Graphene drum mechanical resonators detected by microwaves

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Abstract

The self-supporting monolayer material which is graphene has excited enormous interest over the ten years since its discovery due to its remarkable electrical, mechanical, thermal and chemical properties. We describe transfer of graphene onto a patterned SiO_2/Si substrate which provides freely suspended graphene drums ranging in size from 2μm to 40μm which are being explored as nano-electromechanical (NEMS) resonators. An SEM image of an array of patterned structures for our graphene NEMS resonators is shown in Fig. 1a. An AFM scan across a 5μm square graphene suspended membrane is shown in fig. 1b).

As electromechanical devices become smaller, approaching the nanoscale, the oscillation displacement amplitude scales down in proportion to size. Thus new ultra-sensitive transducer techniques and low dissipation excitation schemes are needed to operate NEMS sensors. Microwave measurement using high Q resonators becomes attractive due to the high sensitivity of frequency measurement and the very low phase noise from synthesized microwave sources, in contrast with optical systems. We have developed a novel near-field microwave probe system which is able to simultaneously excite and readout the oscillation of a range of mechanical resonators, from hundreds of microns to sub-micron size. By using a quarter wave microwave coaxial resonator with the open end connected to a sharp tip we can produce a very localized intense microwave field in a very limited region close to the tip. The spatial range of this high field region is on the order of the radius of curvature of the tip, which can be, comparable to the smallest mechanical resonator dimensions.

We report experimental data on these drums using a variety of microwave excitation and readout methods. An important issue is that there is strong coupling between graphene and microwave fields. This relates to the relatively close matching of the impedance of free space, or a confined geometry like a microwave resonator, and the sheet resistance of high quality graphene [1], making the microwave method particularly suitable for application to graphene NEMS resonator based sensors [2].

References

[1] L. Hao, J. Gallop, S. Goniszewski, O. Shaforost, N. Klein and R. Yakimova, 'Non-contact method for measurement of the microwave conductivity of graphene', Appl. Phys. Lett. Vol.103, 123103 (2013)
[2] Ling Hao, Stefan Goniszewski, Jie Chen and John Gallop, 'Microwave excitation and readout of nano- and micron scale cantilevers', Applied Surface Science vol. 258 pp. 2192-5 (2012).

Figures

a) b)

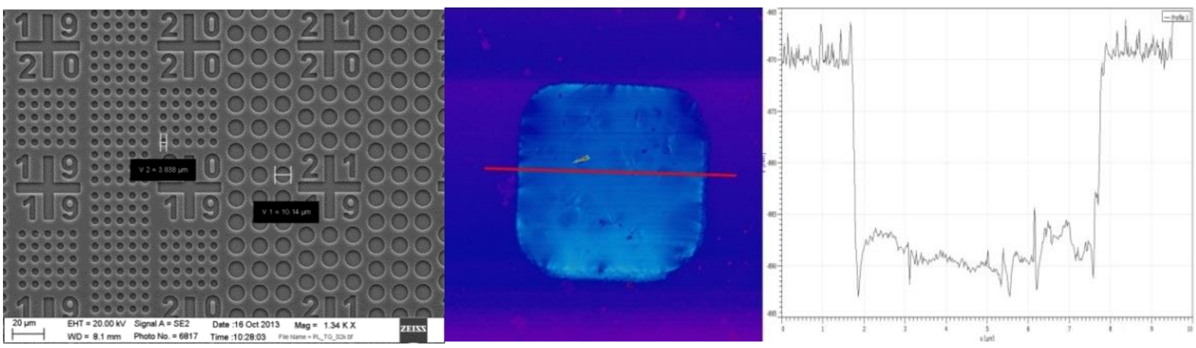

Fig. 1: a) SEM image of the fabricated substrate showing the array of features for graphene suspension. b) AFM image of a 5μm square graphene drum, with line scan across central region.