Suspension of large, electrically contacted graphene for sub-15-nm phononic crystal patterning

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Phononic crystals (PnCs), periodic structures where the period is of similar dimension as the phonon wavelength, promise the opening of phononic band gaps (PnBGs) that could improve thermoelectric conversion efficiency and allow thermal rectification, as shown in Figure 1a [1]. Graphene, the atomic layer of carbon atoms in a hexagonal lattice, has a high Young's modulus of ~1000 GPa and Debye termperature of ~2800 K. Thus, the wavelength of phonons at a given temperature is greatly increased compared to other materials such as silicon. This reduces the requirements for PnC patterning with PnBGs at room temperature.

Recently, we have demonstrated sub-10-nm milling of a 3x3 pore array into suspended graphene by helium ion beam milling, where a tightly focused beam of ions (beam diameter <0.5 nm) interacts with the graphene and carbon atoms are ejected through collisions [2]. Up to 300 nm long PnCs with pitch of 18 nm were demonstrated, as well. However, to allow optical probing and increase the change of thermal conductivity by the PnCs formation above the noise level, larger PnCs with smaller pitch are required.

In this work, we will report the successful suspension of up to 9.6 µm long and 16 µm wide, electrically contacted, monolayer graphene with an air gap of 300 nm, as shown in Figure 1b and c. We show that the HIM milling approach for PnCs formation can be applied for µm-scaled suspended graphene with pore pitch below 15 nm by adjustment of the point dose.

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References:

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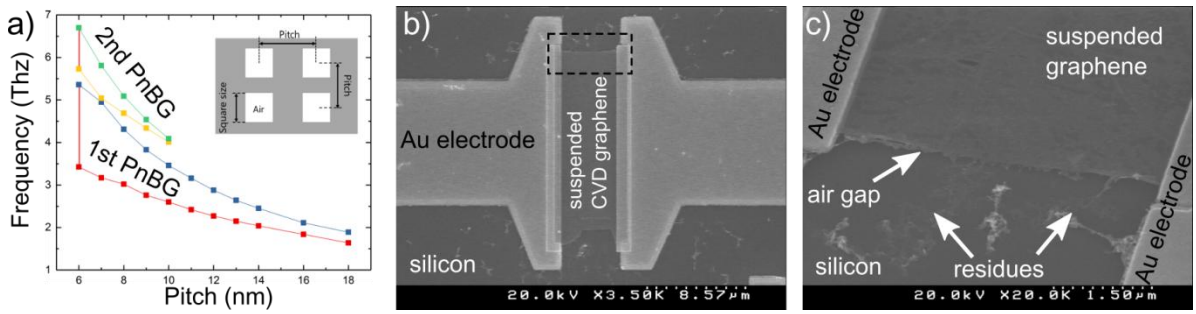

Figure 1: (a) Occurrence of 1st and 2nd phononic bandgap (PnBG) in monolayer graphene with periodic square pores. (b) SE Image of 4.8 µm long and 16 µm wide monolayer CVD graphene suspended above a silicon substrate (300 nm air gap). The graphene is anchored to gold electrodes. (c) Close-up view of upper edge of suspended graphene from (b). Visible contamination can be avoided by improving the suspension process.