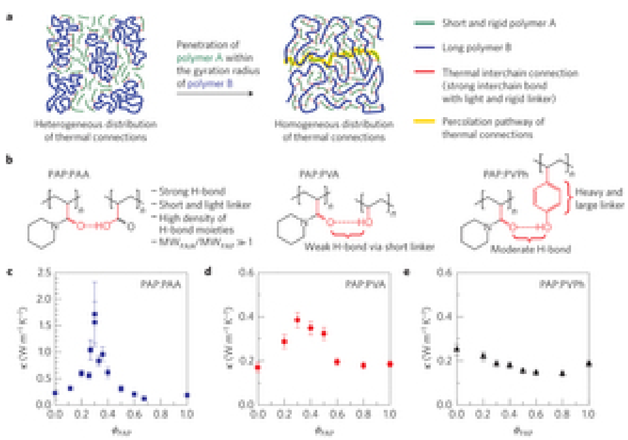
Heat-conducting plastic developed

November 25 2014



High thermal conductivity in amorphous polymer blends by engineered interchain interactions. Credit: *Nature Materials* (2014) doi:10.1038/nmat4141

The spaghetti-like internal structure of most plastics makes it hard for them to cast away heat, but a University of Michigan research team has made a plastic blend that does so 10 times better than its conventional counterparts.

Plastics are inexpensive, lightweight and flexible, but because they restrict the flow of heat, their use is limited in technologies like computers, smartphones, cars or airplanes—places that could benefit from their properties but where heat dissipation is important. The new U-M work could lead to light, versatile, metal-replacement materials that make possible more powerful electronics or more efficient vehicles, among other applications.

The new material, which is actually a blend, results from one of the first attempts to engineer the flow of heat in an amorphous polymer. A polymer is a large molecule made of smaller repeating molecules. Plastics are common synthetic polymers.

Previous efforts to boost heat transfer in polymers have relied on metal or ceramic filler materials or stretching molecule chains into straight lines. Those approaches can be difficult to scale up and can increase a material's weight and cost, make it more opaque, and affect how it conducts electricity and reflects light. The U-M material has none of those drawbacks, and it's easy to manufacture with conventional methods, the researchers say.

"Researchers have paid a lot of attention to designing polymers that conduct electricity well for organic LEDs and solar cells, but engineering of thermal properties by molecular design has been largely neglected, even though there are many current and future polymer applications for which heat transfer is important," said Kevin Pipe, U-M associate professor of mechanical engineering and corresponding author of a paper on the work published in the current issue of *Nature Materials*.

Pipe led the project with Jinsang Kim, another corresponding author and associate professor of materials science and engineering.

Heat energy travels through substances as molecular vibrations. For heat to efficiently move through a material, it needs continuous pathways of strongly bound atoms and molecules. Otherwise, it gets trapped, meaning the substance stays hot.

"The polymer chains in most plastics are like spaghetti," Pipe said. "They're long and don't bind well to each other. When heat is applied to one end of the material, it causes the molecules there to vibrate, but these vibrations, which carry the heat, can't move between the chains well because the chains are so loosely bound together."

The Pipe and Kim research groups devised a way to strongly link long polymer chains of a plastic called polyacrylic acid (PAA) with short strands of another called polyacryloyl piperidine (PAP). The new blend relies on hydrogen bonds that are 10-to-100 times stronger than the forces that loosely hold together the long strands in most other plastics.

"We improved those connections so the heat energy can find continuous pathways through the material," Kim said. "There's still a long way to go, but this is a very important step we made to understand how to engineer plastics in this way. Ten times better is still a lot lower heat conductivity than metals, but we've opened the door to continue improving."

To arrive at these results, the researchers blended PAP plastic strands separately with three other polymers that they knew would form hydrogen bonds in different ways. Then they tested how each conducted heat.

"We found that some samples conducted heat exceptionally well," said Gun-Ho Kim, first author of the paper and a postdoctoral fellow in mechanical engineering and materials science and engineering. "By performing numerous measurements of the polymer blend structures and their physical properties, we learned many important material design principles that govern heat transfer in amorphous polymers."

Two other first authors are Dongwook Lee and Apoorv Shanker, graduate students in macromolecular science and engineering. The paper is titled "High thermal conductivity in amorphous polymer blends by engineered interchain interactions."

More information: High thermal conductivity in amorphous polymer blends by engineered interchain interactions, *Nature Materials* (2014)

DOI: 10.1038/nmat4141

Provided by University of Michigan