September 1, 2021 - Parallel Workshop 1

chem2Dmat
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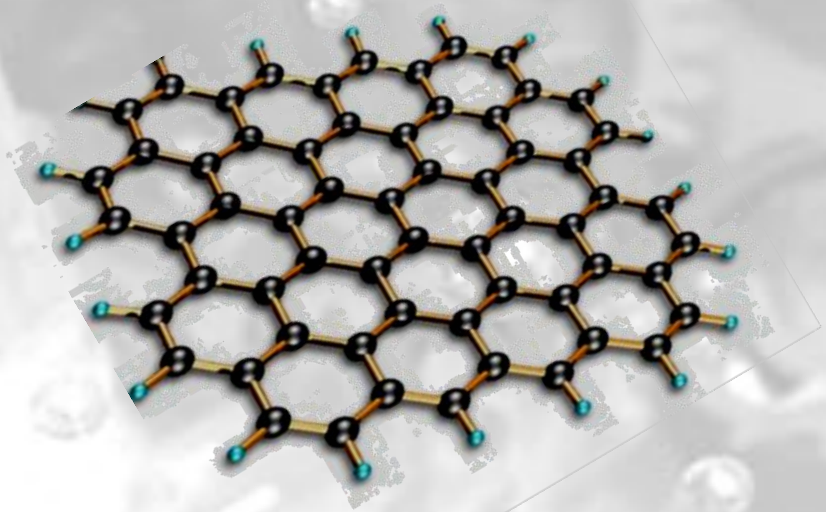
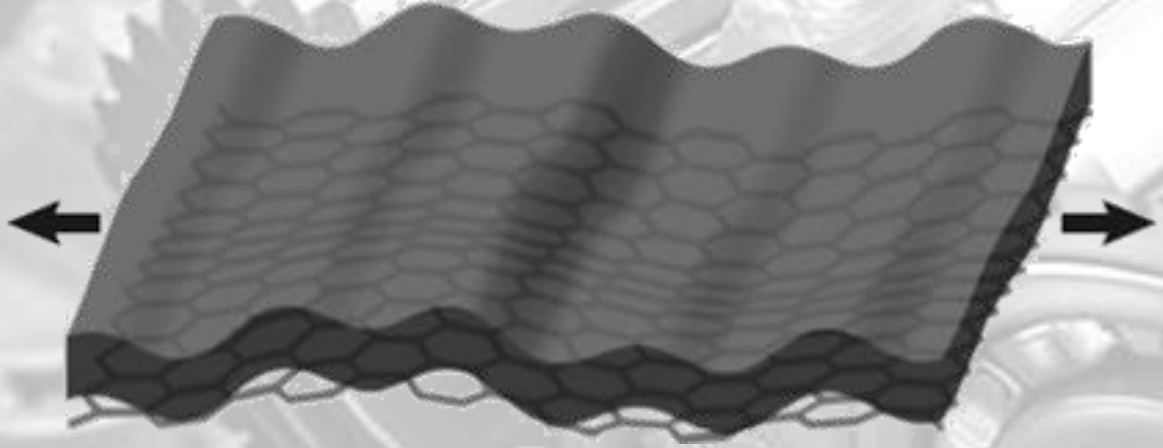
EUROPEAN CONFERENCE ON CHEMISTRY OF TWO-DIMENSIONAL MATERIALS

