VISION: Visualizing nano-mechanics of two-dimensional membranes by in-situ Atomic Force Microscopy-Scanning Electron Microscopy

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Shanghai University: Dengsong Zhang et al.
Motivation: 2D membranes

- Suspended membranes of two-dimensional (2D) materials have wide technological application potential
  - Graphene, MoS$_2$ & other transition metal dichalcogenides etc.

- Example Graphene membranes:
  - Ultrafast electronics via mitigation of substrate-related scattering
  - Nano-electro-mechanical systems (NEMS), e.g. ultrafast resonators
  - Chemical species separation, e.g. filtration or desalination

References:
- Science, 315, 490 (2007)
- Science, 344, 289 (2014)
Challenge: 2D membrane characterisation

- Required: Understanding of 2D membrane nanomechanics → characterisation tools needed

- Characterisation often employs scanning probe microscopy (SPM) techniques
  - Scanning Tunnelling Microscopy (STM)
  - Atomic Force Microscopy (AFM)
  - All SPM techniques rely on a sharp tip rastering across a sample surface and measuring tip-sample interaction at each point to visualize sample topography

- Disturbance-free SPM measurements of freestanding 2D membranes are however an unsolved challenge...

References:

Science, 336, 1557 (2012)
Nano Lett. 13, 1934 (2013)
Nat Commun 5, 3720 (2014)
Carbon 77, 236 (2014)
Nat Commun 5, 4962 (2014)
2D membranes – flexible, wrinkles & ripples

• Suspended 2D membranes highly flexible & are intrinsically wrinkled & rippled

• All SPM measurement rely on the interaction of a sharp tip with a sample surface

• Any SPM tip actually deforms 2D membranes’ wrinkles & ripples and stretches the 2D membranes during the measurement → the measured topographies are highly probe-dependent...

Indirect approach: Strain mapping

- Indirect approach via strain mapping using combined AFM-Raman spectroscopy
- Frequencies of Raman bands in graphene are highly strain dependent → we use Raman spectroscopy to map strain induced from AFM tip
- Actual topography of 2D membrane remains undetermined → direct approach required to visualize 2D membrane deformation from AFM tip
AFSEM™ from GETec

- Austrian company GETec Microscopy GmbH is world-leading in providing a uniquely compact AFM module (AFSEM™) that is readily installed in commercial scanning electron microscopes (SEMs).

- GETec’s AFSEM™ allows unprecedented correlative AFM-SEM measurements (plus additionally correlative energy dispersive X-ray spectroscopy (EDX) and electrical mapping capabilities).

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Graphene membrane in high-speed AFSEM™ AFM module: Varying AFM setpoint drastically changes measured topography of graphene membrane → What is the real topography?
Conclusions & Acknowledgements

• VISION develops a novel in-situ AFM-SEM capability and will thereby elucidate the nanomechanics of 2D membranes under local deformation.

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Thank you!