# Calibration of polymeric micro-actuators for 2D-materials

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Polymeric thin films have been recently exploited to create non-trivial strain profiles in 2D materials [1, 2, 3], paving the way to promising strain engineering applications [4]. Here, I will report a detailed study on the mechanical response of poly-methyl-methacrylate (PMMA) layers under strong electron irradiation in a scanning electron microscope. Two complementary methods are used to study the effects of electron irradiation. In a first set of experiments PMMA is deposited on SiN-cantilevers [figure 1a] and the polymer contraction is quantified by looking at the change of the cantilever deflection using an optical profilometer. In a second step, PMMA is patterned onto a bilayer of epitaxial graphene [figure 1b] and the PMMA shrinkage is measured based on sets of SEM images taken at different electron doses and energies. From the analysis of the cantilever deflection, it is then possible to obtain a relationship between the electron dose and the stress of PMMA after e-beam irradiation. Together with the measured trends of the PMMA shrinkage on graphene, this leads to an estimate of the Young's modulus E = 1.8 GPa. We also obtain a stress vs dose calibration factor 456±86 [N/mC] at a beam energy of 5 keV and the energy dependence is found to largely derive just from the penetration depth of the electron beam in the polymer.

## References

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[2] F. Colangelo et al., 2D Mater. 5, 4 (2018) 045032.
[3] F. Colangelo, et al., Appl. Phys. Lett. 115 (2019) 183101.
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## Figures

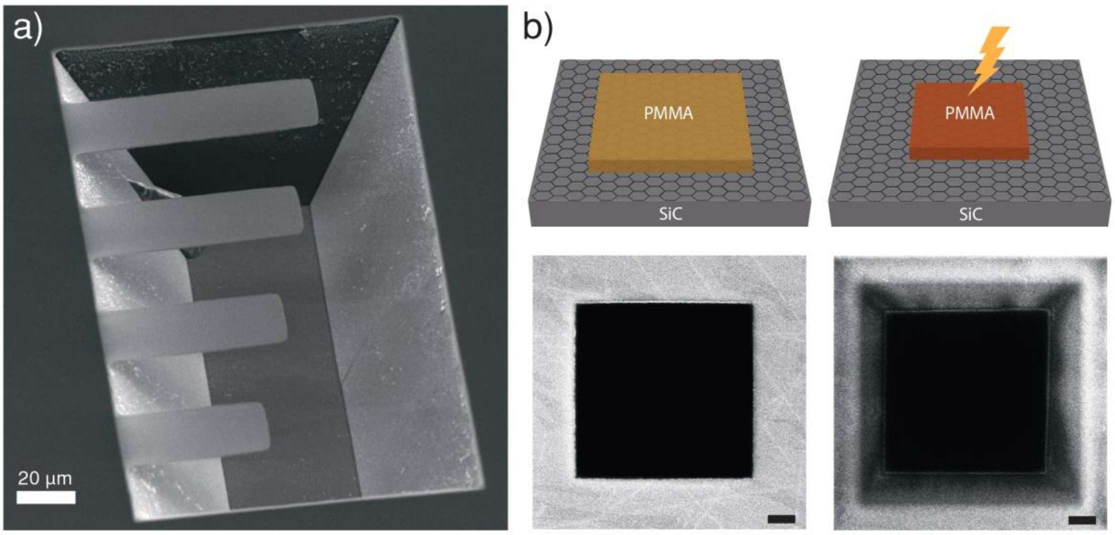


**Figure 1:** (a) SEM image of the SiN cantilevers. (b) Top: schematic diagram of the experiment involving PMMA patterned onto a bilayer of epitaxial graphene. From left to right, the panels illustrate the e-beam induced shrinkage of PMMA. Bottom: SEM image of the experiment showing the PMMA block before (left) and after (right) e-beam irradiation. The scale bar is 200 nm.