Thermal Strain Engineering of WS_2 and MoS_2 Films Investigated by Advanced Atomic Force Microscopy

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Controlling two dimensional (2D) crystals structures through strain engineering is an exciting avenue for further tailoring their electrical and optical properties. The mechanical behavior and electronic structures of atomically thin films under strain still need to be further studied. Here, the local strain induced structures and properties of CVD-grown WS_2 and MoS_2 films on SiO_2 by thermal strain engineering have been detailed investigated by several advanced atomic force microscopies (Multifrequency-AFM, Multiharmonic-EFM, Scaning Microwave Microscopy, and so on) in combination with theory and modeling.

2D-isotropic compressive strains have been applied to the WS_2 flakes from the underlying SiO_2/Si substrate by fast-cooling process. Both tensile cracks and compressive ripples of different configurations are observed within the flakes. The orientations of tensile cracks are depending on the flake size, geometry and crystal orientation. The tensile cracks regions show decreasing band gap than unstrained WS_2, while the compressive ripples regions show enlarged one. We found that the locally conductivity of ripples regions significantly increased when lateral force is applied. The conductivity variation depends on scan direction, which confirms conductivity increasing result from the strain redistribution due to the puckering effects. The frictional, viscosity and elasticity characteristic of different strain regions are also investigated. In contrast, 2D-isotropic tensile strains were applied to the MoS2 flake from the SiO_2/Si substrate by the same fast-cooling process, then the strained structures and properties were further investigated by Advanced AFM.

Our work provides important insight to fabricate predictive local structural and electronic patterns in TMD films through controllable thermal strain engineering, which can be further used for the TMD-based electronic and photonic devices.

References

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