ΓΕΝΙΚΗ ΓΡΑΜΜΑΤΕΙΑ ΕΡΕΥΝΑΣ ΚΑΙ ΤΕΧΝΟΛΟΓΙΑΣ

European Research Council
Executive Agency
Established by the European Commission

ΕΘΝΙΚΟ ΚΕΝΤΡΟ ΤΕΚΜΗΡΙΩΣΗΣ
NATIONAL DOCUMENTATION CENTRE

Ημερίδα για το πρόγραμμα του Ευρωπαϊκού Συμβουλίου Έρευνας (ERC) στον Ορίζοντα 2020

“ERC Advanced Grants”

Costas Galiotis*
University of Patras Chem. Eng.Dept. & FORTH/ ICE-HT

*c.galiotis@iceht.forth.gr OR galiotis@chemeng.upatras.gr

FORTH/ICE-HT

ChemEngUP

Definitions

- *ERC Advanced Grants* allow exceptional established research leaders of any nationality and any age to pursue ground-breaking, high-risk projects that open new directions in their respective research fields or other domains.

- The *ERC Advanced Grant* funding targets researchers who have already established themselves as independent research leaders in their own right.

- *Sole evaluation criterion*: scientific excellence of researcher and research proposal.

- *Funding*: up to € 2.5 million per grant.

- *Duration*: up to 5 years.

- *Calls for proposals*: published once a year

Concepts

- High Risk-High Gain philosophy.
- Brief and conceptual proposals (NB in contrast to what is required in other programmes).
- Team work is important.

Reviewing/ Step 1*/Extended Synopsis

***Marks range from 1 (non-competitive) to 4 (outstanding)**

Criterion 1 - Research Project: Ground-breaking nature, ambition and feasibility

1.1 - Ground-breaking nature and potential impact of the research project

- To what extent does the proposed research address important challenges?
- To what extent are the objectives ambitious and beyond the state-of-the-art?
- To what extent is the proposed research high risk/high gain?

1.2 - Scientific Approach

- To what extent is the outlined scientific approach feasible (based on Extended Synopsis)?

Criterion 2 - Principal Investigator Intellectual capacity and creativity

- To what extent has the PI demonstrated the ability to propose and conduct ground-breaking research?
- To what extent does the PI provide evidence of creative independent thinking?
- To what extent have the achievements of the PI typically gone beyond the state of the art?
- To what extent has the PI demonstrated sound leadership in the training and advancement of young scientists?

Reviewing/ Step 2*/ Full Proposal

***At Step 2 the complete version (i.e. Parts B1 and B2) of the retained proposals are assessed.**

Research Project

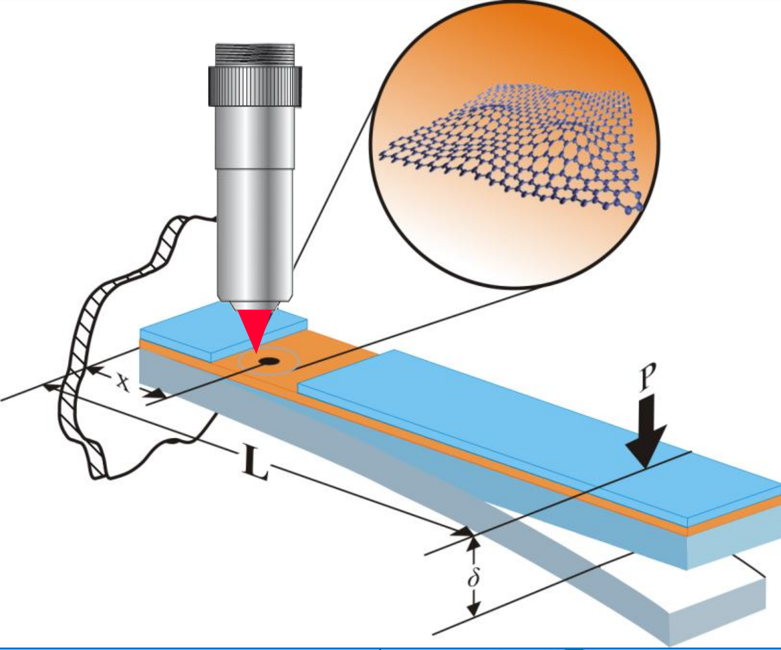
- Ground-breaking nature and potential impact
- Scientific approach

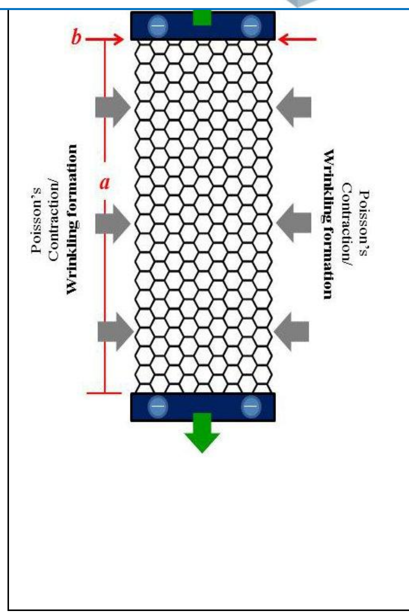
Principal Investigator

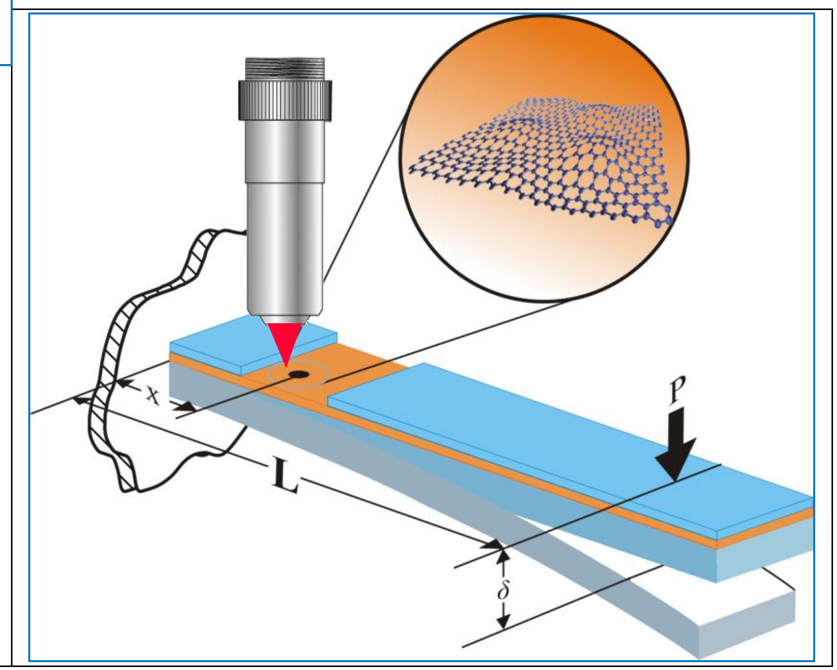
- To what extent has the PI demonstrated the ability to propose and conduct ground-breaking research?
- To what extent does the PI provide evidence of creative independent thinking?
- To what extent have the achievements of the PI typically gone beyond the state of the art?
- To what extent has the PI demonstrated sound leadership in the training and advancement of young scientists?
- To what extent does the PI demonstrate the level of commitment to the project necessary for its execution and the willingness to devote a significant amount of time to the project (min 30% of the total working time on it and min 50% in an EU Member State or Associated Country) (based on the full Scientific Proposal)?

