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Strategic heat dissipation could keep next-gen electronics cool

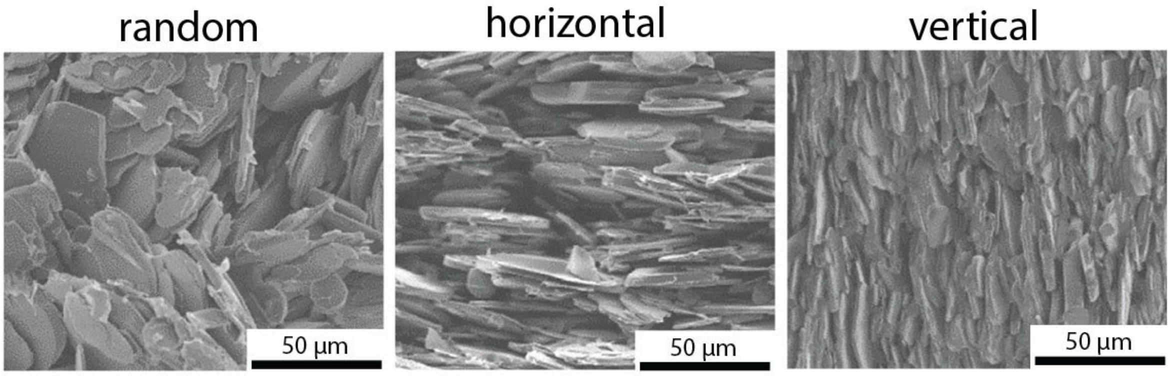
(Nanowerk Spotlight) As electronics become smaller, faster and more powerful, managing the heat they generate is becoming increasingly challenging. Densely packed 3D electronics, made by stacking components vertically, are especially prone to overheating as the heat has limited routes to escape. But scientists in Singapore have developed a smart way to channel heat away strategically before devices get too hot.

They reported their findings in *Advanced Materials* ("Microstructured BN Composites with Internally Designed High Thermal Conductivity Paths for 3D Electronic Packaging").

Using magnetic fields to precisely align microscopic platelet-shaped particles made of a heat-conducting material called hexagonal boron nitride (BN), the researchers were able to direct heat along tailored pathways within the particle network. This capability could prevent overheating in next-generation high-performance electronics like 3D-stacked chips.

The research was led by Assistant Professor Hortense Le Ferrand from the School of Mechanical and Aerospace Engineering at Nanyang Technological University, Singapore. Her team coated BN particles with iron oxide nanoparticles to make them responsive to magnetic fields. They then suspended these coated particles in a solvent and cast the mixture into small blocks of about 1 mm height.

By tuning the orientation of a rotating magnetic field during the casting process, the researchers could align the platelet-shaped BN particles locally, within the samples. They found that samples with vertically aligned particles were exceptionally good at conducting heat in the direction of alignment, with thermal conductivities over 12 W/mK – more than six times higher than samples with randomly scattered particles.



Microscopic particles of hexagonal boron nitride in various configurations. (Image: NTU)

"The large contact area between vertically aligned particles allows lattice vibrations to transfer easily from one particle to the next, creating 'highways' for heat conduction," explains Le Ferrand.

But the most significant finding was that tailoring the alignment of BN particles at different positions enabled directional control over heat flow. For instance, by gradually shifting particle orientation from vertical to horizontal, the researchers produced films that could channel heat sideways.

Such strategic heat channeling could prevent hotspots when electronics components are stacked directly on top of each other – a common setup in high-density 3D chips. Normally, heat dissipation vertically between layers is undesirable as it risks damaging components. But with tailored microstructures, the heat could be diverted sideways to a heat sink instead.

To demonstrate this, the scientists simulated a 3D chip setup by applying heat to both surfaces of a film with inclined BN particles. Infrared imaging confirmed that the heat travelled laterally along the orientation of the particles, instead of vertically.

According to Le Ferrand, the tailored microstructures were easily achieved using a technique called magnetically assisted slip casting. "Complex alignments can be programmed just by changing the direction of the magnetic field during casting. The process is simple and scalable," she says.

Importantly, the films offer more than just enhanced heat dissipation. With highly packed BN particles making up over 60% of the material, the films possess useful mechanical properties like compressive strength, hardness and stiffness. The low density and dielectric constant are also advantageous for electronics applications.

The exceptionally high thermal conductivity combined with customizable microstructures makes these electrically insulating BN composites promising for efficient thermal management in next-generation high power electronics. Beyond electronics, tailored heat channeling could benefit other sectors like aerospace engineering and nuclear energy.

"Our study demonstrates a unique approach to strategically direct heat within a material to where it needs to go," concludes Le Ferrand. "This could provide new solutions for heat management in complex systems and tightly packed environments."

By Michael Berger

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