Characterization of Step, Ridge, and Crack Submicro/Nanostructure on Epitaxial Graphene using Tip-enhanced Raman Spectroscopy

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Epitaxial graphene grown on SiC has many attractive properties such as wafer-size sheet area, minimal defects, and tremendously high carrier mobility. One of its unique features is the nanostructures of graphene grown on C-face of SiC, which affects band gap, electron mobility, and internal strain. However, the spectroscopic characterization of these structures has a complication since their sizes are smaller than the diffraction limit. To overcome this, we used tip-enhanced Raman scattering (TERS) spectroscopy, which employs a near filed enhancement from plasmon resonance between excitation laser and metallic nanotip to acquire Raman signal from confined area of the sample. Therefore, Raman signal with the spatial resolution better than diffraction limit was achieved and each nanostructure could be studied individually.

Graphene sample was synthesized by heating 4H-SiC (000$\bar{1}$) to 1800 °C for 15 minutes in high vacuum. Step, ridge, and crack submicro/nanostructures on the sample were then characterized by atomic force microscopy (AFM) and TERS (514 nm excitation laser, silver bulk tip, non-contact mode).

TERS results show that the step nanostructure does not affect Raman spectra. On the other hand, TERS spectra from ridge nanostructures provide 8.7 cm^{-1} downshift of G' band compared to neighbor area, which can be calculated into 1.6 × 10^{-3} and 5.8 × 10^{-4} uniaxial and biaxial strain difference, respectively. The positive sign in strain difference indicates a reduced compressive strain on the ridge, which confirms a hypothesis of previous researches that nanoridges on epitaxial graphene form as a relief against compressive strain. The TERS measurements on the crack submicrostructure also show that there is lower graphene content in the crack center by using the G/SiC peak intensity ratio. All of these information cannot be obtained by conventional Raman spectroscopy since the spatial resolution is too large. This study demonstrates that TERS is a powerful tool for the characterization of nanostructures on epitaxial graphene.

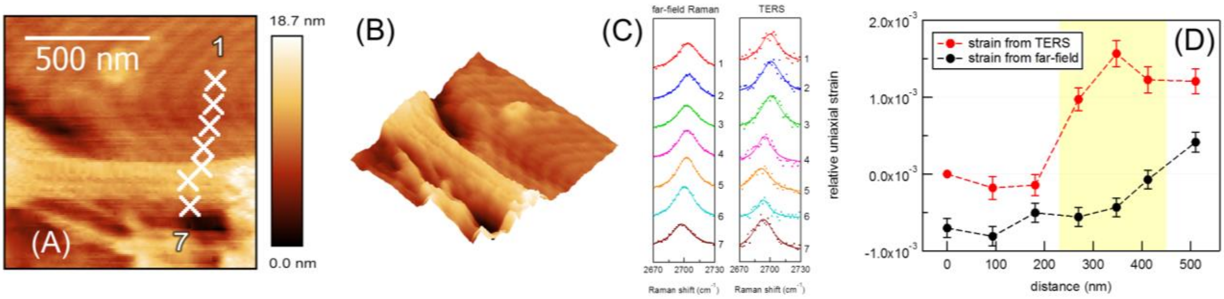

Fig 1. (A),(B) 2D and 3D AFM topology, (C) G' in TERS spectra and, (D) calculated strain of the ridge nanostructure.

Reference : [1] Vantasin et al., *J. Phys. Chem. C* **2014**, *118*, 25809–25815.

[2] Suzuki et al., *Phys. Chem. Chem. Phys.* **2014**, *16*, 20236–20240.