Our project

ne to Withstand Large Deformations



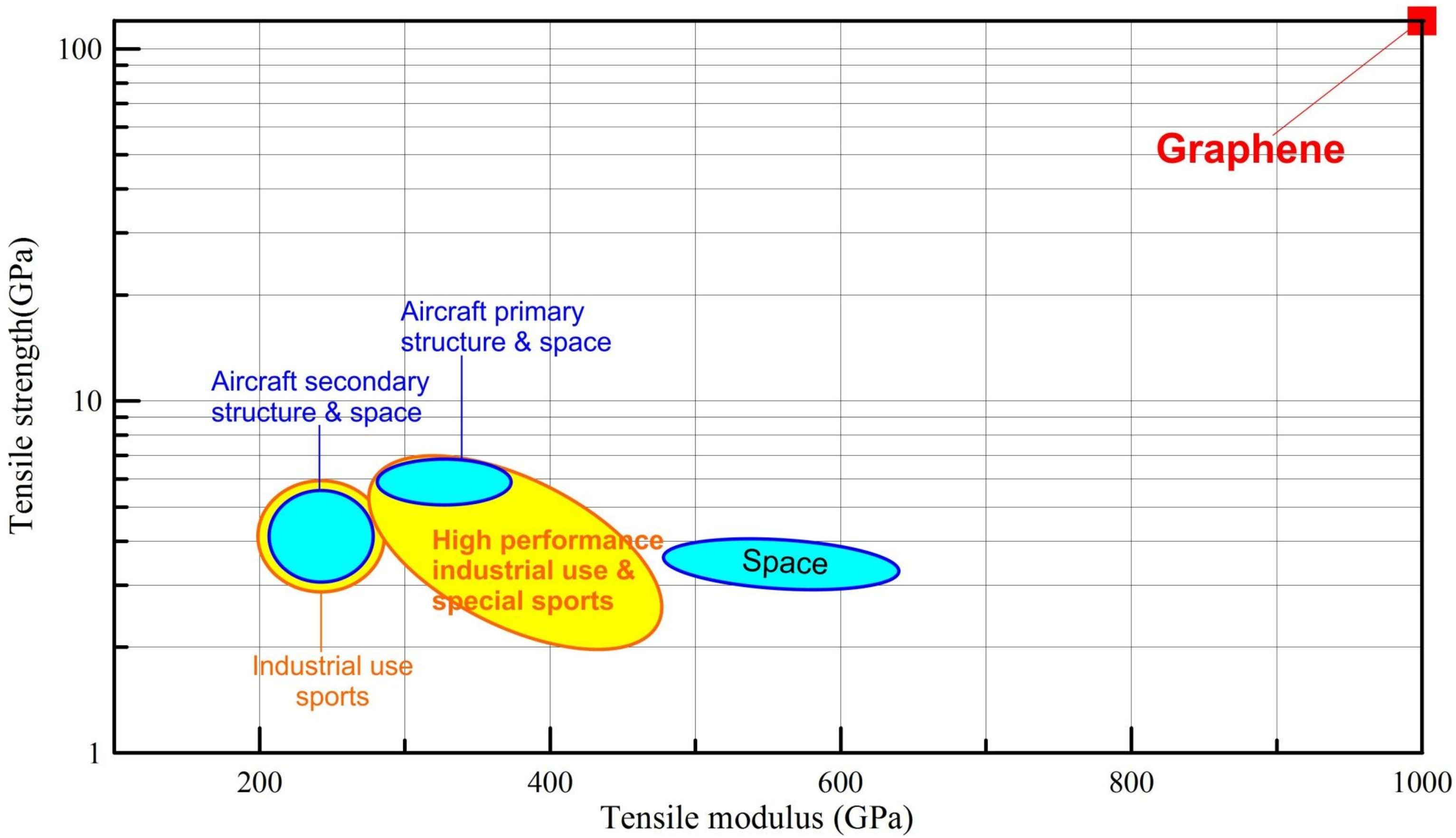




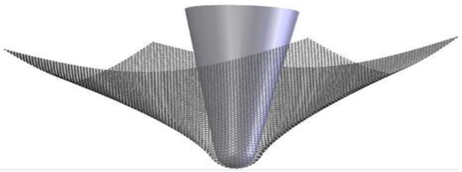
Exfoliated Graphene: The Ideal Reinforcing Material?

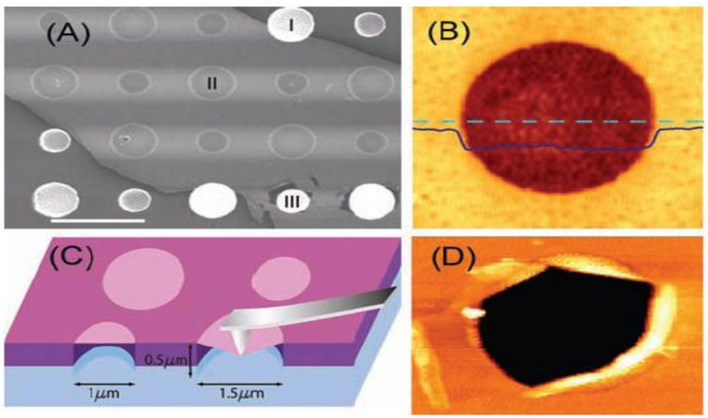
Expected Properties

- High Young's modulus (1 TPa)
- High fracture strength and strain in tension (>100 GPa, >30%)

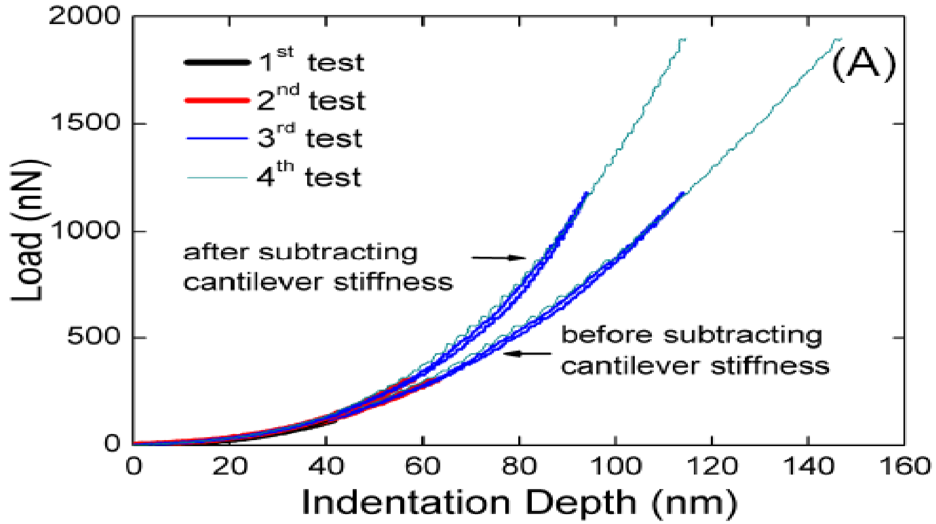


Initial Experiments: Nanoidentation (bending) Experiments in Air





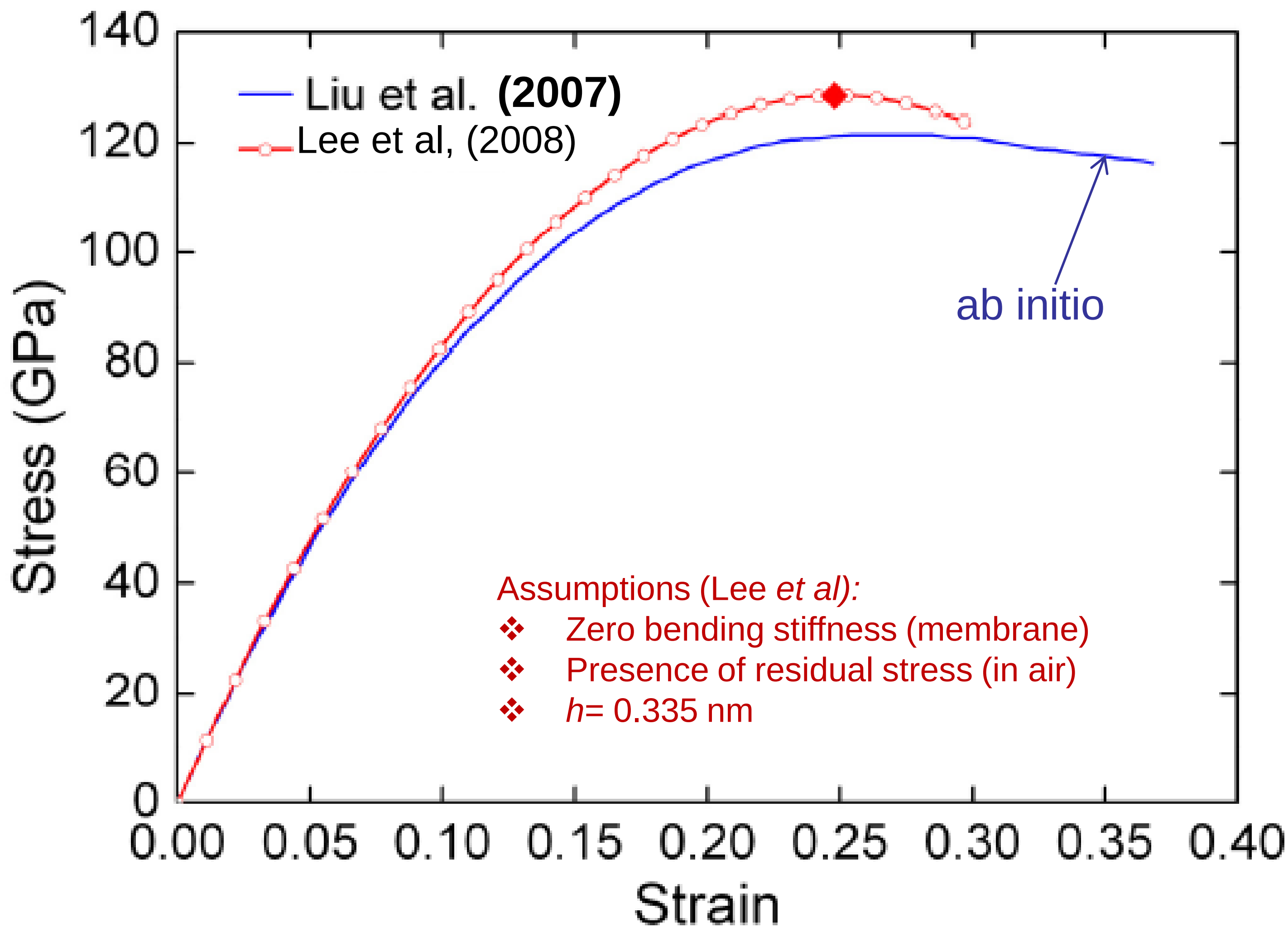
[1] Lee, et al., *Science*, 321, (2008), 385-388



