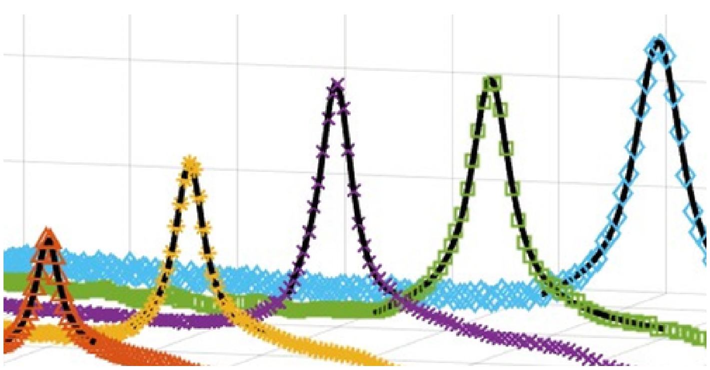
Surface Defects Affect Heat Transport

The scattering of helium atoms off a crystal surface reveals how defects in the crystal's lattice influence its ability to transport heat.

By **Charles Day**

Heat in thin crystalline films dissipates via surface phonons, the quantum particles of vibration and sound. The longevity of these phonons—and their ability to transport heat—is curtailed by impurities, dislocations, and other defects in the film. This connection is well established but not yet fully quantified. Now Boyao Liu of the University of Cambridge and his collaborators have taken a step toward that goal by quantifying the dependence of the lifetimes of six surface phonon modes on a thin crystal's defect density [1]. Their findings could lead to improvements in the heat-transport properties of materials for next-generation electronic devices.

For their experiments the team used a technique called helium spin-echo spectroscopy, which involves directing a beam of spin-polarized helium-3 atoms through the coils of an electromagnet toward a target surface. Atoms that scatter off the surface travel through a second, identical electromagnet before reaching a detector. The magnetic fields in both electromagnets cause the spin of each atom to rotate by an angle inversely proportional to the atom's speed.



Credit: B. Liu *et al.* [1]

Ordinarily, an atom scatters elastically off a crystal. But if its wave properties match those of the phonons in the material, the atom can absorb phonon energy. That absorption causes an increase in the atom's speed and a measurable decrease in the angle through which its spin rotates.

Liu and his collaborators examined pristine and roughened nickel targets, identifying six distinct phonon modes. Scattering helium-3 atoms off the roughened surfaces, they found that the rougher surfaces contained phonons with shorter lifetimes, an expected result. But the relationship between roughness and phonon lifetime turned out to be both linear and independent of temperature, which Liu says was an unexpected finding, as no one had anticipated what the high-energy resolution data might reveal.

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REFERENCES

1. B. Liu *et al.*, "Experimental characterization of defect-induced phonon lifetime shortening," **Phys. Rev. Lett. 132, 056202 (2024).**