Nano Focus

Tellurium binds bismuth-telluride and gallium-arsenide thermoelectric material

Bismuth telluride (Bi_2Te_3) and gallium arsenide (GaAs) make quite a pair, combining to form a highly efficient electronics-cooling thermoelectric material. Although scientists have been using this material pair for years, how the two materials stick together has remained a mystery. Now, with the aid of high-powered, highly sensitive imaging systems, researchers at North Carolina State University have found a definitive answer.

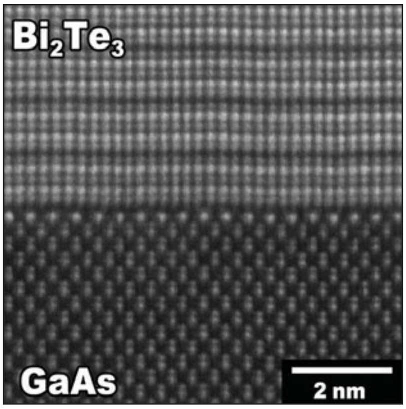
Most inorganic compounds are held together with chemical bonds, says James LeBeau, a professor of materials science and engineering at North Carolina State University. But for some time, scientists have known that Bi_2Te_3 and GaAs do not follow this pattern. Instead, the two materials combine through van der Waals interactions that are considerably weaker than a chemical bond. Just how the bond is formed and how it manages to hold the system together was the real mystery, says LeBeau.

Solving the mystery was a difficult task. Identifying the van der Waals connection between two thin sheets of materials required instrument resolution higher than most standard systems could provide. LeBeau and his team combined an atomic-resolution aberration-corrected scanning transmission electron microscope (STEM) with a high-powered atomic resolution x-ray spectroscopy system. Such a combination would theoretically image not only the physical structure of the Bi_2Te_3 and GaAs, but also the chemical structure at the binding interface.

Scientists had some suspicions as to what was occurring at the interface. GaAs would have dangling bonds that would prevent van der Waals epitaxy. Therefore, either bismuth or tellurium had to interact. To pinpoint which element was reacting with the GaAs, LeBeau and his colleagues along with researchers from RTI International used a vapor deposition technique. Using GaAs as a substrate, Bi_2Te_3 was grown layer by layer.

The results, which were published in *Applied Physics Letters*, were surprising, says LeBeau. The STEM images show that the interface between Bi_2Te_3 and GaAs is very bright, suggesting that a heavy element must be settled there. The interpretation of the image, says LeBeau, points to the bismuth interacting with the arsenide at the interface.

However, x-ray spectroscopy told a different story. The chemical makeup at the interface included tellurium, not bismuth.



Electron micrograph of the Bi_2Te_3/GaAs interface. Image credit: James LeBeau.

An ultrathin layer of gallium telluride—less than a quarter the width of a normal GaTe structure—solves the long-standing mystery as to how Bi_2Te_3 grows through van der Waals epitaxy into remarkably pristine lattices.

"The crystallography tells us that these materials should not grow nicely on top of one another, but they do," says LeBeau. "And it's ultimately because there are no strong bonding forces directly between the substrate and the film that enable that."

Meg Marquardt

Resonant inelastic x-ray scattering probes spin excitations in iron-pnictide superconductors

New high-temperature iron-based superconductors (or iron-pnictides), principally comprising iron-arsenide, iron-phosphor, and iron-selenide alloys, were discovered in 2008. In a move to understand the origins of their behavior, an international group of researchers from the Paul Scherrer Institute (PSI), Harwell Science and Innovation Campus, Chinese Academy of Sciences, the University of Tennessee, and the Leibniz Institute for Solid State and Materials Research has now found that magnetic interactions are of fundamental importance in their high-temperature superconductivity.

As reported in the February 12 issue of *Nature Communications* (DOI: 10.1038/ncomms2428), the researchers compared a sample of a superconducting material with a sample of the parent material, which is non-superconducting. The base material—in this case a barium-iron-arsenide compound—becomes superconducting when it is doped with a defined quantity of potassium atoms.

The research team was particularly interested in the dynamic magnetic properties of the base materials and superconductors. In order to investigate these properties, they excited magnetic fluctuations in the material samples, where these are accompanied by a reorientation of the neighboring electron spins, which extends in a wavelike manner through the sample. In the base material, spin waves are clearly detectable.

The researchers wanted to know if this was also true for the doped material samples. At first sight, one might suspect that the holes would constitute obstacles, breaking the long-range magnetic order of spins and thus strongly attenuating the spin waves. However, the research team found that the spin waves experienced little attentuation in the superconductor, and that they exhibited almost the same intensity as in the base material.

In the experiment, the dynamic magnetic properties of the base material and