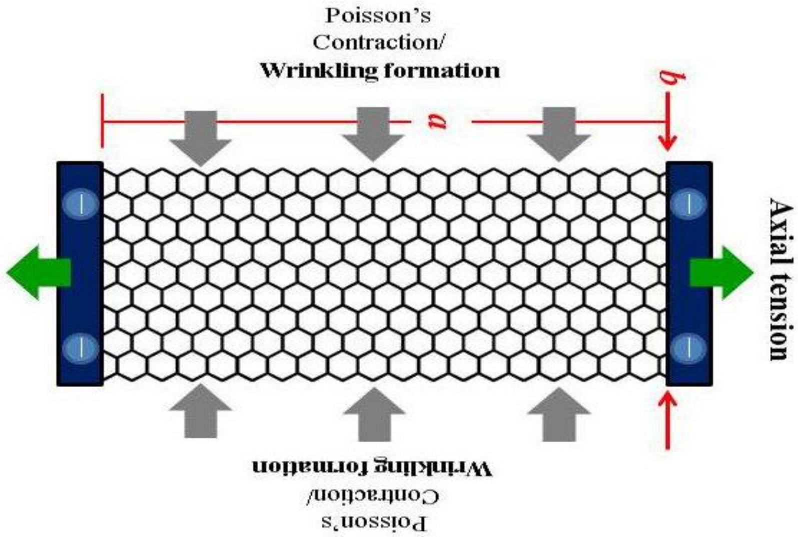
❖ The force-displacement behaviour obtained from AFM nanoindentation was interpreted in terms of nonlinear elastic stress-strain response.[1]

Derived axial stress-strain curves

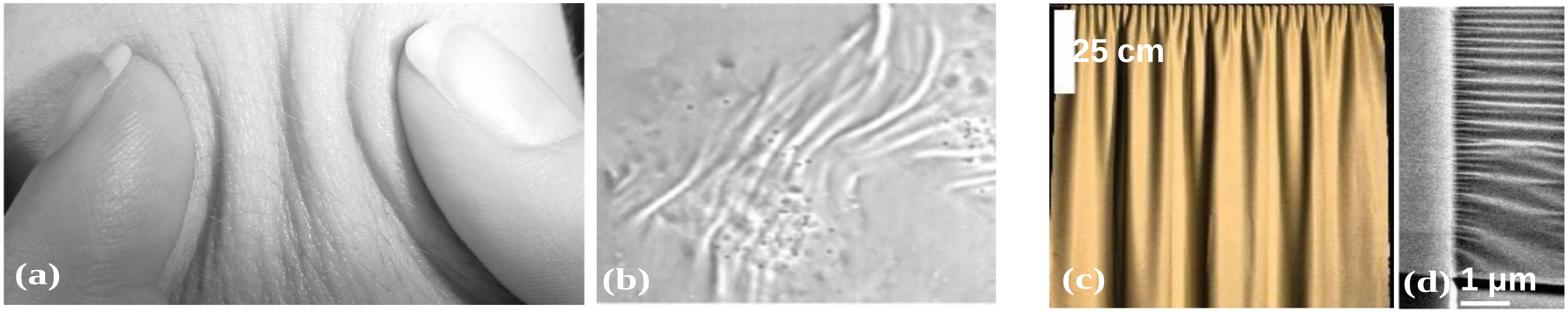
Lee, et al., *Science*, 321, (2008), 385-388



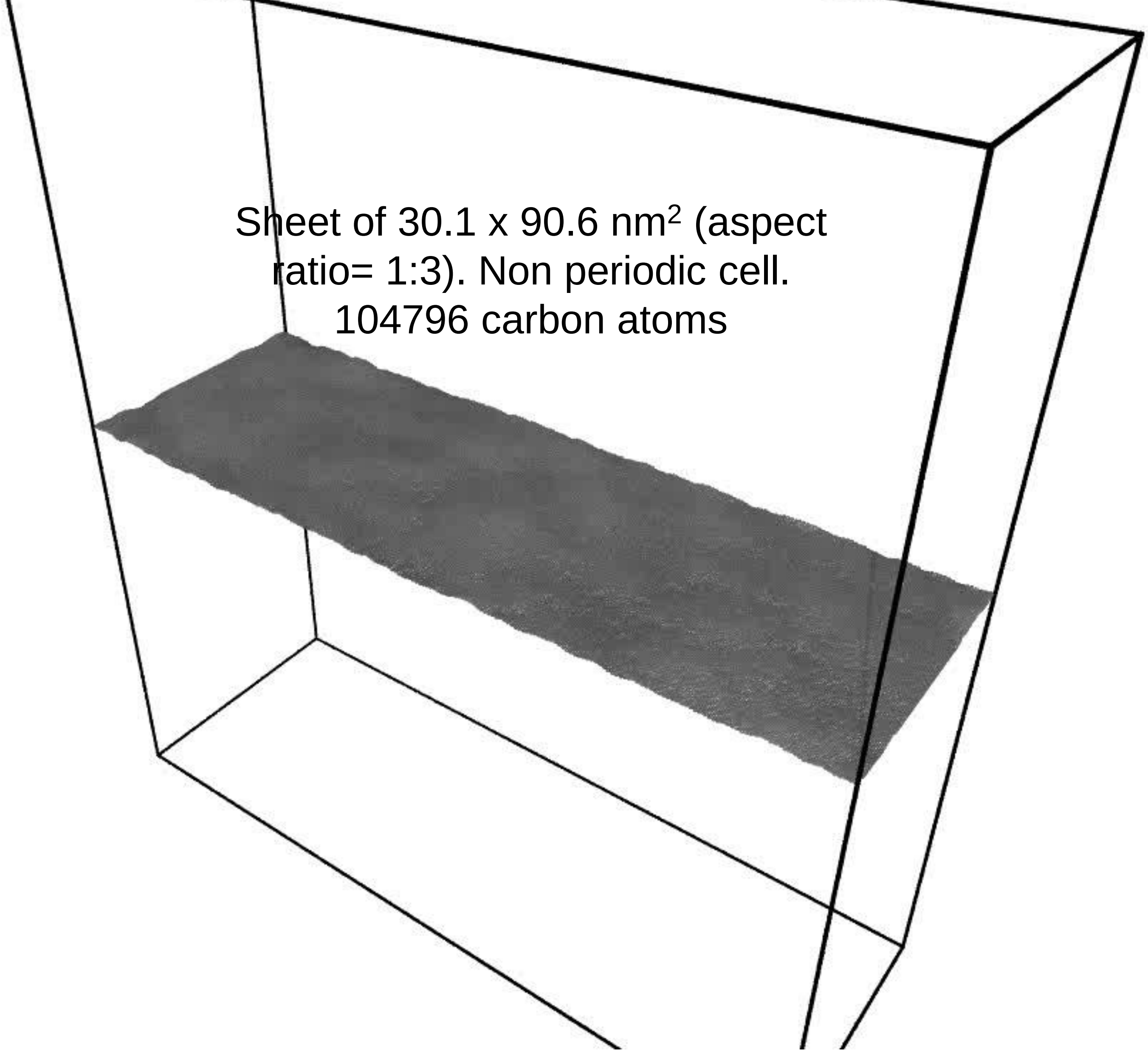
Wrinkling of thin membranes



- The *wrinkling* of thin elastic sheets occurs over a range of length scales.

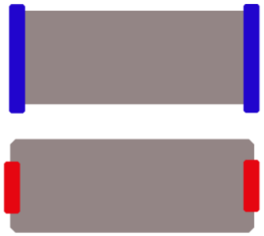


Human Skin | Human Cell on Si | House Curtains | Graphene

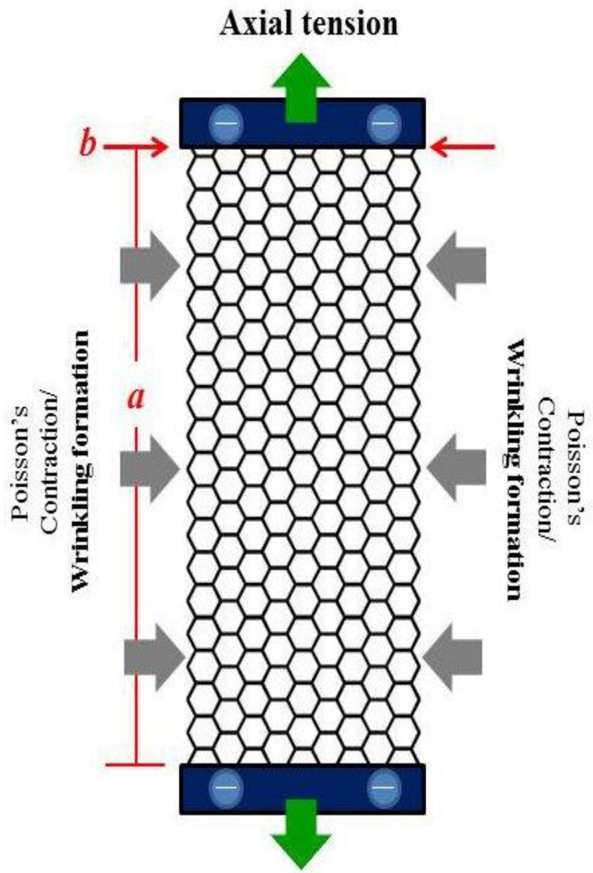


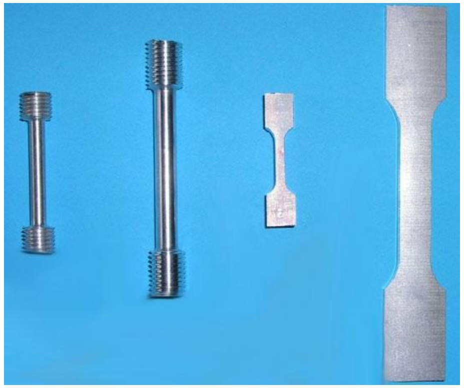
Sheet of 30.1 x 90.6 nm^2 (aspect ratio= 1:3). Non periodic cell. 104796 carbon atoms

