Phononic crystals in patterned and in disordered MoS_2 membranes

Clivia M Sotomayor Torres[1,2], Peng Xiao[2], Alex El Sachat[2,3], Emigdio Chavez-Angel[2], Ryan C Ng[2], Giorgos Nikoulis[3], Joseph Kioseglou[3], Konstantinos Termentzidis[4], Visnja Babacic[5], Thomas Vasileiadis[5], Bartlomiej Graczikowski[5] and Marianna Sledzinska[2]

[1]International Iberian Nanotechnology Laboratory, Braga, Portugal

[2]Catalan Institute of Nanoscience and Nanotechnolpogy, Bellaterra, Spain.

[3]National Center for Scientific Research "Demokritos", Athens, Greece

[4]Univ. Lyon, CNRS, INSA Lyon, Villeurbanne, France

[5] Adam Mickiewicz University, Poznan, Poland

Clivia.sotomayor@inl.int

Abstract

Thermal transport in 2D materials is an active area of research due to their specific promise of thermal dissipation engineering as well as the inherent van der Waals nature of the layered structure [1]. This has led to research to ascertain to what degree can the vastly different in-plane and out-of-plane thermal transport provide a way to incorporate 2D materials in 3D integration to control heat dissipation.

In this talk I will report work on MoS_2 thermal transport studies covering the thickness regime from few to several layers and comparing it to similar thickness ranges in silicon free-standing membranes [2]. Results from measurements in bilayers and heterolayers will be described [3] as well as our recent work delimiting the heat transport by phononic crystal patterning in layers of MoS_2 [4]. In this part we will discuss heat confinement, and the role of surfaces.

The phononic crystal approach to control thermal transport [5] was extended to imperfect phononic crystals with an additional parameter to break the mid plane symmetry [6]. In this part we will discuss the impact of disorder on the band gap and band frequencies.

Overall, the concept of phononic crystals will be shown to have ample use in thermal transport in 2D materials and we will discuss advantages and disadvantages of this approach.

References

[1] A El-Sachat, F Alzina Sureda, C M Sotomayor Torres and E Chavez-Angel, Nanomaterials, 11 (2021) 175.

[2] D Saleta Reig, S Varhese, R Farris, A Block, J D Mehew, O Hellman, P Wozniak, M Sledzinska, A El Sachat, E Chavez-Angel, S O Valenzuela, N Van Hulst, P Ordejon, Z Zanolli, C M Sotomayor Torres, M J Verstraete and K J Tielrooij, Advanced Materials, 22 (2022) 2108352.

[3] E Chavez-Angel, P Tsipas, P Xiao, M Ahmadi, A Daaoub, H Sadeghi, C M Sotomayor Torres, A Dimoulas and A El Sachat, Nano Letters 23 (2023) 6883.

[4] P Xiao, A EL Sachat, E Chavez-Angel, R C Ng, Giorgos Nikkoulis, Josep Kioseoglou, K Termentzidis, C M Sotomayor Torres and M Sledzinska, Science Advances 10, (2024).

[5] M Sledzinska, B Graczikowski, J Maire, E Chavez-Angel, C M Sotomayor Torres and F Alzina, Advanced Functional Materials, 30 (2020) 1904434 .

[6] V Babacic, M Sledzinska, T Vasileiadis, C M Sotomayor Torres and B Graczykowski, APL Materials 12 (2024) 041108.