UCLA develops defect-free boron arsenide as most efficient semiconductor material for thermal management

Better heat conduction from hotspots could boost computer chip performance and energy efficiency.

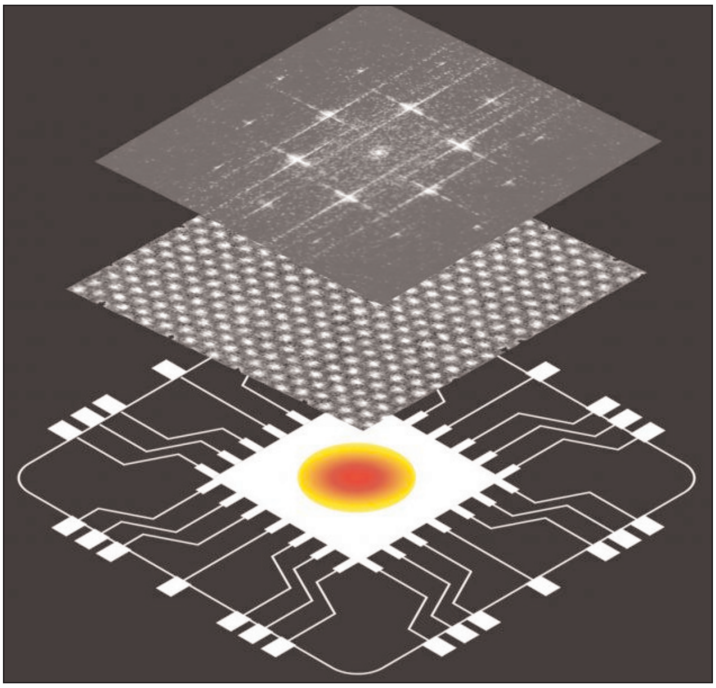
Working to address 'hotspots' in computer chips that degrade their performance, researchers at University of California, Los Angeles (UCLA) graduate students Joonsang Kang, Man Li, Huan Wu and Huuduy Nguyen in the research group of assistant professor of mechanical and aerospace engineering Yongjie Hu have developed defect-free boron arsenide as a new semiconductor material that is more effective at drawing and dissipating waste heat than any other known semiconductor or metal materials (Joon Sang Kang et al, 'Experimental observation of high thermal conductivity in boron arsenide', Science; DOI: 10.1126/science.aat5522). This could potentially revolutionize thermal management designs for computer processors and other electronic components or for light-based devices such as LEDs, it is reckoned.

Managing heat in electronics has increasingly become one of the biggest challenges in optimizing performance, for two reasons. First, as transistors shrink in size, more heat is generated within the same footprint. This slows down processor speeds, in particular at hotspots on chips where heat concentrates and temperatures soar. Second, a lot of energy is used to keep those processors cool. If CPUs did not get as hot in the first place, then they could work faster and much less energy would be needed to keep them cool.

The UCLA study was the culmination of several years of research by Hu and his students that included designing and making the materials, predictive modeling, and precision measurements of temperatures.

The defect-free boron arsenide, which was made for first time by the UCLA team, has record high thermal conductivity (more than three times faster at conducting heat than currently used materials, such as silicon carbide and copper), so that heat that would otherwise concentrate in hotspots is quickly flushed away.

"This material could help greatly improve performance and reduce energy demand in all kinds of electronics, from small devices to the most advanced computer data-center equipment," says Hu. "It has excellent potential to be integrated into current manufacturing processes because of its semiconductor properties and the demonstrated capability to scale-up this technology," he adds. "It could replace current state-of-the-art semiconductor materials for computers."



Schematic of computer chip with a hotspot (bottom); an electron microscope image of defect-free boron arsenide (middle); and image showing electron diffraction patterns in boron arsenide.

In addition to the impact for electronic and photonics devices, the study has also revealed new fundamental insights into the physics of how heat flows through a material, the researchers reckon.

"This success exemplifies the power of combining experiments and theory in new materials discovery, and I believe this approach will continue to push the scientific frontiers in many areas, including energy, electronics, and photonics applications," Hu says. ■

www.hu.seas.ucla.edu

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