Partially (34%) Clamped



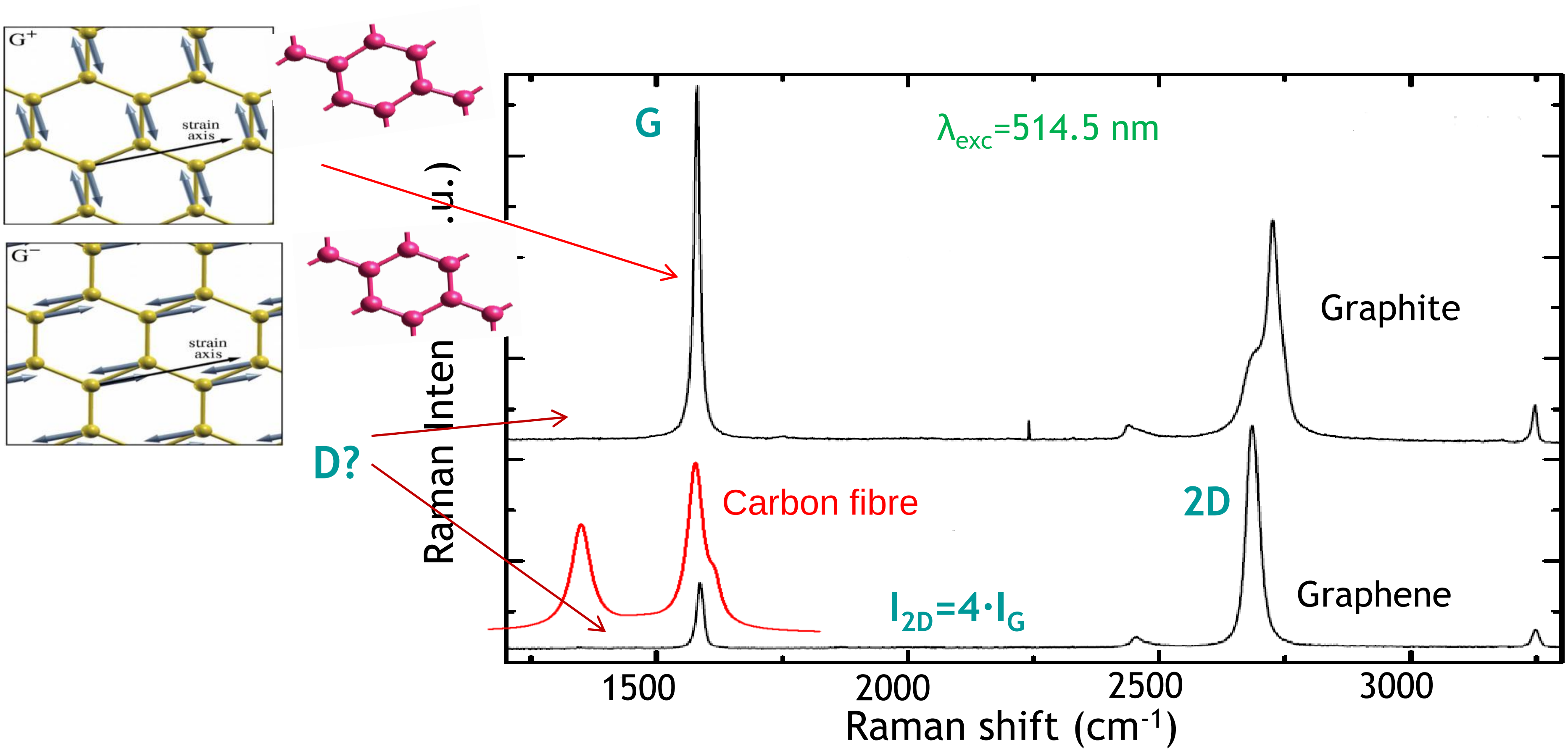
Conventional tensile testing of graphene…is it possible?





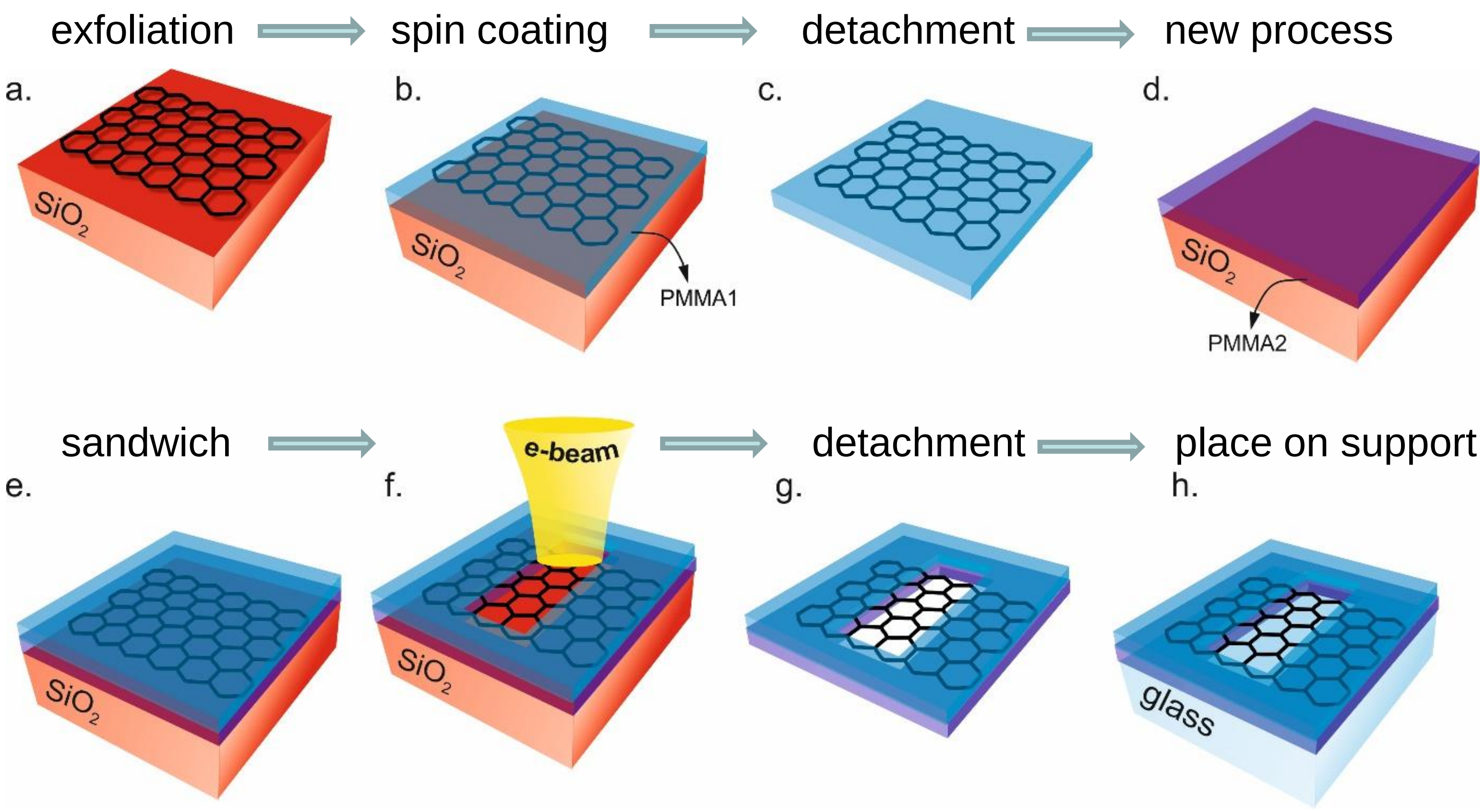
130 GPa for a flake of 20 μm in width correspond to ~4 pN !