Frictional Response of Texture Induced Strained Graphene





Andrea Mescola, Ph.D.
Istituto Nanoscienze,
CNR Nano S3, Italy

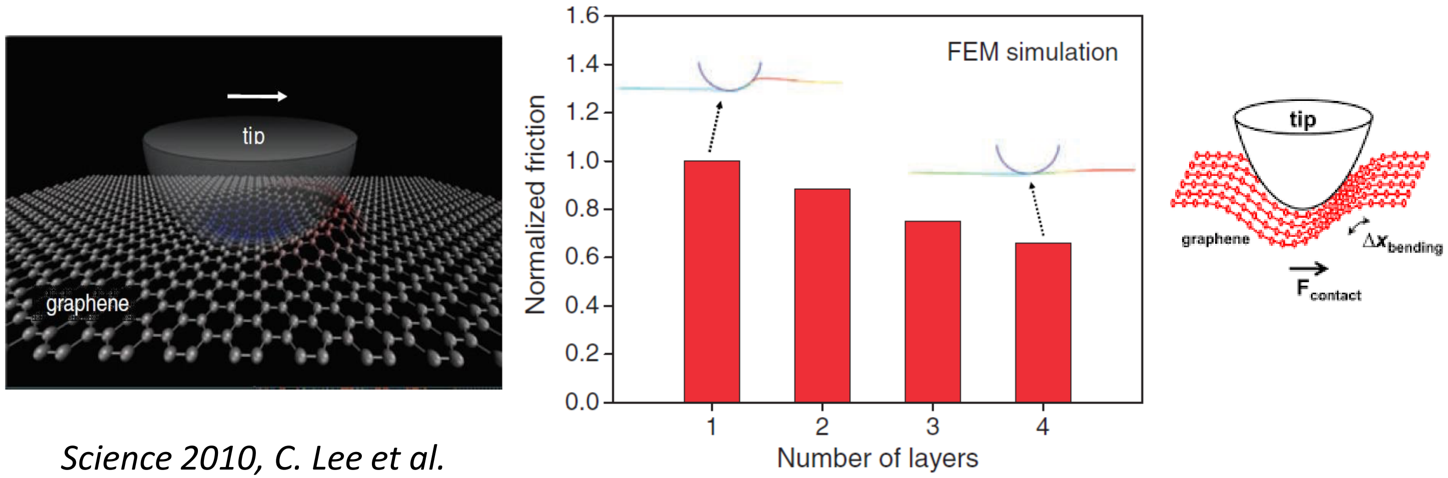
Results under review on Small

Graphene: the thinnest solid lubricant

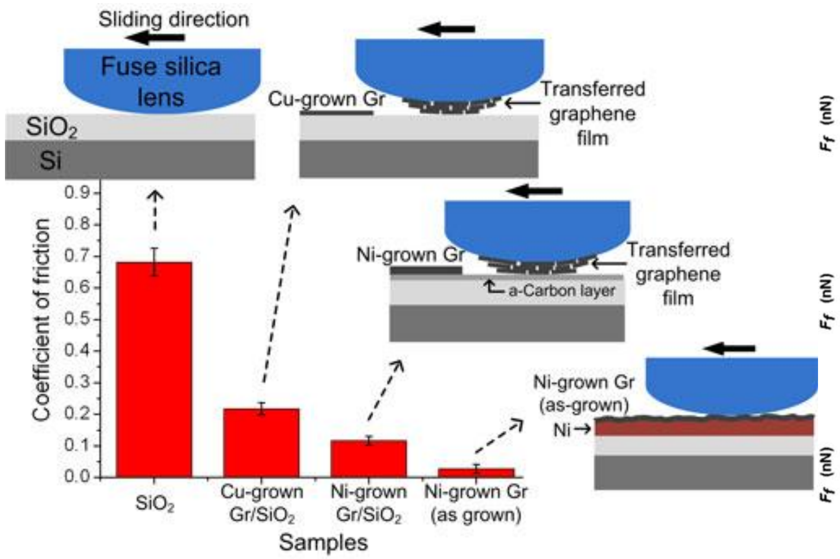
- Tensile strength, lightness, Young's modulus, surface energy, shear strength and permeability make it an excellent lubricant (even better than bulk graphite).
- Layer dependency of friction responses
- Puckering mechanism: out-of-plane deformation
- Pivotal role of underlying substrate

Tuning of Ultra-low friction/Superlubric state

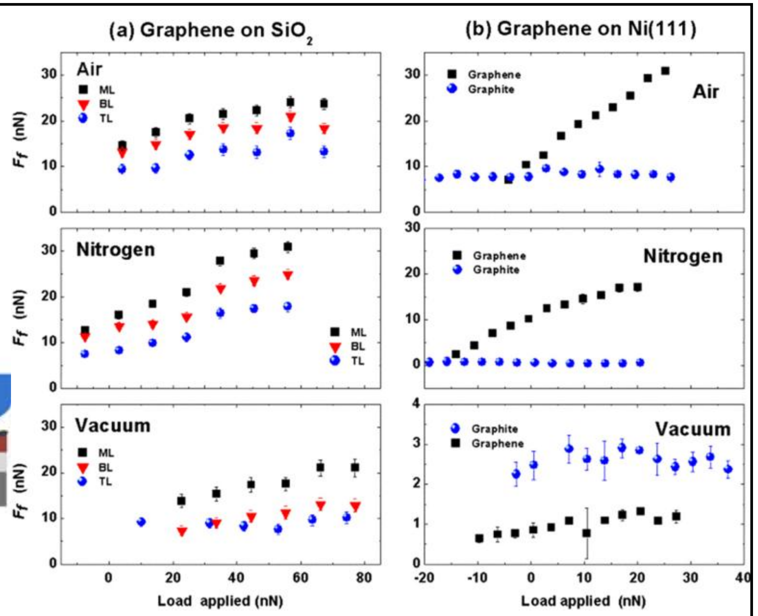
CoF < 0.01



Science 2010, C. Lee et al.



