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Capacitive pressure and touch sensors with suspended graphene-polymer heterostructure membranes

Single layer chemical vapor deposited (CVD) graphene has shown great promise in enabling Micro and Nano-electromechanical Systems (MEMS/NEMS) that can outperform current state of the art. However, existing methods in forming single layer graphene electromechanical devices result in low yields during the graphene device fabrication process. In addition, the suspended membranes that survive often suffer from a distorted topography due to transfer polymer residue, limiting the in-plane span, and poor device reproducibility.
We present the fabrication and characterization of a suspended graphene/polymer heterostructure membrane that aims to tackle the prevailing challenge of constructing high yield, environmentally robust suspended graphene devices whilst preserving the mechanical and electronics properties. [1] The fabrication method enables the construction of suspended membrane structures that can be multiplexed over entire wafers with 100% yield.
Further, we describe the fabrication and characterization of a capacitive pressure sensor formed by a graphene-polymer heterostructure membrane spanning a large array of micro-cavities each up to 30 µm in diameter with 100% yield. Sensors covering an area of just 1 mm^2 show reproducible pressure transduction under static and dynamic loading up to pressures of 250 kPa. The measured capacitance change in response to pressure is in good agreement with calculations. Next, we demonstrate a novel strained membrane transfer and optimizing the sensor architecture. This method enables suspended structures with less than 50 nm of air dielectric gap, giving a pressure sensitivity of 123 aF/Pa per mm^2 over a pressure range of 0 to 100 kPa. [2]
Lastly, we demonstrate a touch-mode capacitive pressure sensor (TMCPS) incorporating a SU-8 spacer grid structure. [3] This results in a partially suspended membrane configuration, which produces reproducible deflection, even after exposing the membrane to pressures over 10 times the operating range. The device shows a pressure sensitivity of 27.1 ± 0.5 fF/Pa over a pressure range of 0.5 kPa to 8.5 kPa.
We demonstrate the operation of the above devices as air pressure, water pressure and force touch sensors.

References

[1] Berger C, Dirschka M, Vijayaraghavan A, *Nanoscale*, 8 **2016**, 17928-17939.
[2] Berger, C.; Phillips, P.; Centeno, A.; Zurutuza, A.; Vijayaraghavan, A.; *Nanoscale* **2017**, Advance Article.
[3] Berger, C.; Phillips, R.; Pasternak, I.; Sobieski, J.; Strupiński, W.; Vijayaraghavan, A.; *2D Materials* **2017**, Accepted Manuscript

Figures

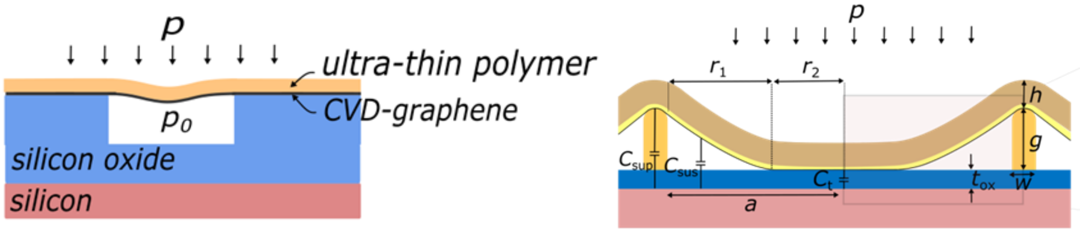

Figure 1: Schematic of a graphene-polymer heterostructure membrane based pressure sensor operating in (a) fully suspended more and (b) touch mode.