Suspended Monolayer Graphene by Adhesion Lithography

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Adhesion lithography (a-lith) is a process whereby coating of an initial metal (M1) with the appropriate self-assembled monolayer (SAM) significantly reduces its adhesion to a second metal layer (M2) which is deposited on top of the first. Due to this reduced adhesion, M2 on M1 can be easily delaminated, leaving behind M2 only where it was not overlapping with M1. This can be used in a clever way to obtain a nanogap between the two metal contacts. For nearly a decade, a-lith has been used in the fabrication of self-aligned, high aspect ratio metallic contacts at low cost, with high yields that require little time and effort compared to conventional lithographic techniques [1]. It has been utilized to fabricate various sensors, diodes, and light-emitting diodes [2, 3].

In this work, we show how a-lith can be used to fabricate suspended monolayer graphene. A dielectric material (SiO_2) is added in the second metal deposition step by thermal evaporation, and acts as a sacrificial layer. Monolayer CVD graphene grown on copper foil transferred on the metal/dielectric stacks is released by a critical point drying step following the buffered oxide etch of the sacrificial layer. The fabrication process utilizes both a-lith and photolithography in order to pattern an array of suspended graphene structures on large substrates, where the aspect ratio of trench width to trench depth of $\sim$10 is achieved. Such suspended graphene devices could be used as electromechanical switches, gas sensors and pressure sensors [4]. In previous works, such systems relied often on multiple layers of graphene, considering the yield strength of monolayer graphene hinders reliability. Careful design of the trench aspect ratio based on a theoretical model of the electromechanical devices allows for higher yields, while the geometry that can be achieved is compatible with low voltage actuation graphene switches [4, 5, 6].

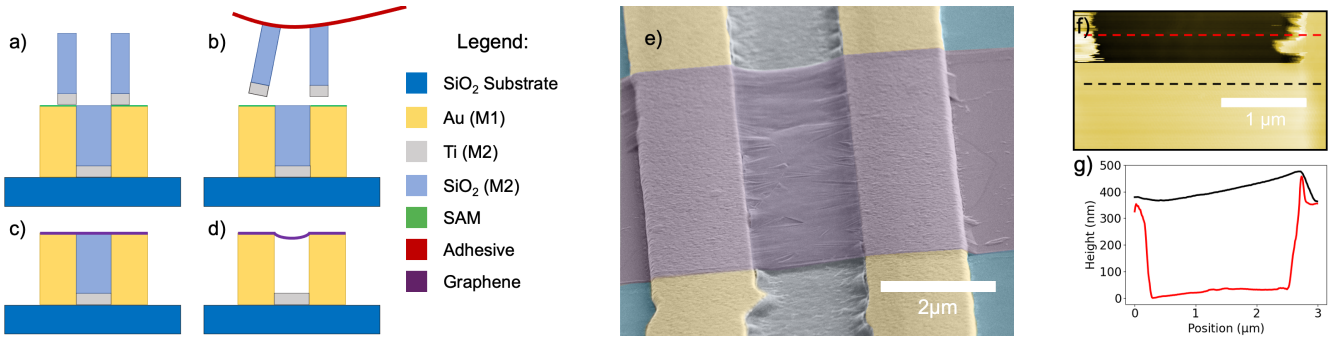

Figure 1: Fabrication of suspended graphene structures using a-lith, where **a)** SiO_2/Ti is deposited in the trench and on gold contacts coated in a SAM. **b)** An adhesive is used to remove the overlapping oxide layer, leaving it only inside the trench. **c)** The SAM is removed and graphene is transferred and patterned. **d)** The oxide layer in the trench is etched, revealing a suspended graphene ribbon. **e)** False-colored SEM image of the suspended graphene over the trench between gold contacts. **f)** AFM scan and **g)** profiles corresponding to the lines shown, where the black curve shows suspended graphene above the trench while the red curve shows the profile of the trench between gold contacts.

References:

[1] D.J. Beesley *et al.*, Nat. Comm. 5, 3933 (2014)
[2] G. Wyatt-Moon *et al.*, ACS Appl. Mater. Interfaces 9, 41965-72 (2017)
[3] J. Semple *et al.*, npj Flex. Electron. 2, 18 (2018)
[4] T. Szkopek & E. Martel, Prog. Quant. Electron. 76, 100315 (2021)
[5] P. Li *et al.*, Appl. Phys. Lett. 104, 113110 (2014)
[6] J. Kulothungan *et al.*, Adv. Physics Res. 2, 2200050 (2023)