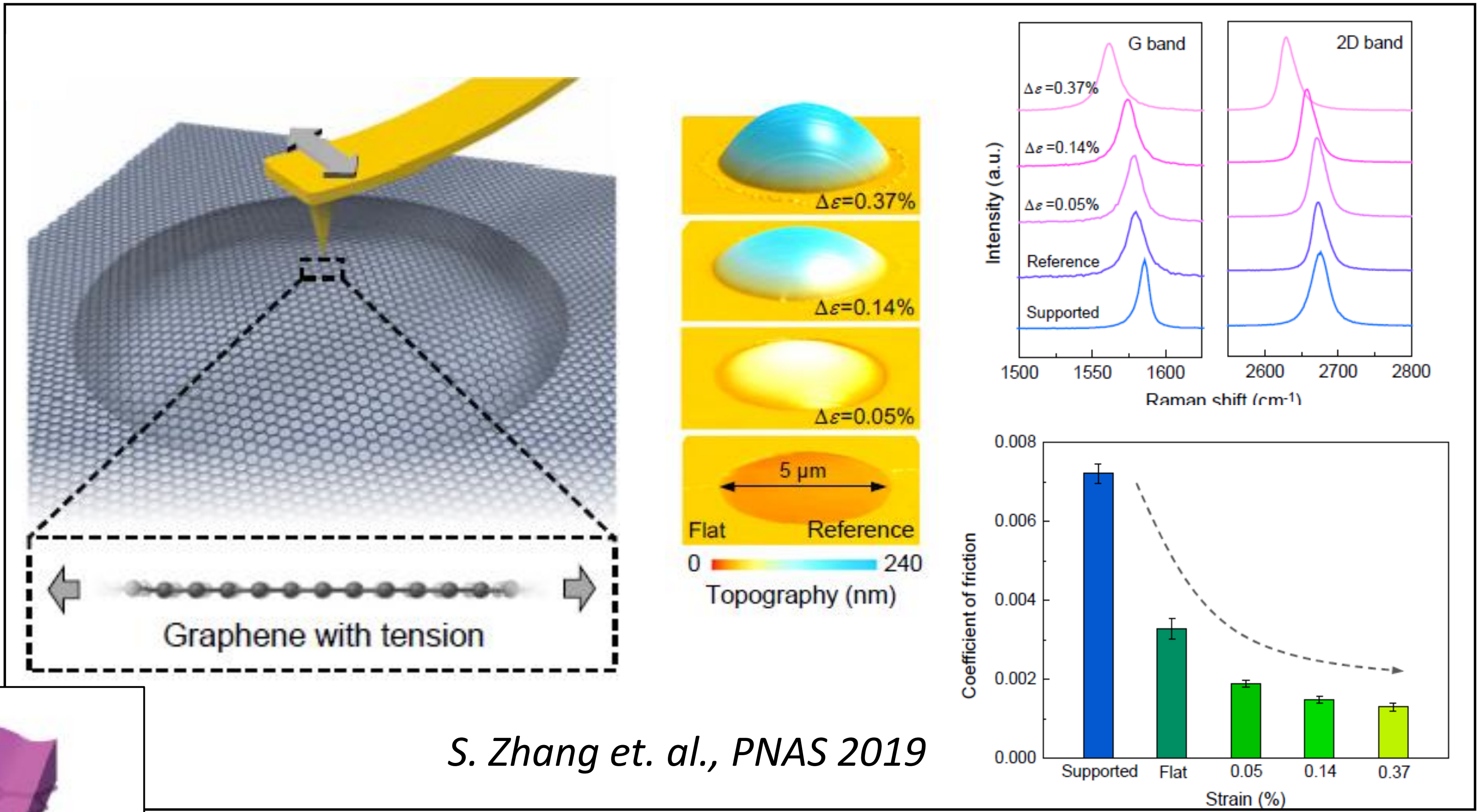
ACS Nano 2011, K.-S. Kim et al.



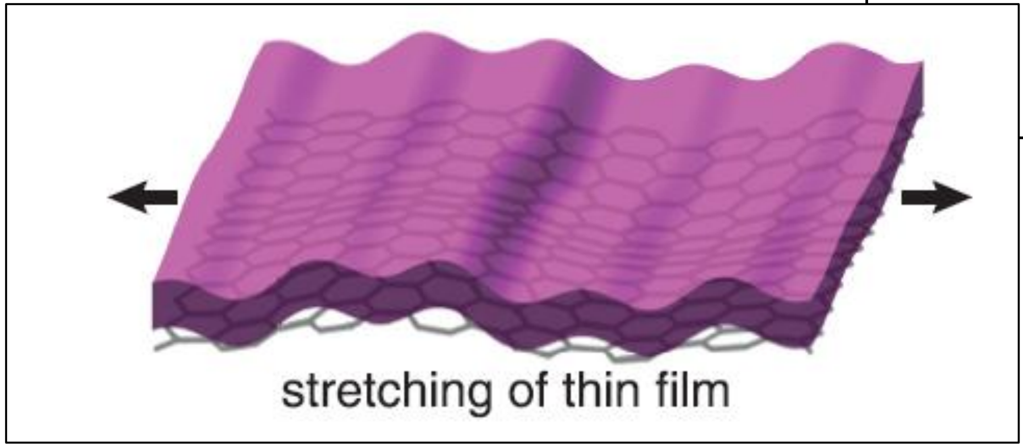
IOP Nanotechnology 2015, G.Paolicelli et al.

Superlubric state via in-plane straining

- Superlubric state (CoF nearly 0.001) achieved by applying tensile strain (0.60%) on suspended graphene revealing reveal that the in-plane strain effectively modulates the flexibility of graphene.