Typical Raman Spectra



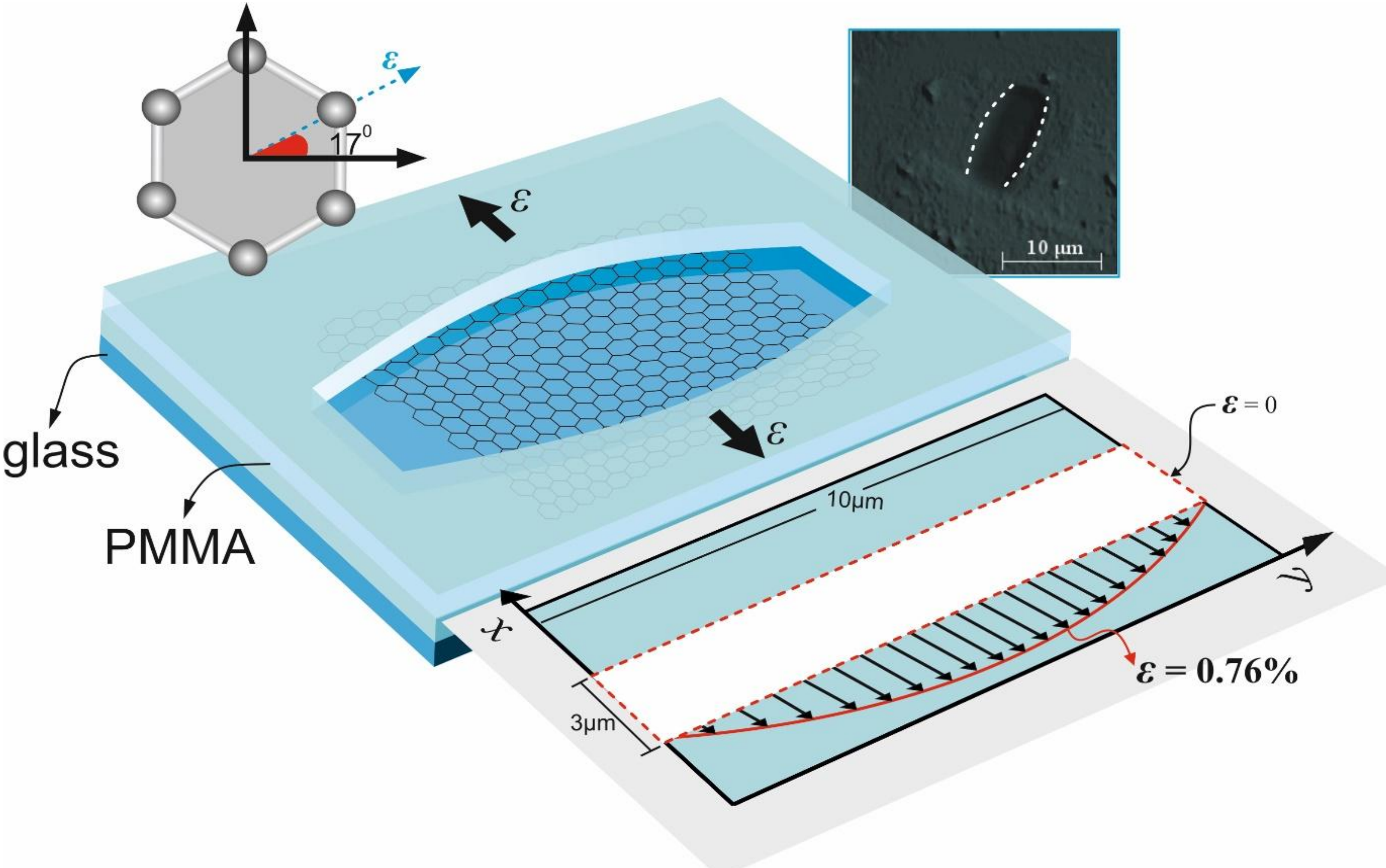
Fabrication of suspended graphene monolayer

Polyzos et al, *Nanoscale* (2015)



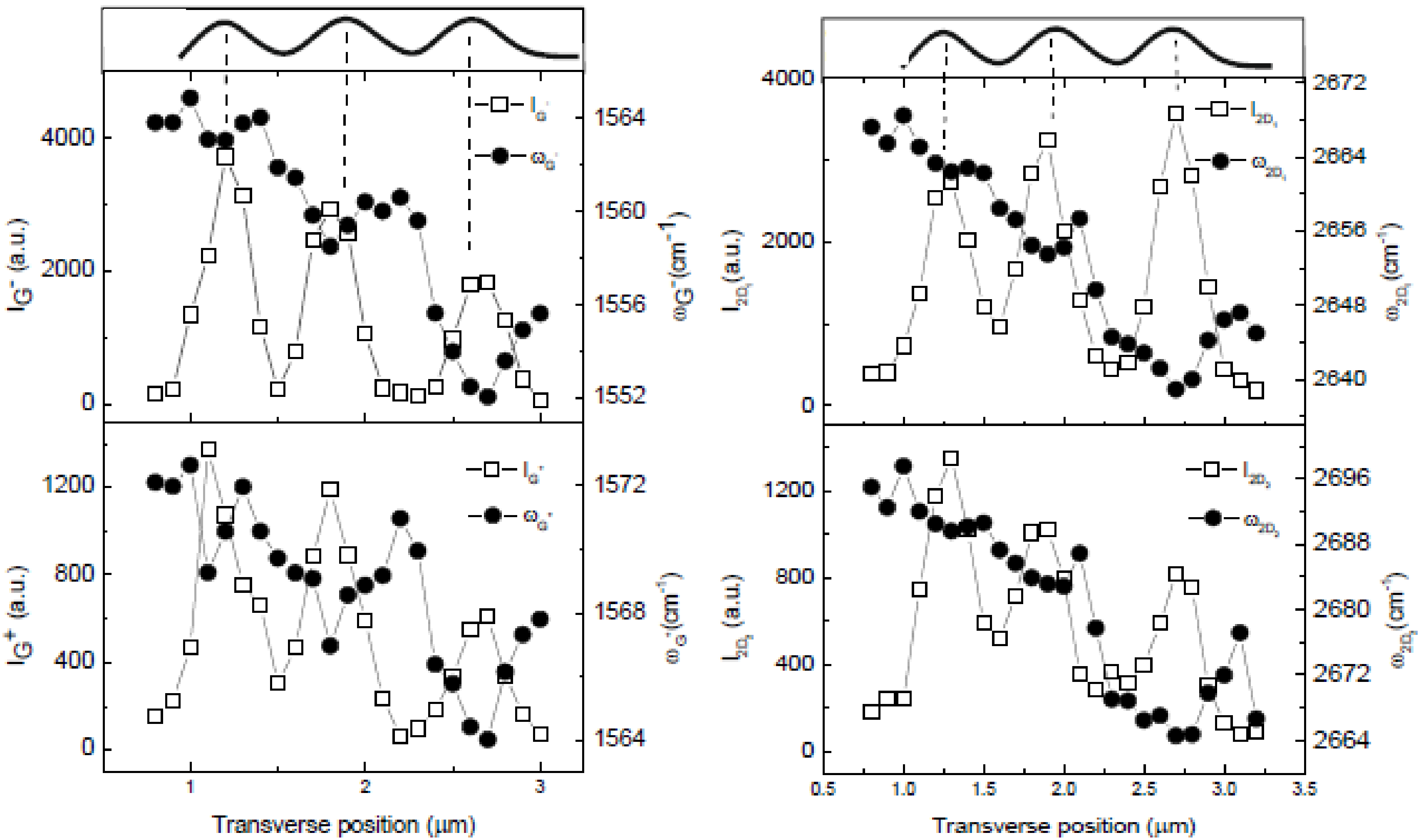
Fabrication-induced stress/strain gradient

Polyzos et al, *Nanoscale* (2015)

