Strain engineering of MoS_2/graphene heterostructrures by thermal treatment

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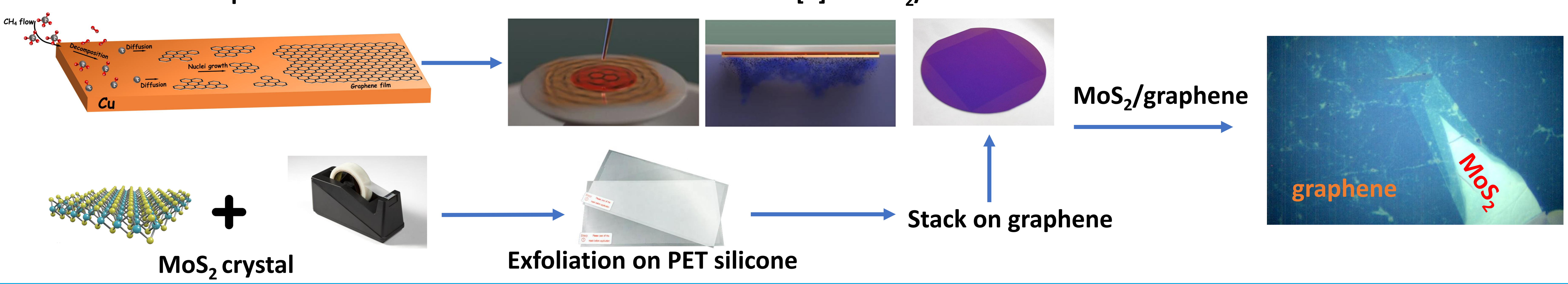
Introduction