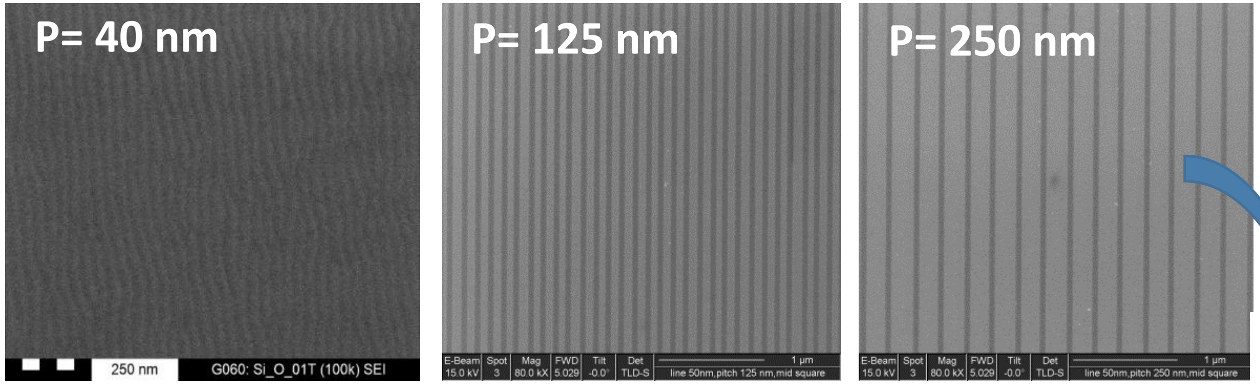


S. Zhang et. al., PNAS 2019

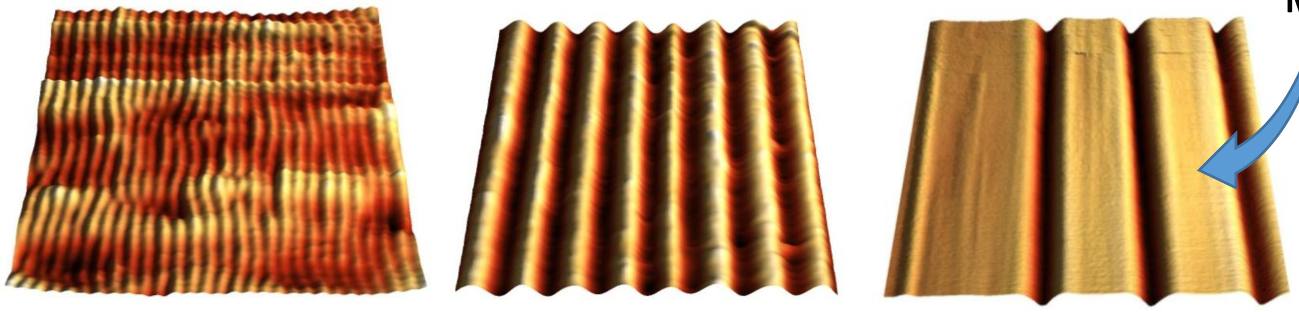


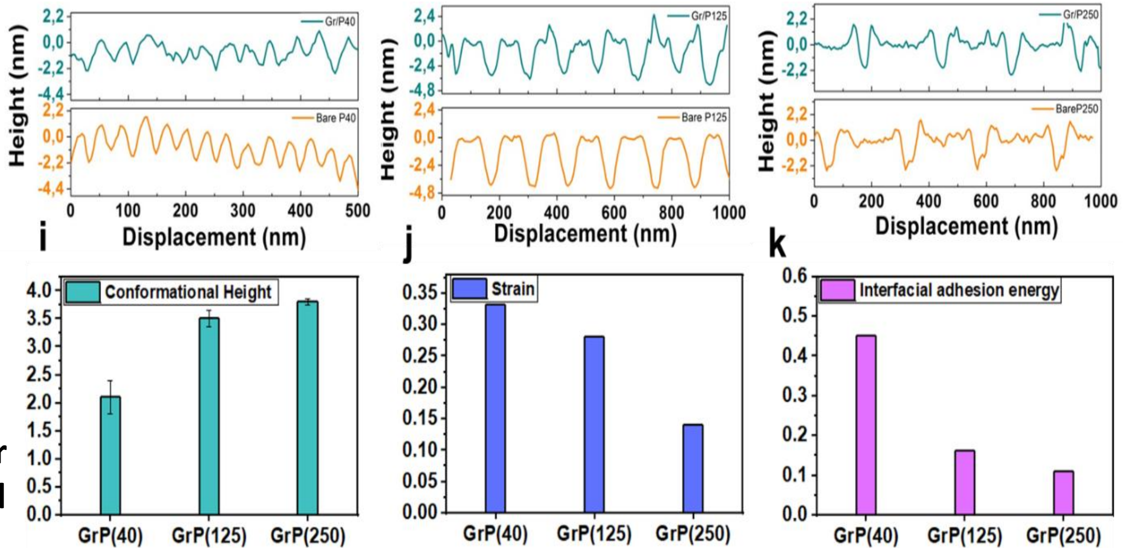
➢Strain can be as well induced by exploiting the interactions with patterned substrates which modulate the conformation/suspension of graphene