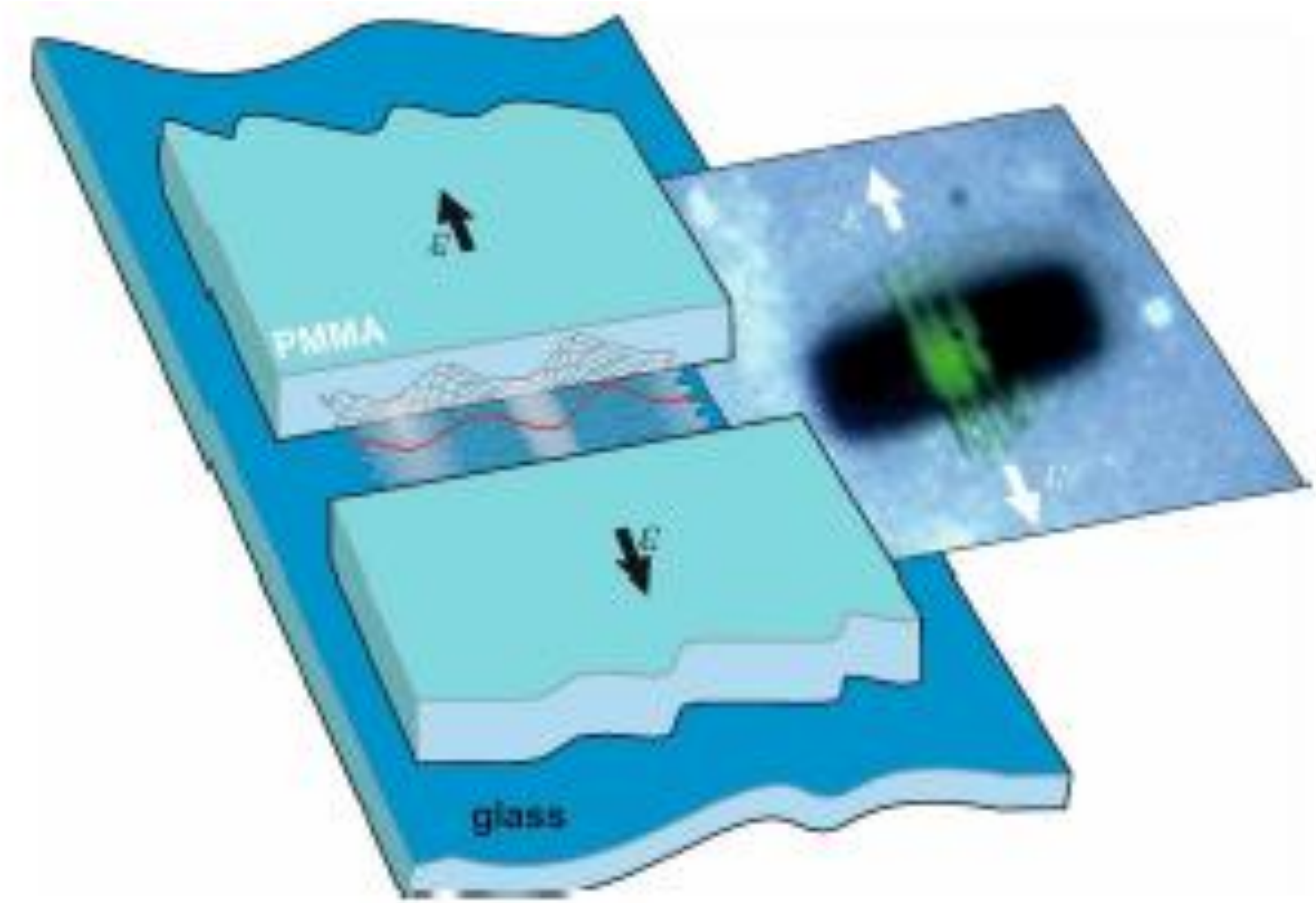


Strain distribution along the width of flake

Polyzos et al, *Nanoscale* (2015)

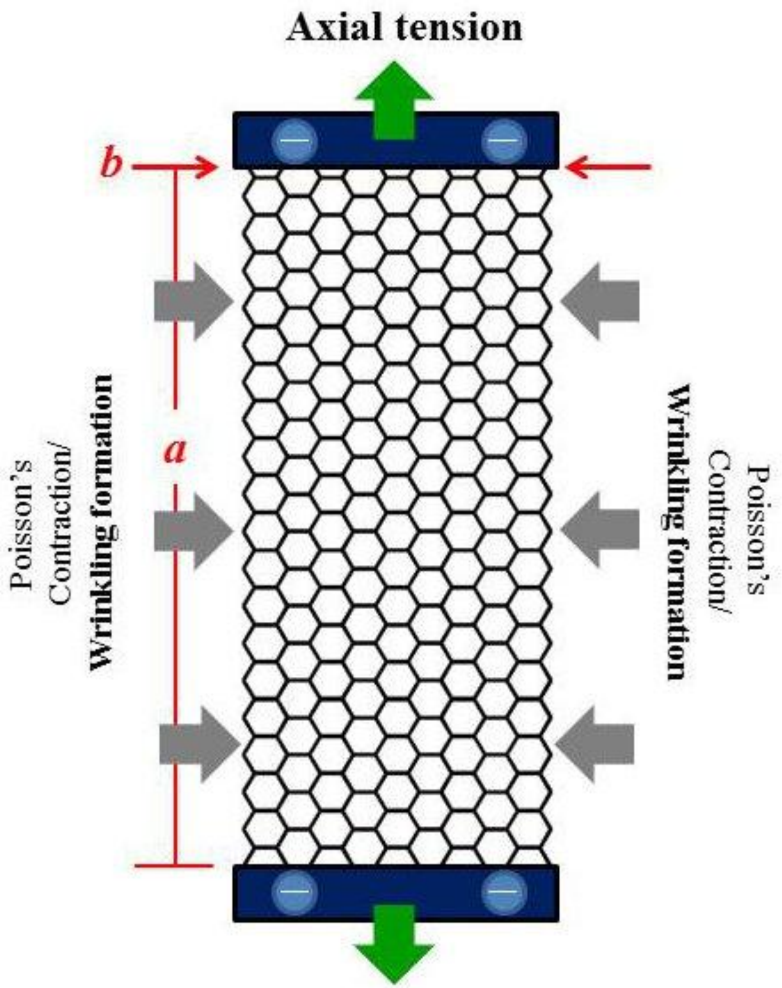


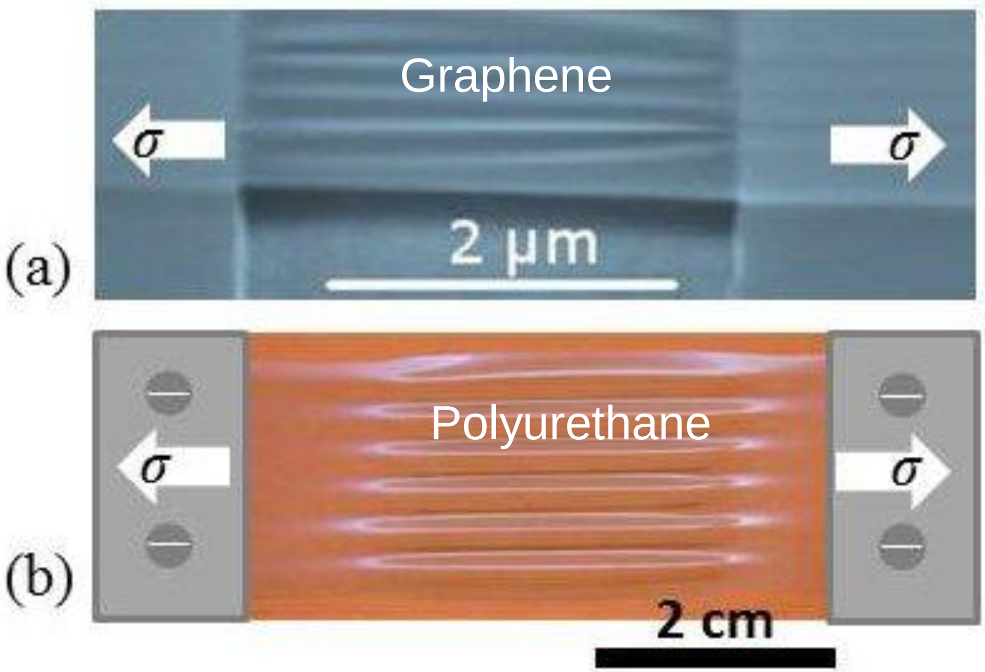
Orthogonal buckling (wrinkling) in air due to uniaxial deformation



Orthogonal buckling (wrinkling) in membranes: a universal effect

Polyzos et al, *Nanoscale*, 2015





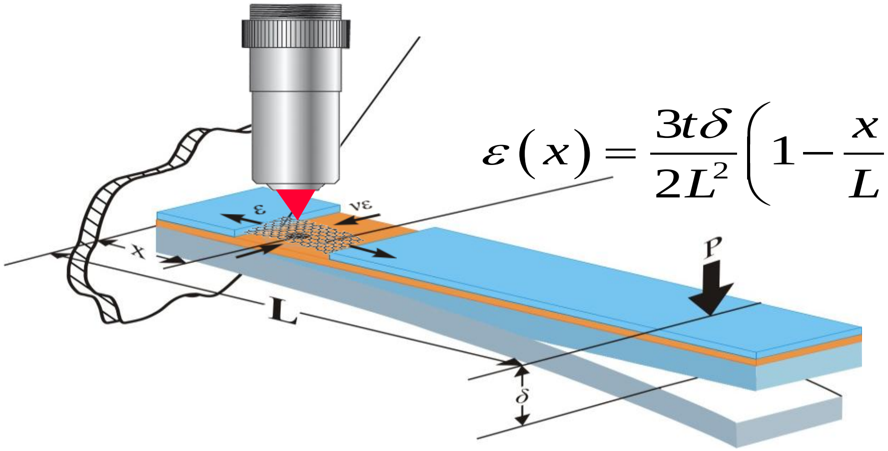
For a layer of atomic thickness in air, $\varepsilon_c \approx 10^{-9}$ (1 nanostrain**)**

FORTH/ICE-HT

ERC Event, 13 January 2016, NHRF, Athens

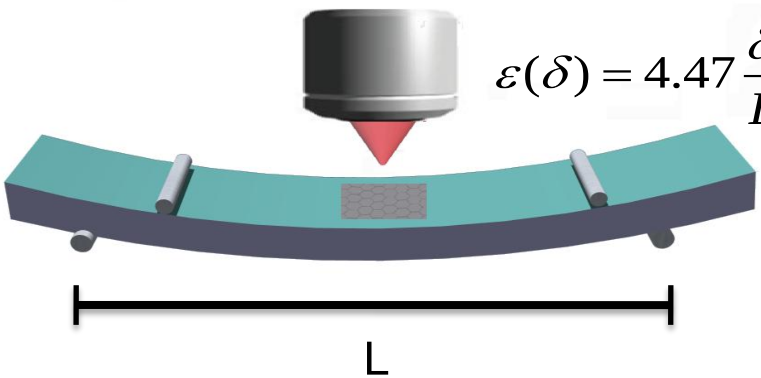
ChemEngUP

Loading Devices: top layer under uniaxial tension or compression



$$\varepsilon(x) = \frac{3t\delta}{2L^2}\left(1 - \frac{x}{L}\right)$$

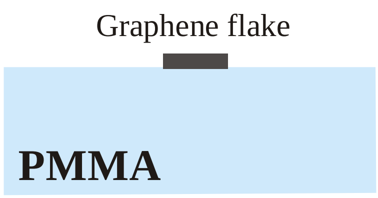
δ: deflection of the beam neutral axis
L: span of the beam
t : beam thickness



