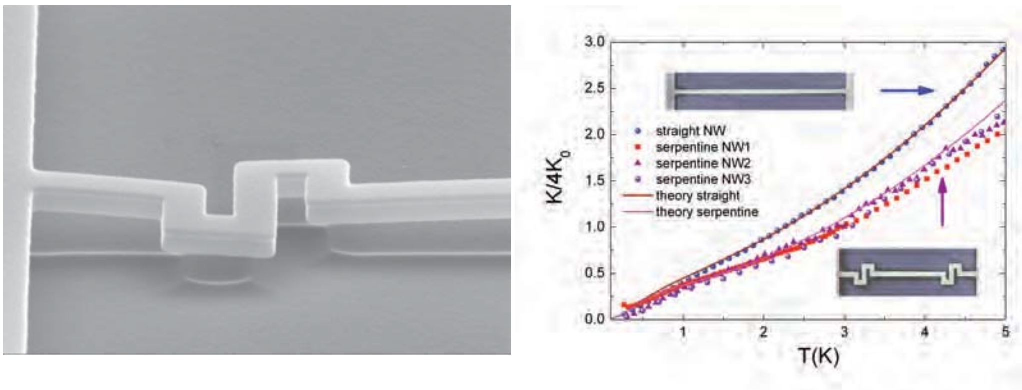
# Blocking heat transfer at the nanoscale

Phonons are tiny packets of vibrational energy, quanta of vibration of the lattice. When acoustic (i.e. low frequency) phonons propagate, they give rise to thermal conductance, the property of a solid to conduct heat. At room temperature, many phonons are present and they are strongly scattered by each other as well as by electrons or impurities; the transport is called diffusive. At low temperature, the probability of phonon scattering greatly decreases and, finally, heat transport will be limited only by scattering on the rough surface of the solid. At even lower temperature, the wavelength of phonons becomes so large that the surface behaves like a mirror for them: they undergo specular reflection. In this "ballistic" regime, phonons will conserve their energy until they reach a thermal bath, a large reservoir where they can finally thermalize with their counterparts.

Working in the ballistic regime with silicon dielectric nanowires having cross-sections of order 200 nm, we have found that we can block heat transfer by blocking the circulation of ballistic phonons. Introducing a structured serpentine into a nanowire (see Figure), we found that the thermal conductance was considerably reduced as compared to a straight nanowire having the same length. This effect was detected by very sensitive thermal conductance measurements on the two different types of nanowire. The phonons can be considered as spheres that are reflected by the serpentine and then cannot transport heat towards the thermal reservoir. The phonons are blocked in the centre of the nanowire, between the two serpentines.

This nano-engineering trick provides a useful way to improve the performance of thermoelectric components. Such a device can be called an electron transmitting/phonon blocking system. Because there is nothing of a quantum nature here, the idea can be implemented at a smaller length scale at room temperature, to improve the factor of merit of nano-thermoelectric devices.




The Scanning Electron Microscope photograph shows a serpentine section in a silicon nanowire. The curves represent the thermal conductance of two different types of nanowire. One nanowire is straight and serves as reference. The others are serpentine nanowires, and show a reduced thermal conductance, thus illustrating blocking of heat transfer.

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FURTHER READING

BLOCKING PHONONS VIA NANOSCALE GEOMETRICAL DESIGN
J-S. Heron, C. Bera, T. Fournier,
N. Mingo, and O. Bourgeois,
Phys. Rev. B 82, 155458 (2010).