CVD Graphene deposited on artificially corrugated SiO_2 substrates



CVD Wet Transfer Method





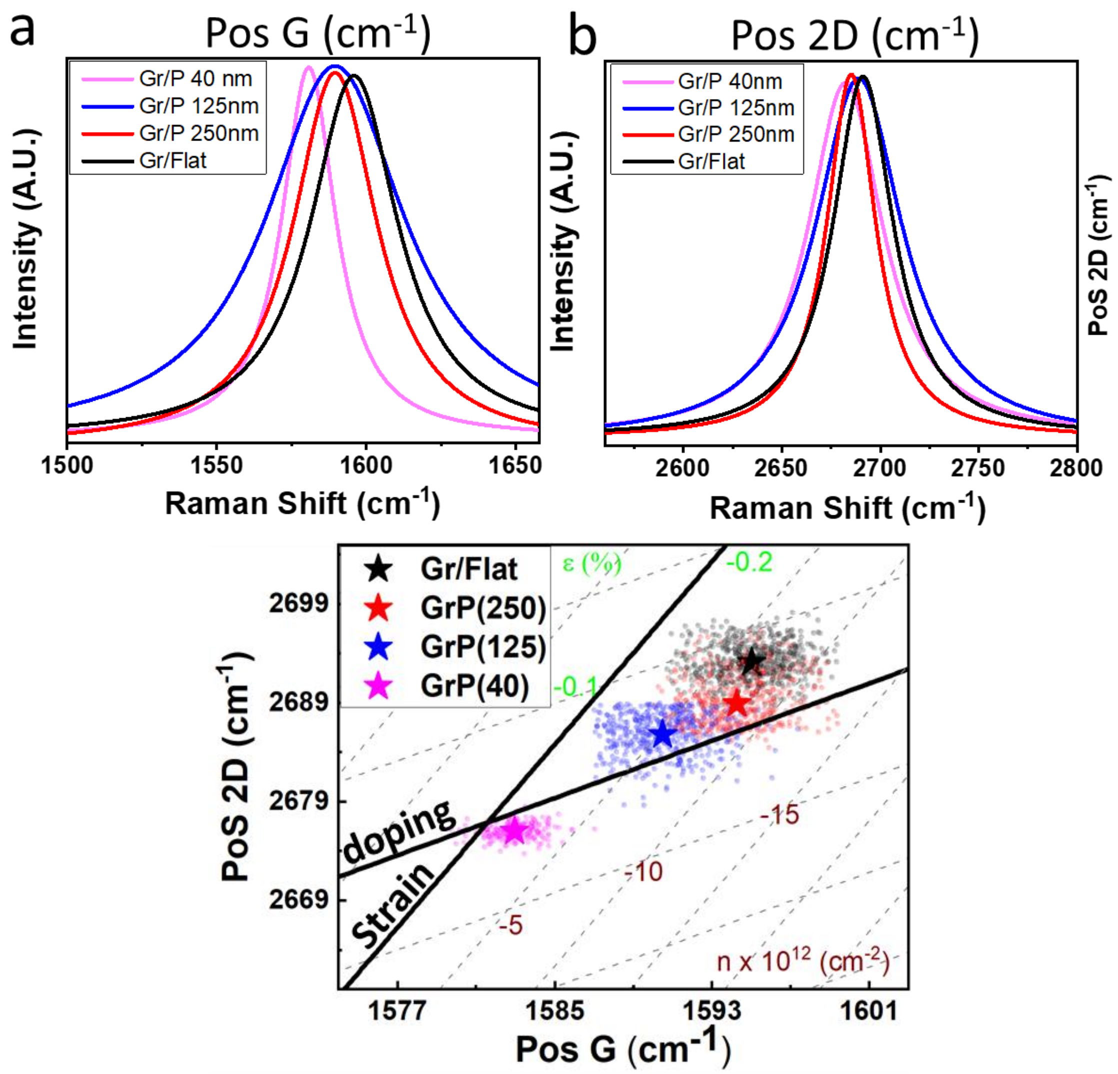
10-15% | 7-10% | 3-5%

Measured depth reduction after Graphene deposition

$$l' = \int_L y_G(x)\,dx = \int_0^\lambda \sqrt{1+\left(\frac{\partial y_G}{\partial x}\right)^2}\,dx \qquad l' = 2\delta_1 + 2\delta_2$$

$$y_G(x) = A\sin\left(\frac{2\pi}{\lambda}x\right) \qquad \varepsilon_x = \frac{l'-\lambda}{\lambda}$$

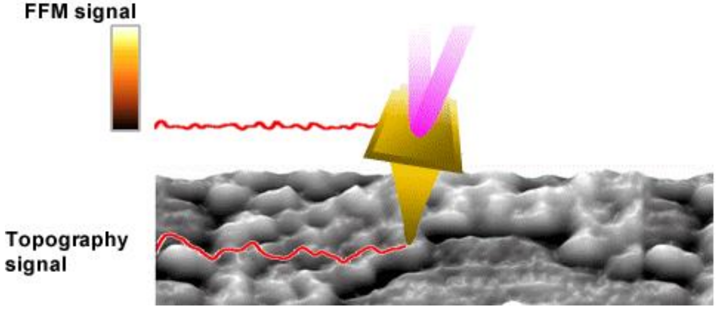
Substrate-induced stretching/compression and the doping by Raman spectroscopy



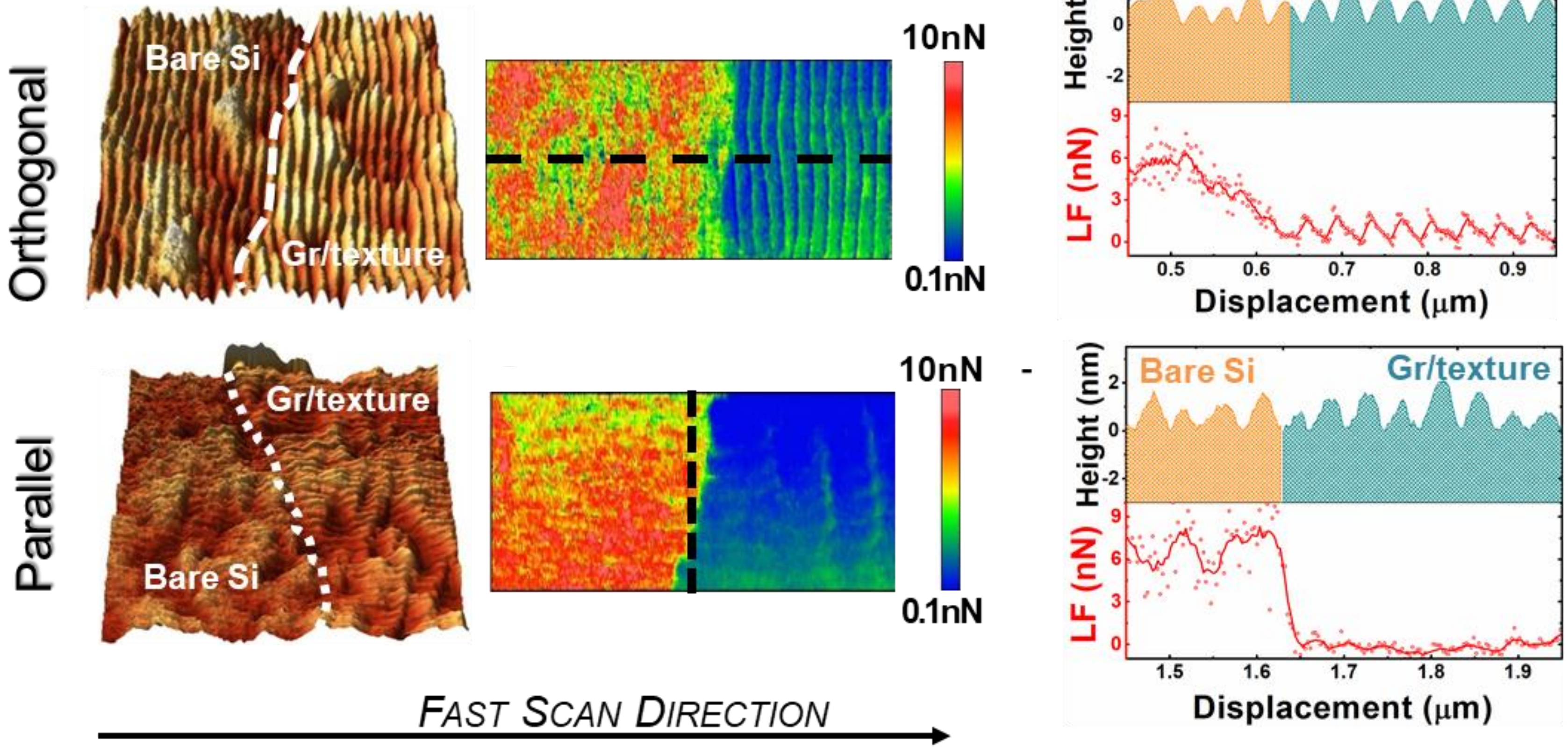
- ➢G and 2D peak position are associated with strain, since a change in lattice constant leads to a variation in the phonon modes.
- ➢A gradual phonon softening of G and 2D peak position of graphene deposited over texturing has been observed.
- ➢The correlation plot illustrates a relative change in the average compressive strain
- ➢It is known that physically deposited graphene over flat Si substrate get p-type doped system of compressive strain. The textured regions reduces the compressive strain in graphene with smaller P values.
- ➢Releasing of compressive strain from the flat surface in the textured regions

Friction Force Microscopy (FFM) on P40

Sample Orientation | 3D-Topography | Lateral Force map | Topography/Lateral Force profile

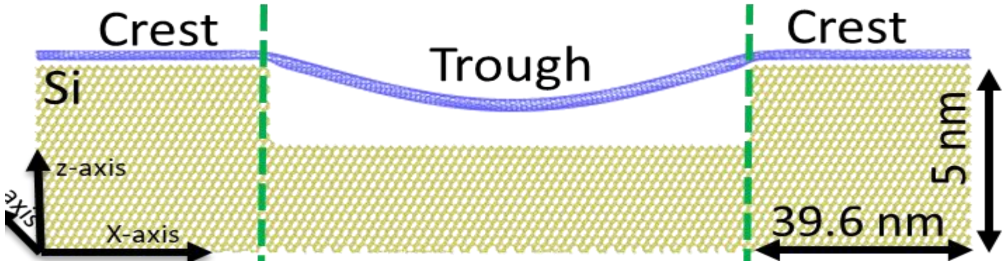


The sample is scanned in the direction in which the cantilever is twisted. Frictional force, occurring between probe and sample, is converted into cantilever's torsion which is simultaneously detected as frictional and topographic images

