Thermal conductivity measurement of suspended graphene by heat spreader method

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Recent studies on the control and manipulation of thermal phonons show that specifically designed periodic arrays can reduce the thermal transport through a material by suppressing the transmission of a certain phonon wavelength [1,2]. It has been observed by finite element method (FEM) simulations that, in case of graphene, periodic nanopores with sub-10 nm pitch exhibit phononic band gap in the low THz regime [3]. Recently, periodic arrays of 3-4 nm sized pores have been successfully nanopatterned in suspended graphene by focused helium ion beam milling (HIM) [4]. In order to understand the influence of such periodic nanopores on the transmission of THz phonon, we are working on establishing a characterization platform to be able to measure practically the in-plane thermal conductivity of the suspended graphene.

Heat spreader method uses microfabricated metal lines to create thermal gradient through the sample and resistance thermometry is used for in plane thermal transmission measurement. Owing to the high in-plane thermal conductivity of graphene, we are aspiring to study the temperature profile using a source heater and three resistance temperature sensors as shown schematically in fig.1(a). To measure the resistances at different distance from the source, we utilize the 4-probe measuring technique, which uses two separate pairs of current-carrying and voltage-sensing electrodes and offers higher sensitivity compared to the two-terminal methods [5]. As shown in fig. 1(b), we require a special chip assembly and fabrication of a suitable device to support a total of 16 measurement probes. The process of fabrication and primary test execution of our thermal measurement system will be presented in this research work. The heaters and thermometers are fabricated on silicon substrate using e-beam lithography (EBL). To separate graphene from the conducting metal layer, the transfer and patterning of an insulating layer of hexagonal boron nitride is being carried out. Also, we are working on the transfer and patterning of the graphene layer for HIM milling. The optimization of lithography conditions is extremely crucial at this point. We are also conducting experiments to understand the operational condition of our thermal measurement system and found out that excessive current through the microfabricated metal lines causes joule heating and results in melting the gold nanowire as shown in the SEM images in fig: 1(c). In our presentation, we will report on our progress regarding the thermal transport properties of graphene samples with and without nanopores.

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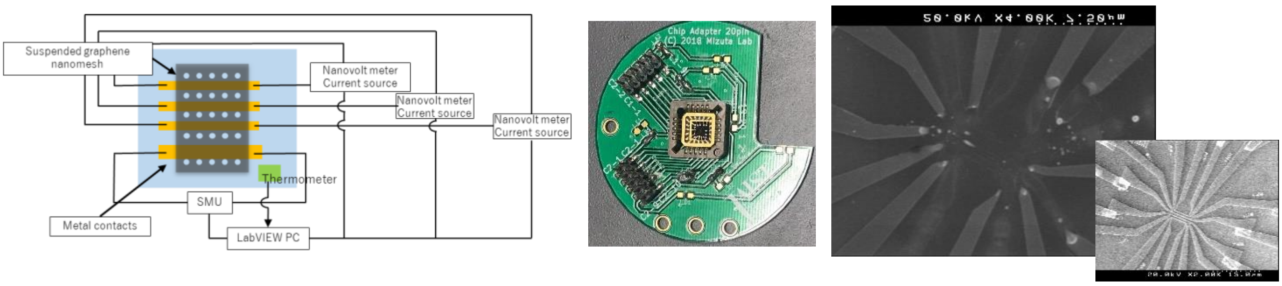

Fig. 1: (a) Schematic of the thermal conductivity measurement setup. (b) Customized chip assembly for heat spreader measurement setup. (c) Melted gold wire due to joule heating caused by excessive calibration current. Inset: nanowires before calibration is shown in the smaller window.