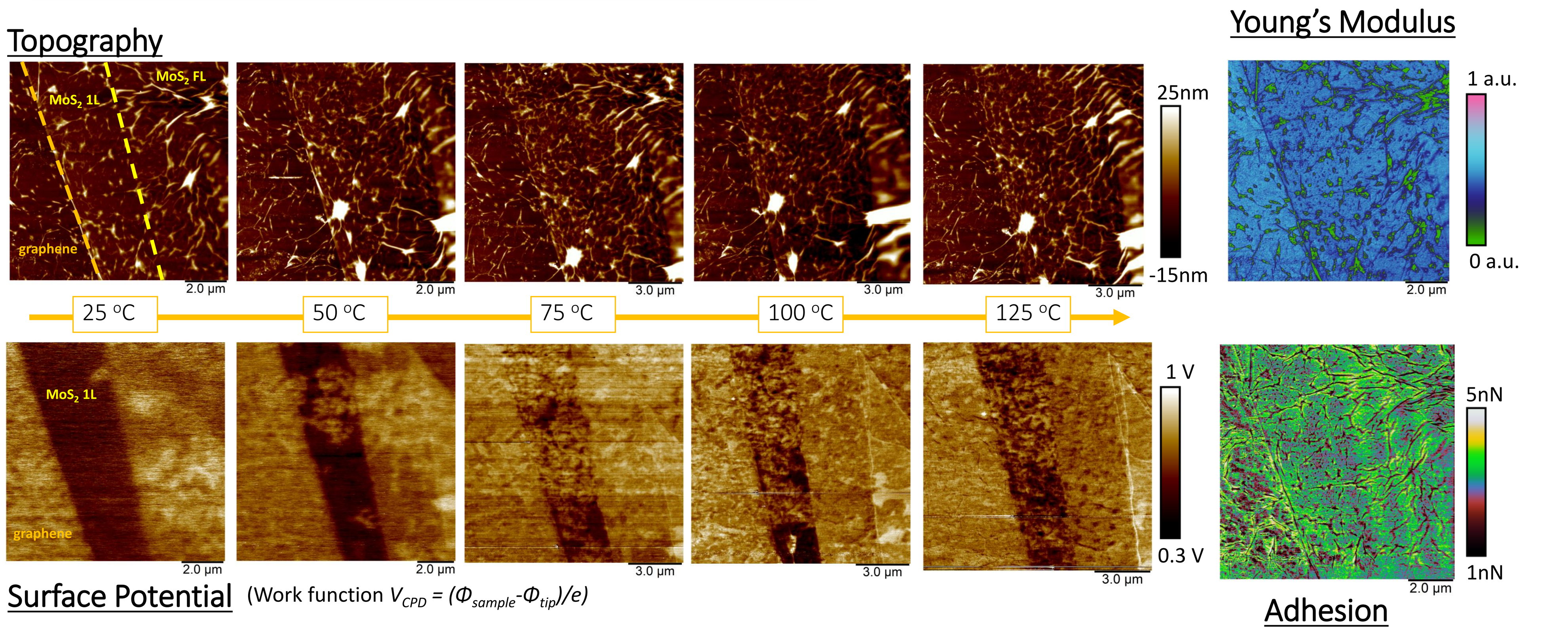
Thanks to their characteristic exceptional mechanical strength and flexibility, 2D materials provide an ideal platform for **strain engineering**, enabling tunable modulation and significant improvement of their optical properties [1]. With the **application of external fields** such as uniaxial or biaxial strain, one can demonstrate **flexible control** over their electronic states. Meanwhile, many nondestructive spectroscopic and microscopic characterization tools can be readily harnessed to quantitatively determine strain-engineered alterations in these properties. Furthermore, transferring 2D materials onto **pre-patterned substrates** provides a means of introducing inhomogeneous and **guided local strains** into any type of 2D material, which is of great technological interest [2]. In the work presented here, molybdenum disulfide (MoS_2) was directly exfoliated on top of transferred CVD graphene, which enabled directed strain distributions hailing from the wrinkled graphene topography. Additionally, another degree of strain was introduced and controlled by a simple thermal treatment owing to the thermal expansion of the substrate, which also affected the interlayer bonding of the heterostructures. The variations in the resulting optical and electrical properties were assessed with Raman spectroscopy, Photoluminescence and Kelvin Probe Force Microscopy, and displayed effective control in temperatures as low as 125 °C for the aforementioned properties. The prospect of these findings can pave the way for low-cost and controllable engineering of devices directly on insulating substrates.

Materials & Methods



Results

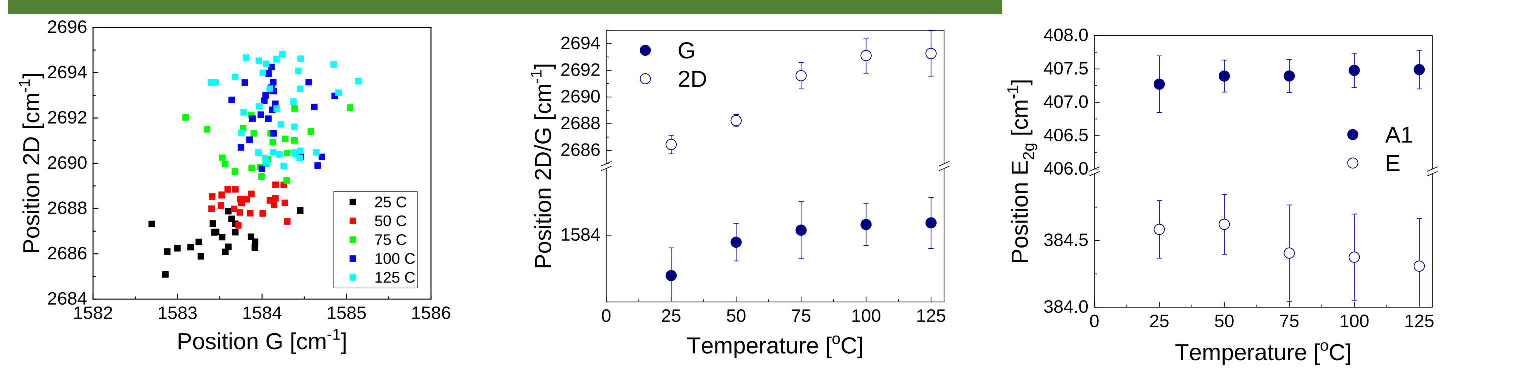
PeakForce-KPFM



(Work function $V_{CPD} = (\Phi_{sample}-\Phi_{tip})/e$)

