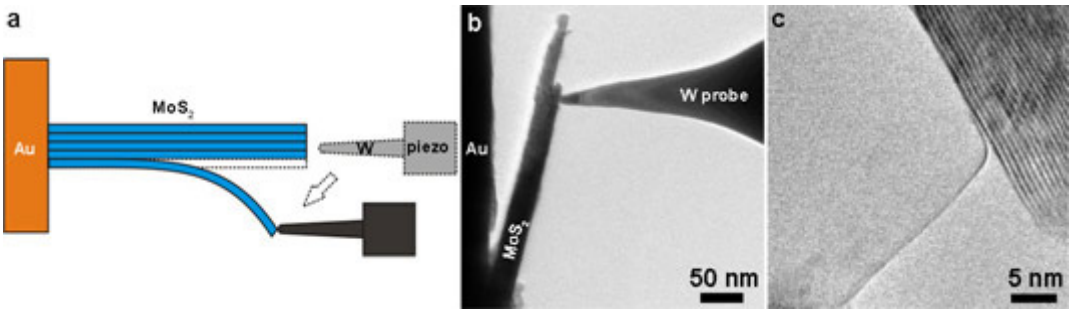

Figure : Nanomechanical cleavage of molybdenum disulphide atomic layers. (left) Schematics of the experimental setup inside HRTEM. (center) TEM image of a sharply etched tungsten nanoprobe in contact with the MoS_2 single crystal deliberately placed with (0002) basal atomic planes viewed edge-on. (right) HRTEM image of a cleaved MoS_2 atomic monolayer.

The simplest mechanical cleavage technique using a primitive “Scotch” tape has resulted in the Nobel-awarded discovery of graphenes and is currently under worldwide use for assembling graphenes and other two-dimensional (2D) graphene-like structures toward their utilization in novel high-performance nanoelectronic devices.

The simplicity of this method has initiated a booming research on 2D materials. However, the atomistic processes behind the micromechanical cleavage have still been poorly understood.

A joined team of experimentalists and theorists from the International Center for Young Scientists, International Center for Materials Nanoarchitectonics and Surface Physics and Structure Unit of the National Institute for Materials Science, National University of Science and Technology “MISiS” (Moscow, Russia), Rice University (USA) and University of Jyväskylä (Finland) led by Daiming Tang and Dmitri Golberg for the first time succeeded in complete understanding of physics, kinetics and energetics behind the regarded “Scotch-tape” technique using molybdenum disulphide (MoS_2) atomic layers as a model material.

The researchers developed a direct *in situ* probing technique in a high-resolution transmission electron microscope (HRTEM) to investigate the mechanical cleavage processes and associated mechanical behaviors. By precisely manipulating an ultra-sharp metal probe to contact the pre-existing crystalline steps of the MoS_2 single crystals, atomically thin flakes were delicately peeled off, selectively ranging from a single, double to more than 20 atomic layers. The team found that the mechanical behaviors are strongly dependent on the number of layers. Combination of *in situ* HRTEM and molecular dynamics simulations reveal a transformation of bending behavior from

spontaneous rippling (< 5 atomic layers) to homogeneous curving (~ 10 layers), and finally to kinking (20 or more layers).

By considering the force balance near the contact point, the specific surface energy of a MoS_2 monoatomic layer was calculated to be ~0.11 N/m. This is the first time that this fundamentally important property has *directly* been measured.

After initial isolation from the mother crystal, the MoS_2 monolayer could be readily restacked onto the surface of the crystal, demonstrating the possibility of van der Waals epitaxy. MoS_2 atomic layers could be bent to ultimate small radii (1.3 ~ 3.0 nm) reversibly without fracture. Such ultra-reversibility and extreme flexibility proves that they could be mechanically robust candidates for the advanced flexible electronic devices even under extreme folding conditions.

Reference

"Nanomechanical cleavage of molybdenum disulphide atomic layers"
Daiming Tang, Dmitry G. Kvashnin, Sina Najmaei, Yoshio Bando, Koji Kimoto, Pekka Koskinen, Pulickel M. Ajayan, Boris I. Yakobson, Pavel B. Sorokin, Jun Lou, Dmitri Golberg
Journal : Nature Communications 5:3631 (2014).
DOI : 10.1038/ncomms4631

Affiliations

International Center for Materials Nanoarchitectonics (WPI-MANA), National Institute for Materials Science (NIMS), Namiki 1-1, Tsukuba, Ibaraki 305-0044, Japan

Contact information

International Center for Materials Nanoarchitectonics(WPI-MANA)

National Institute for Materials Science
1-1 Namiki, Tsukuba, Ibaraki 305-0044 Japan
Phone: +81-29-860-4710
E-mail: mana-pr[AT]ml.nims.go.jp