Controlling heat transfer at the nanoscale with ferroic materials

Supervisor: Dr Ray McQuaid

Over the last century, progressive mastery over the control of charge transport in solids has enabled the microelectronics revolution, underpinned by the ability to amplify and switch electrical signals using semiconductor transistors. By comparison, the understanding and control of thermal transport in solids is less developed and such a paradigm shift has not occurred. This issue has come into focus since the continually increasing performance expectations for microelectronics devices comes with increased thermal management requirements also. At the level of fundamental research, one promising approach to control heat flow is to use functional materials with reconfigurable microstructure as the basis for a thermal conductivity switch. Of these, the class of ferroic materials are promising candidates since they offer several mechanisms to manipulate heat flow. The existence of field-modifiable domain structure enables heat flow toggling by exploiting the thermal anisotropy inherent to domains and/or by scattering of thermal vibrations at the interfaces (domain walls) that separate domains. Even larger effects can be obtained by driving these materials through phase transitions, with the goal of seeking significant changes in structure and in the associated thermal transport properties.

You will join the ongoing research program looking at how microstructure in oxide ferroelectric materials can be used to affect and control thermal transport. Our lab has dedicated systems that enable heat flow measurements across different length scales and temperature ranges in materials. We have a cryostat for sensitive low temperature measurements and Scanning Thermal Microscopy for thermal imaging at the nanoscale. This year we are acquiring a commercial thermoreflectance system that will enable laser-based spatial mapping of thermal transport properties, opening up further investigations over a broad range of temperature and under applied fields. In terms of materials, there are a variety of candidate oxide materials to be explored including exotic materials supplied by collaborators and nanostructured samples prepared in-house using Focused Ion Beam machining (details on request). The research activity will mainly be fundamental and with an experimental focus. The ideal candidate will be interested in nanoscale heat flow and thermometry, reconfigurable devices and microscopic imaging.

Applications should be made through the QUB system and informal discussions with Dr McQuaid are encouraged. The project will be supported by his ongoing UKRI Future Leaders Fellowship program, which sees £1.5m committed to the activity over 7 years.

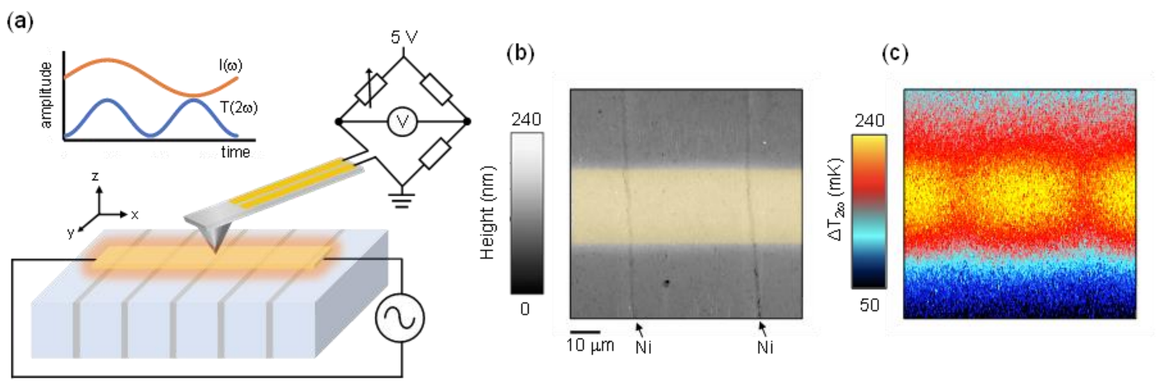

Figure 1: (a) Setup for Scanning Thermal Microscopy investigation of thermal transport in a mixed microstructure. (b) Topography and (c) thermal map revealing spatial variation in thermal conductivity.