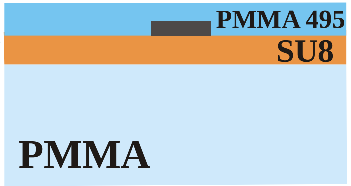
$$\varepsilon(\delta) = 4.47\frac{\delta t}{L^2}$$

δ: deflection (manually applied)
t: thickness of PMMA bar
L: length of supporting span

Specimens



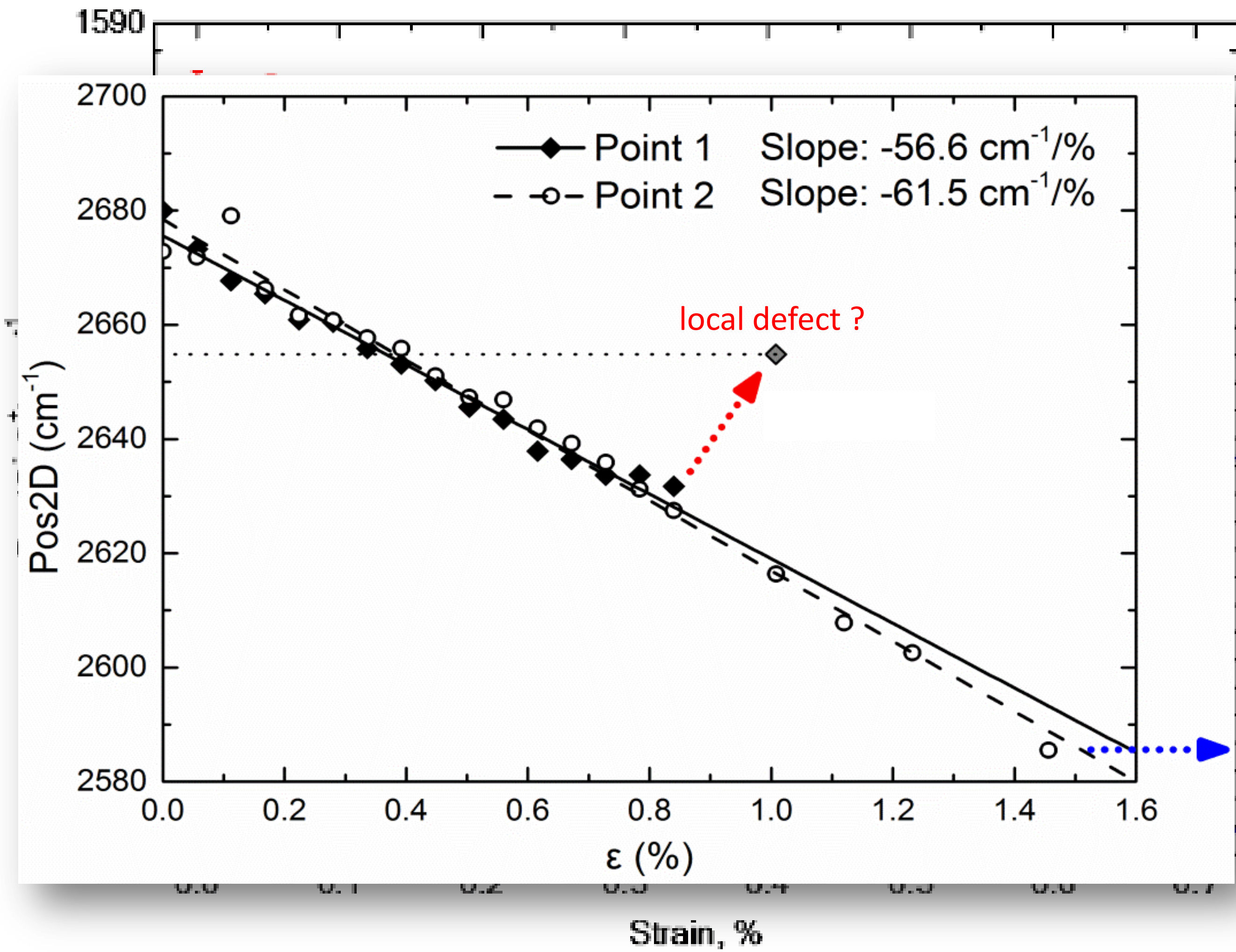
Simply supported



Fully embedded

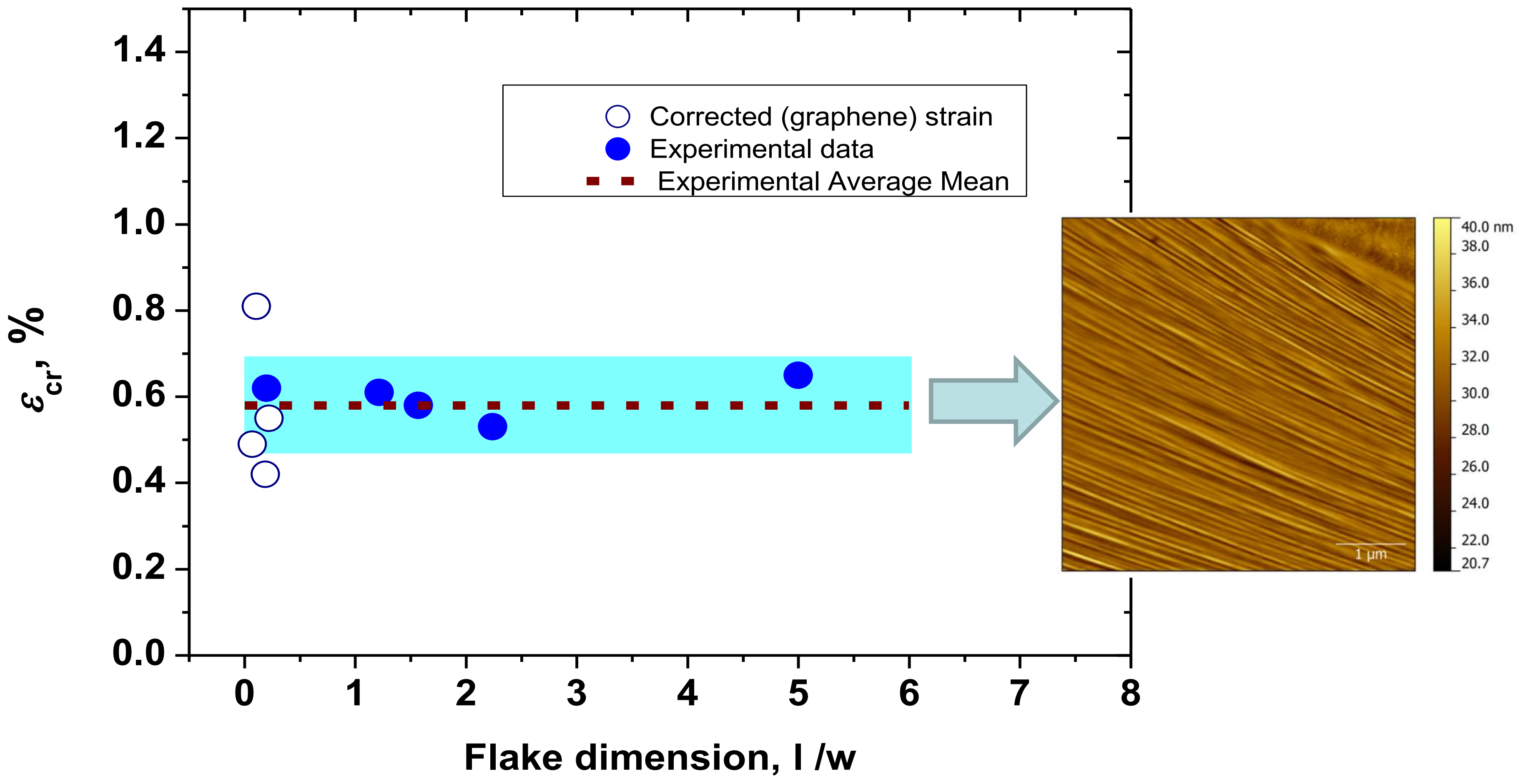
Tensile deformation of embedded flakes on PMMA beams

2D peak



Critical strain for buckling vs flake dimensions for embedded 1LG

Androulidakis et al. *Sci. Rep. (Nature)* 4 : 5271 (2014)



Critical tensile strain for lateral buckling under uniaxial loading

- According to the compression data for all cases for which *l>w* and for efficient load transfer, lateral buckling will occur at a value of -0.6%. Hence the required axial strain for lateral buckling for EMBEDDED graphene is given by:

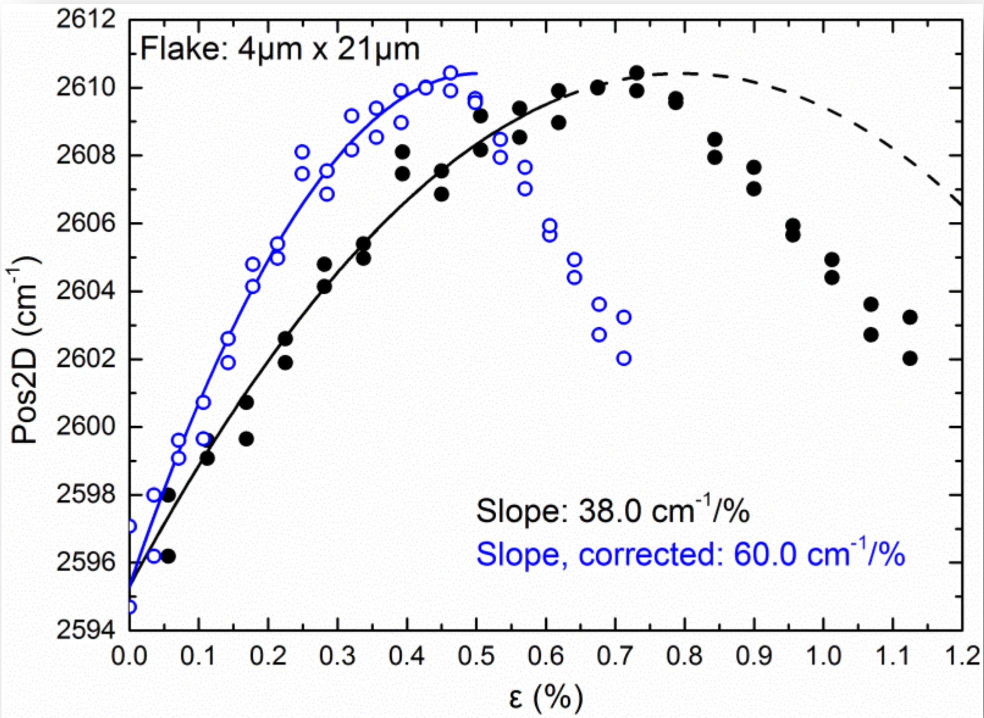
$$\varepsilon_{tensile}^{critical} = \frac{0.006}{\nu} \sim 1.8\% \quad \text{(for a typical polymer)}$$

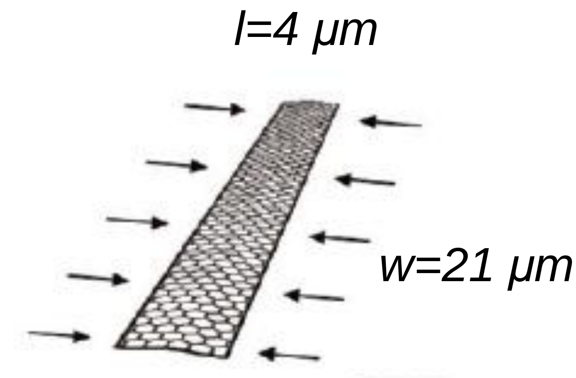
- This is OK for engineering applications but quite disappointing for a material that is EXPECTED to stretch to 30%.

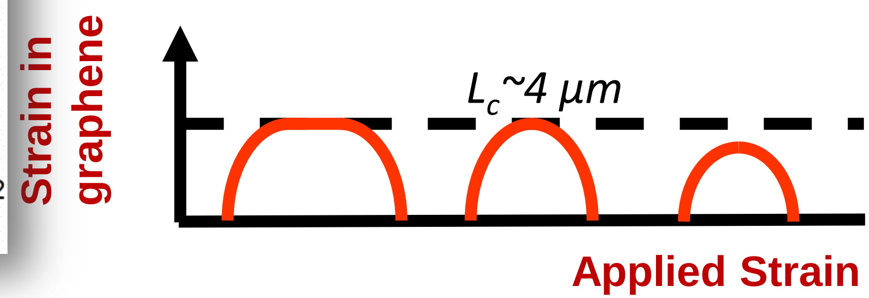
Compression data on short flakes: effect of transfer length

Androulidakis et al. *Sci. Rep. (Nature)* 4 : 5271 (2014)

Anagnostopoulos et *al, ACS- Appl. Mats & Interfaces,* 7, 4216–4223 (2015)







Turning inefficiency to our advantage…

- If the width is less than 4 μm then the shear field generated is not sufficient for a FULL stress/strain transfer.

- **THIS IS GOOD NEWS SINCE LATERAL BUCKLING IS "DELAYED" UPON TENSILE LOADING:**

$$\varepsilon_{tensile} = \frac{\varepsilon_{lateral}}{\nu} \qquad (1)$$

$$\varepsilon_{graphene} = \left(\frac{\text{measured RS}}{\text{maximum RS}}\right)\varepsilon_{lateral} \qquad (2)$$

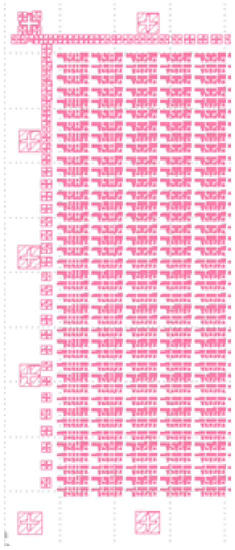
$$(1),(2) \Rightarrow \varepsilon_{tensile} = \frac{\varepsilon_{graphene}}{\nu}\left(\frac{\text{maximum RS}}{\text{measured RS}}\right)$$

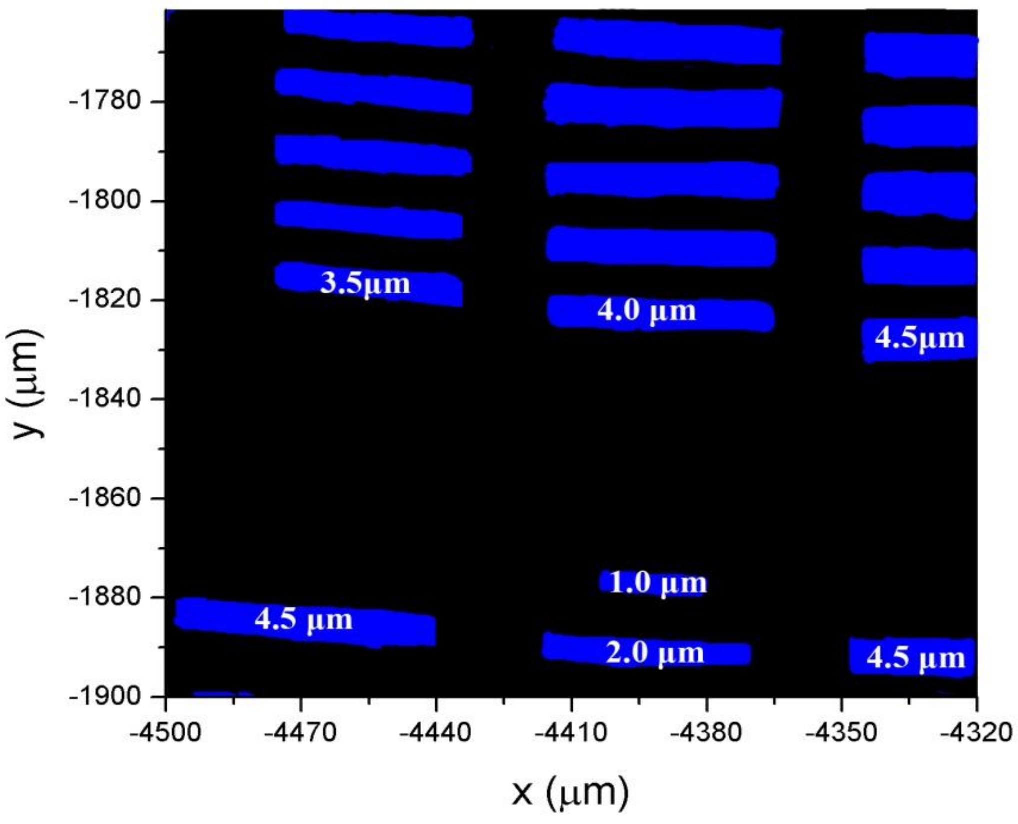
$$\text{To reach } \varepsilon_{graphene}^{critical} = 0.006 \Rightarrow \varepsilon_{tensile} \sim 3\%$$

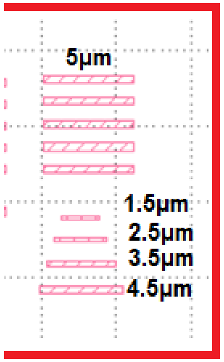
- In the case examined above the width of the ribbon was 4 μm. Further advantages are expected for widths of approx. 1 μm.

How to Tailor Graphene

- ❖ **IN AIR:** Nano-ribbons of less than 250 nm (half wavelength) in width.
- ❖ **EMBEDDED IN MATRICES:** Micro-ribbons of less than 4 μm in width







Points to take home

ERC Advanced Grants

- **The PI:** ***Solid career with achievements beyond (each time) the state-of-the art. Leadership in training of young scientists must be demonstrated.***

- **The Project:** ***Ambitious and ground-breaking (but feasible).***

Thanks for your attention!