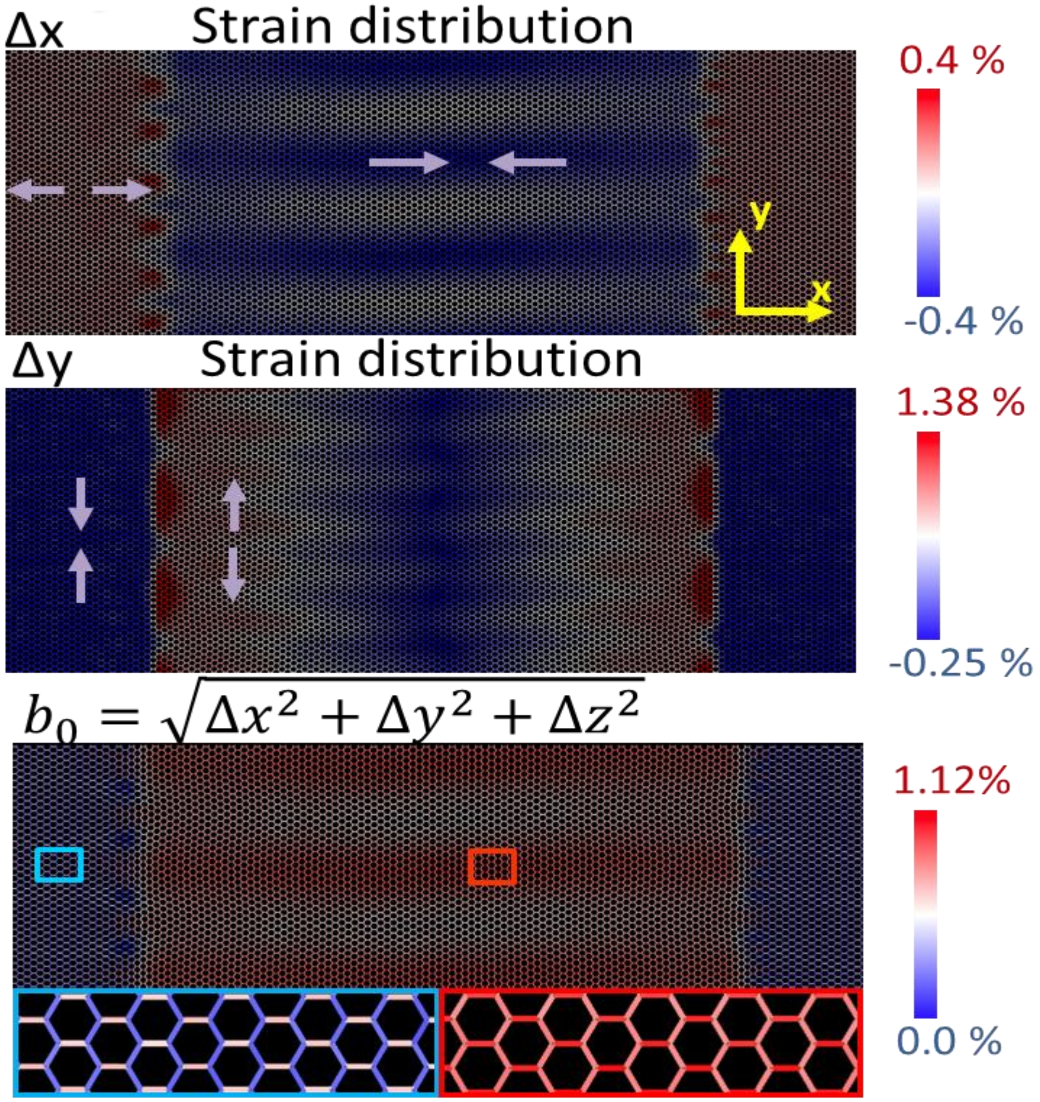


Molecular dynamics simulations on P40

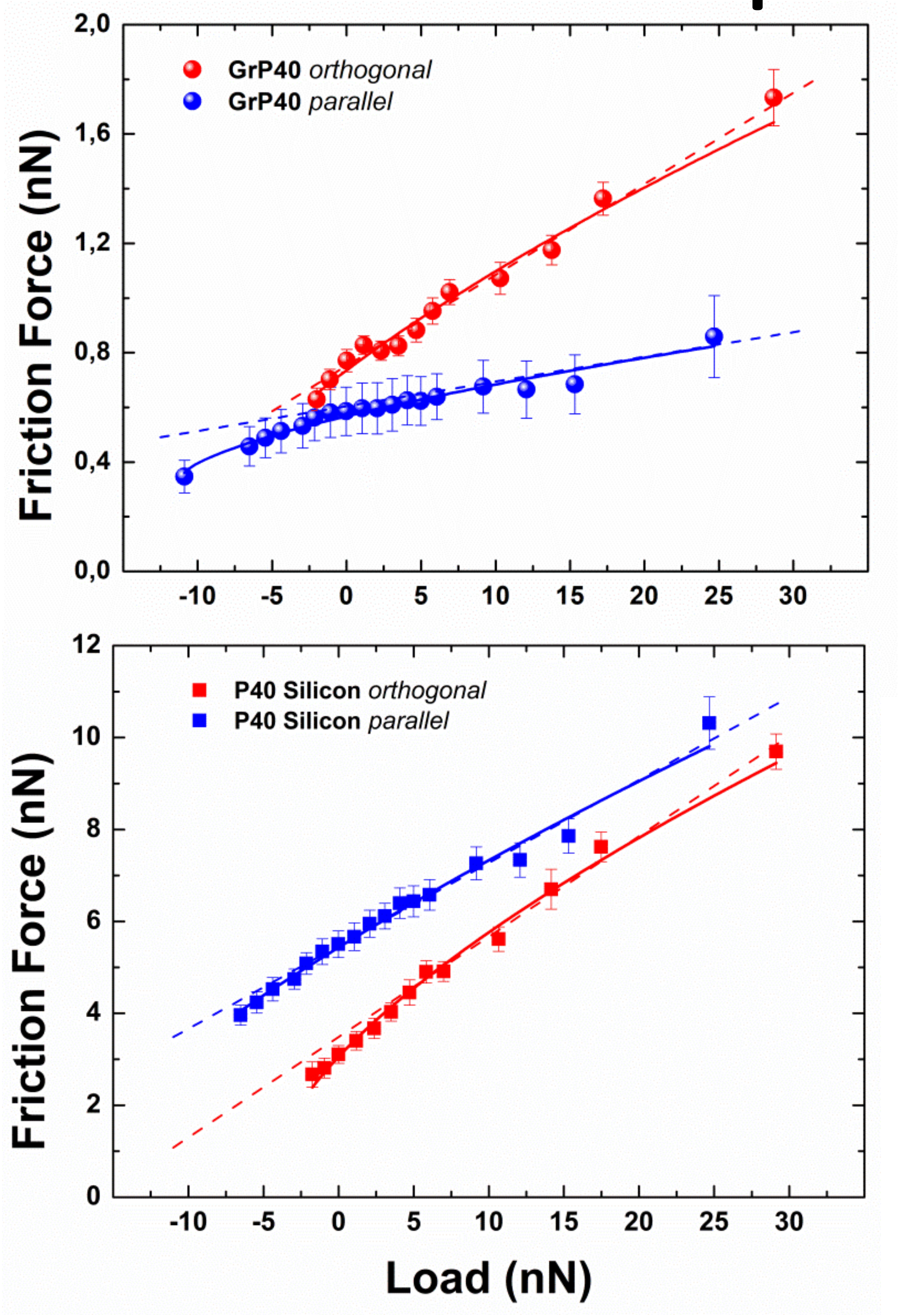
Strain distribution along the crests and the trough based on bond strain variation along the x-axis (Δx), y-axis (Δy) and total bond length (b_0).



