Ballistic to diffusive crossover of heat flow in suspended graphene membranes

A. El Sachat

F. Könemann, F. Menges, E. Del Corro, J. A. Garrido, C. M. Sotomayor Torres, F. Alzina and B. Gotsmann

[1]*Catalan Institute of Nanoscience and Nanotechnology (ICN2), CSIC and BIST, Campus UAB, Bellaterra, 08193 Barcelona, Spain*
[2]*IBM Research - Zurich, Saümerstrasse 4,8803 Rüchlikon, Switzerland*
[3]*ICREA, Passeig Lluis Companys 23, 08010 Barcelona, Spain*
[4]*Present address: Facultad de Ciencias, Departamento de Física de la Materia Condensada and Condensed Matter. Physics Center (IFIMAC), C/ Francisco Tomás y Valiente 7, Universidad Autónoma de Madrid, 28049, Madrid, Spain*
[5]*Present address: Department of Physics, University of Colorado, CO-80309, Boulder, United States of America*

Contact@E-mail: alexandros.elsachat@icn2.cat

Abstract

Monolayer graphene has received a significant attention owing to its remarkable electrical, optical and thermal properties. Here, we investigate the transport of phonons in suspended CVD single-layer graphene disks with radius between 150 and 1600 nm using a high-vacuum scanning thermal microscope. Our experimental results reveal a ballistic phonon transport and a decrease of the thermal contact resistance between tip and graphene with radius, r, up to 775 nm. In graphene discs with r >775 nm, the in-plane heat transport is suppressed by phonon–phonon scattering and the measured thermal contact resistance increases from 1.15 and 1.52×10^{8} KW^{-1}. These results suggest that the value of the average mean free path of acoustic phonons in clean suspended graphene that dominate heat conduction at room temperature is approximately 775 nm. Our approach[1] allowed the direct nanoscale thermal imaging of suspended graphene with spatially resolved heat flux measurements down to few-nanometre spatial resolution by simultaneously analysing the surface morphology of the graphene samples. The combination of a high-resolution scanning thermal microscope and suspended materials provided a promising platform to reveal intrinsic heat transport properties of graphene and other 2D material systems at the nanoscale.

References

[1] A. El Sachat, F. Könemann, F. Menges, E. Del Corro, J. A. Garrido, C. M. Sotomayor Torres, F. Alzina and B. Gotsmann 2D Materials, 6 (2019) 22

Figures

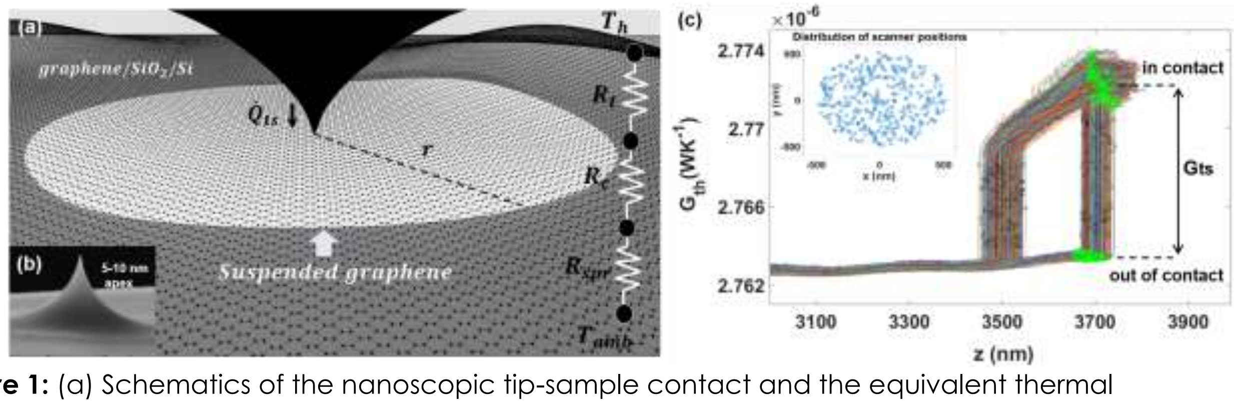

Figure 1: (a) Schematics of the nanoscopic tip-sample contact and the equivalent thermal resistance circuit, (b) a scanning electron microscopy image of the tip apex of the scanning thermal microscope cantilever with a radius of a = (5–10) nm and (c) a typical example of the measured thermal conductance signal during several tip-graphene point contacts. The distribution of the selected positions of the contacts in the membrane is shown in the inset of figure 1(c).