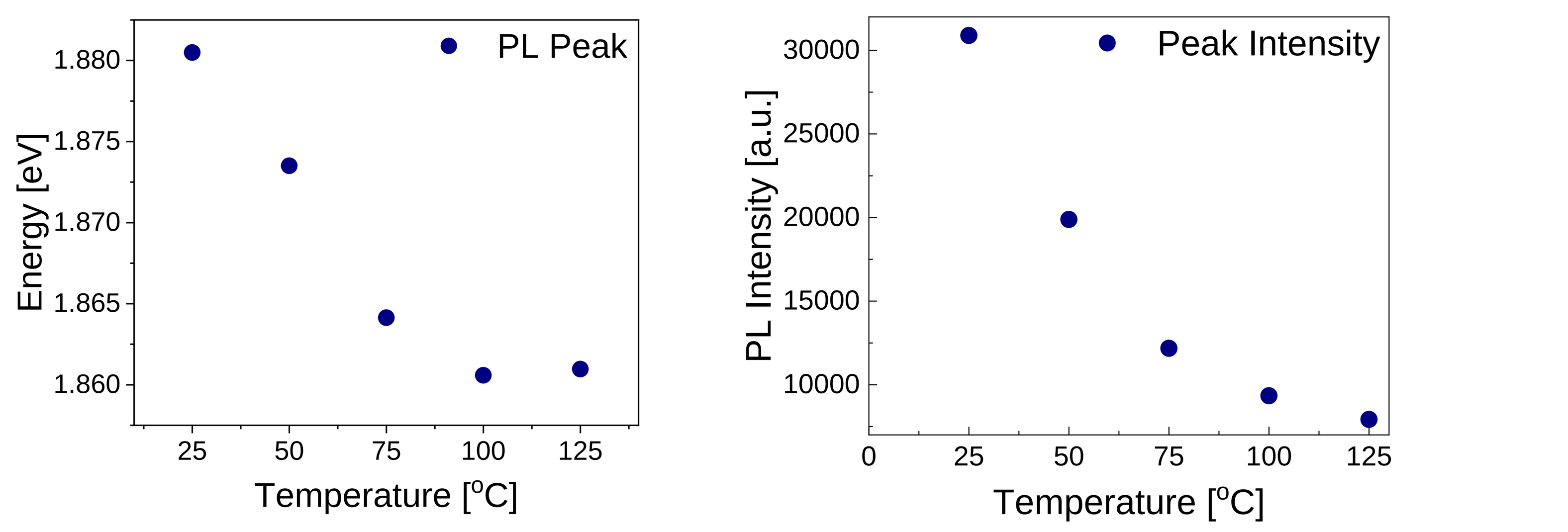
- MoS_2 work function was found to be 5 eV at room temperature
- As temperature rises, we can tune reversibly the work function guided by the wrinkle patterns (increased up to 5.3 eV)

Raman



- Raman mappings denote p-type doping and induced compressive strain for graphene as the temperature rises [3]
- Same applies to MoS_2 deduced from the increased Δω of the main Raman bands *A1* and *E*.

PL



- As the temperature rises, the band gap and PL intensity of MoS_2 is decreasing which is attributed to the compressive strain.

Conclusions

- Easy heterostructure fabrication without expensive setups.
- Effective guided doping on wrinkles.
- Effective band gap engineering of ~0.2 eV with simple annealing up to 125 °C.

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