- x-axis, the localised stretching of C-C bonds at the interface leads to a net compressive strain distribution at the trough.
- y-axis, a significant tensile strain dominates from interface to the trough region.
- The integral bond length (b_o) distribution illustrates asymmetric bond alteration along the orthogonal (stretching) and parallel (compressive) to the groove axis results in anisotropy in friction forces orthogonal and parallel to the groove axis.

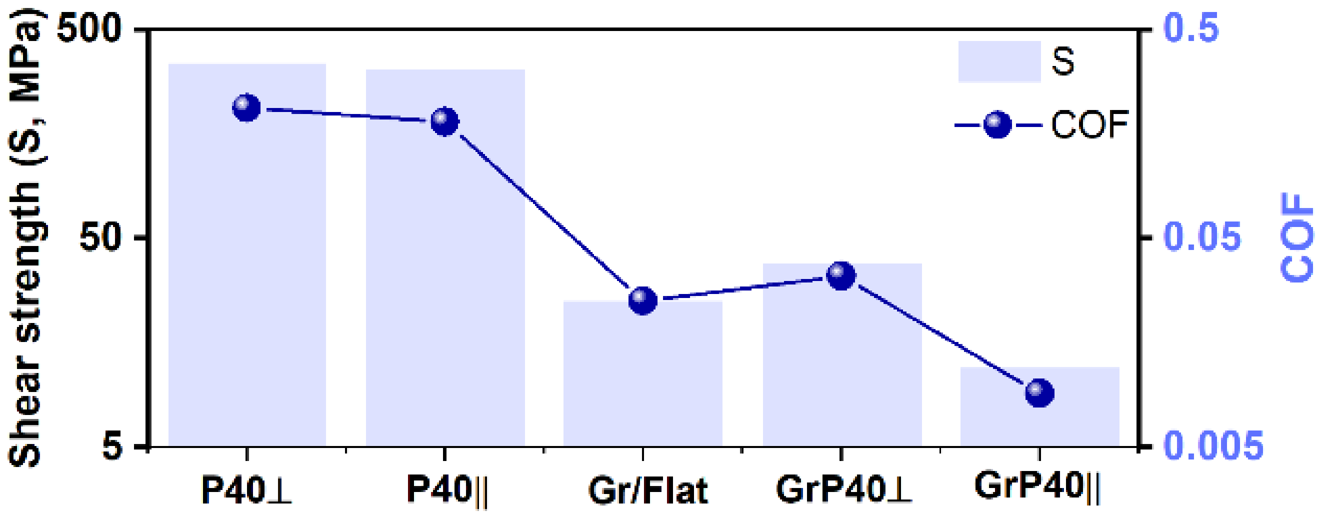


Anisotropic Frictional Response on P40



- The shear strength (S = friction force/area) of the interface is measured by fitting the data through the Derjaguin-Muller-Toporov (DMT) model following 2/3 power law within continuum mechanical modelling of the contact region
- the coefficient of friction (COF) is measured by a linear fit of the curves (dashed lines)

SAMPLE	SAMPLE ORIENTATION	COEFFICIENT OF FRICTION	
		Location 1	Location 2
GrP40	Orthogonal	0.033±0.002	0.040±0.002
GrP40	Parallel	**0.009±0.001**	**0.011±0.002**
P40 Silicon	Orthogonal	0.21±0.01	
P40 Silicon	Parallel	0.18±0.01	



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