Graphene-based MEMS devices and route to manufacturing

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Graphene is the novel atomically-thin carbon layer with superlative properties that are ideal for MEMS applications – a combination of extremely high stiffness and breaking strength, high elasticity, and extremely low mass [1]. I will present our results on the development of the graphene-polymer heterostructure MEMS membrane which demonstrated a viable solution to the challenge of large-area defect free graphene MEMS device fabrication with high yield and excellent device performance [2]. Latest results will include extending the previous demonstrated 'strained transfer' technique for producing uniaxially pre-tensioned graphene membranes [3,4] to a biaxially pre-tensioned membrane which provides further significant improvement in performance. The deflection performance of the graphene membrane and the resulting capacitance changes are modelled and verified by a von-Karman finite element solver [5]. We have recently shown that the graphene MEMS membrane can be integrated into commercial multi-user MEMS processes. We will demonstrate pressure sensors and capacitive micromachined ultrasound transducers (CMUTs) based on graphene-polymer heterostructure MEMS membranes integrated with chips fabricated on the PiezoMUMPs and PolyMUMPs platforms. The pressure sensors offer a combination of very high sensitivity and wide operating pressure range while the CMUTs are novel in being able to operate at near-zero DC bias, in the frequency range of 1 – 10 MHz, which is commensurate with medical ultrasound and non-destructive testing applications. The combination of these significant and novel advances means that graphene MEMS devices can now be fabricated based on commercial MEMS platforms, allowing for vastly increased device complexities and yield and a route to large-scale manufacturing and commercial implementation.

References

[1] Z. H. Khan et al, J Phys D: App Phys, 50 (2017) pp. 053003.
[2] C. Berger et al, Nanoscale, 8 (2016) pp. 17928-17939.
[3] C. Berger et al, Nanoscale, 9 (2017), pp. 17439 - 17449.
[4] C. Berger et al, 2D Materials, 5 (2018) pp. 015025
[5] K. Smith et al, ACS Appl Mater Int,15 (2023), pp. 9853 - 9861

Figures

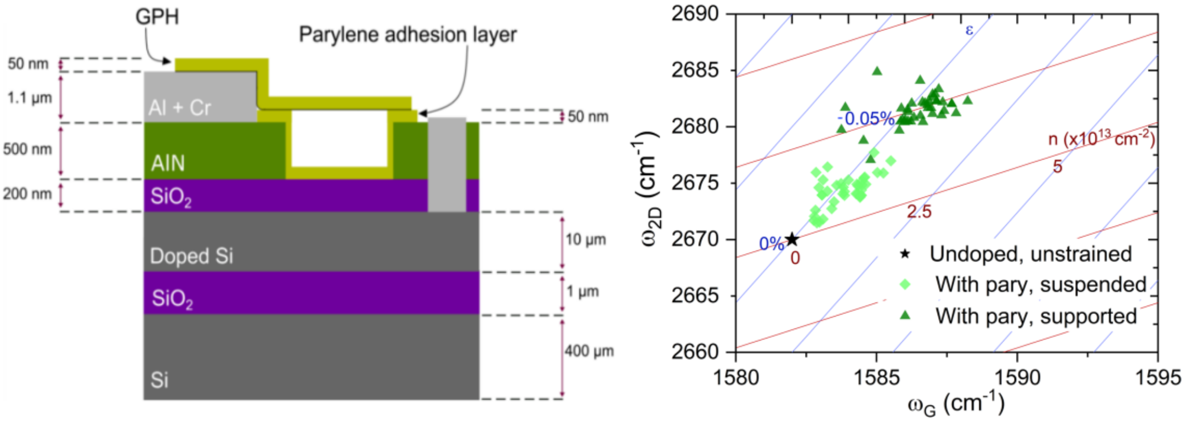

Figure 1: (a) Schematic cross-section of a graphene-parylene heterostructure membrane integrated on a PiezoMUMPs architecture substrate. (b) Statistical Raman peak-shift analysis to confirm biaxial pre-tension in the graphene membrane.