CONTRATOS PREDOCTORALES – MATRANS24 (CEX2023-001263-S)

RESEARCH CHALLENGE:

Efficient heat management materials and novel phononic devices

PROJECT TITLE / JOB POSITION TITLE:

Understanding and engineering phonon anisotropy for efficient thermal management

RESEARCH PROJECT / RESEARCH GROUP DESCRIPTION:
(Max. 2.000 characters – including spaces)

Moore's law has described for more than 50 years the increase of density of transistors in integrated circuits. Although it got all the spotlights, it had a silent partner all along, Dennard scaling, which states that, as transistors got smaller, their power density remain constant and thus assures that such a device density increase drives an overall improvement of the performances. Unfortunately, Dennard scaling did not take into account leakage currents, which can lead to a significant heating up of the chips. Therefore, as their role became important, Dennard scaling started breaking down and, as matter of fact, since this happened around 2006, processor clock frequencies have been in practice limited to approximately 4 GHz.

This fact, sometimes known as thermal bottleneck, established thermal management as one of the most important research fields in condensed matter and keeping a low thermal budget is perhaps the most pressing issue in modern electronics.

This PhD project takes up the challenge of heat control in solids and its main goal is advancing our knowledge regarding anisotropic thermal transport. It will tackle two classes of anisotropy: (i) natural, built-in anisotropy that results directly from the anisotropy of the crystal structure or morphology; (ii) artificial anisotropy induced by tailor-made nanostructuring. In this latter case our main case study will be superlattices (SLs), which are known to foster phonon coherence, and thin films with a controlled thickness gradient. In the first case, by controlling the SL period, we will be able to simultaneously tune the anisotropy of the system and the cross-over between incoherent/particle-like and coherent/wave-like phonon transport; in the second case, on the other hand, we will introduce an innovative approach to "phonon spectroscopy", where by means of single-shot measurements performed on the same sample, we can obtain the thermal conductivity as a function of the thickness.

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CSIC
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

JOB POSITION DESCRIPTION:
(Max. 2.000 characters – including spaces)
Include all the relevant information about the position, role, responsibilities and skills required within the project/group

The student will be trained in state-of-the-art methodologies to study thermal transport in nanoscale systems. She/he will receive training in both theoretical and experimental techniques to heat transport in solids and will operate with increasing independence. The exact balance between the two "souls" of the proposed research activity will be tuned depending on the student interests and expertise.

The theoretical activity will focus on the calculation of the phonon dispersion and the lattice thermal conductivity of functional oxides and nanostructured semiconductors. Most of the calculations will be based on density-functional theory (DFT), *de facto* standard in theoretical condensed matter theory. The calculations will require massive computational resources and will be performed in large high-power computation infrastructures, such as the Barcelona Supercomputing Center (BSC) and the Supercomputing Center of Galicia (CESGA); access to these facilities is granted on competitive basis, so the student will also be trained in writing proposals to apply for computational time. On the other hand, experimental activity will revolve around the use of a recently developed in house experimental setup suitable to study steady state thermal transport with the particularity of providing enhanced sensitivity to in-plane heat flow. This method has the important advantage of being contactless, and it is based on the concept of heating the sample using a 1D heat source with uniform power distribution along its main axis.

The PhD student will be supervised by a well-established team of PIs (R. Rurali, theory; J. S. Reparaz, experiments) who routinely work together and have co-directed or are co-directing four national projects.

PhD CO-DIRECTORS:

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RELATED LINKS TO THE POSITION (optional)
URL:
Title link: