Fabrication process and thermal conductivity measurement setup of graphene phononic crystal

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High frequency phonons are responsible for heat conduction in semiconductors and dielectric materials. Fabrication of phononic crystals (PnCs) has become a subject of interest in the scientific community for the potential it offers for heat propagation control [1]. With the development of nanotechnology, miniaturization of electronic devices became possible which influenced studies regarding nanoscale heat transfer in materials [2]. Fabrication of intricate nanopatterns on materials like silicon and steel has long since been realized with the optimization of various focused ion beam (FIB) techniques. Recently, however, graphene has garnered much interest for room temperature phononic applications due to its high Young's modulus (~1 TPa) and Debye temperature (~2800 K), which resulted in various attempts in fabricating graphene PnCs. Fabricating nanopore arrays in suspended graphene with sub-10-nm pitch by direct focused helium ion beam milling (HIBM) has recently been demonstrated by our lab [3].

The heat spreader method has recently been applied to measure the thermal conductivity of graphene and ultrathin graphite [4]. In this method, a temperature gradient is created in the investigated material by applying current through a heater electrode while monitoring the voltage changes in adjacent electrodes due to temperature change. The heaters and thermometers are fabricated on silicon substrate using e-beam lithography (EBL). To separate graphene from the conducting metal layer, an insulating layer will be transferred and patterned. Finally, graphene will be transferred, pattered and suspended by HF release which will later be exposed to HIBM to create the nanomesh. Metal contacts are designed specifically for the sample to fit into a ceramic chip carrier and allow wire bonding (Fig. 1 a+b). The large number of terminals makes it impractical to use probe needles. The chip carrier is then placed in a custom made printed circuit board that can be fitted inside the temperature controlled vacuum chamber. Source meter units (SMUs) are used in this measurement setup as shown in Figure 2. In our presentation, we will report on our progress regarding fabrication and measurement.

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References:

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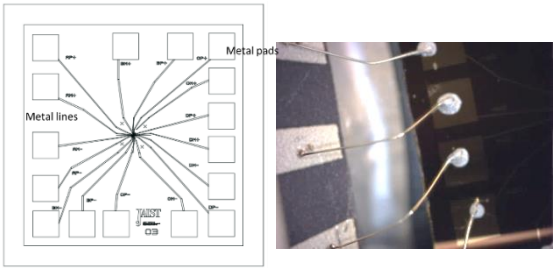

Fig. 1: (a) Mask pattern for metal contacts on CVD graphene. (b) Fabricated gold contacts wire bonded with the chip carrier.

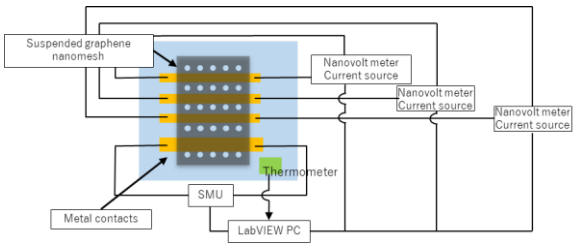

Fig. 2: Schematic of thermal conduction measurement setup.