Hybrid nanomaterials hold promise for improved ceramic composites

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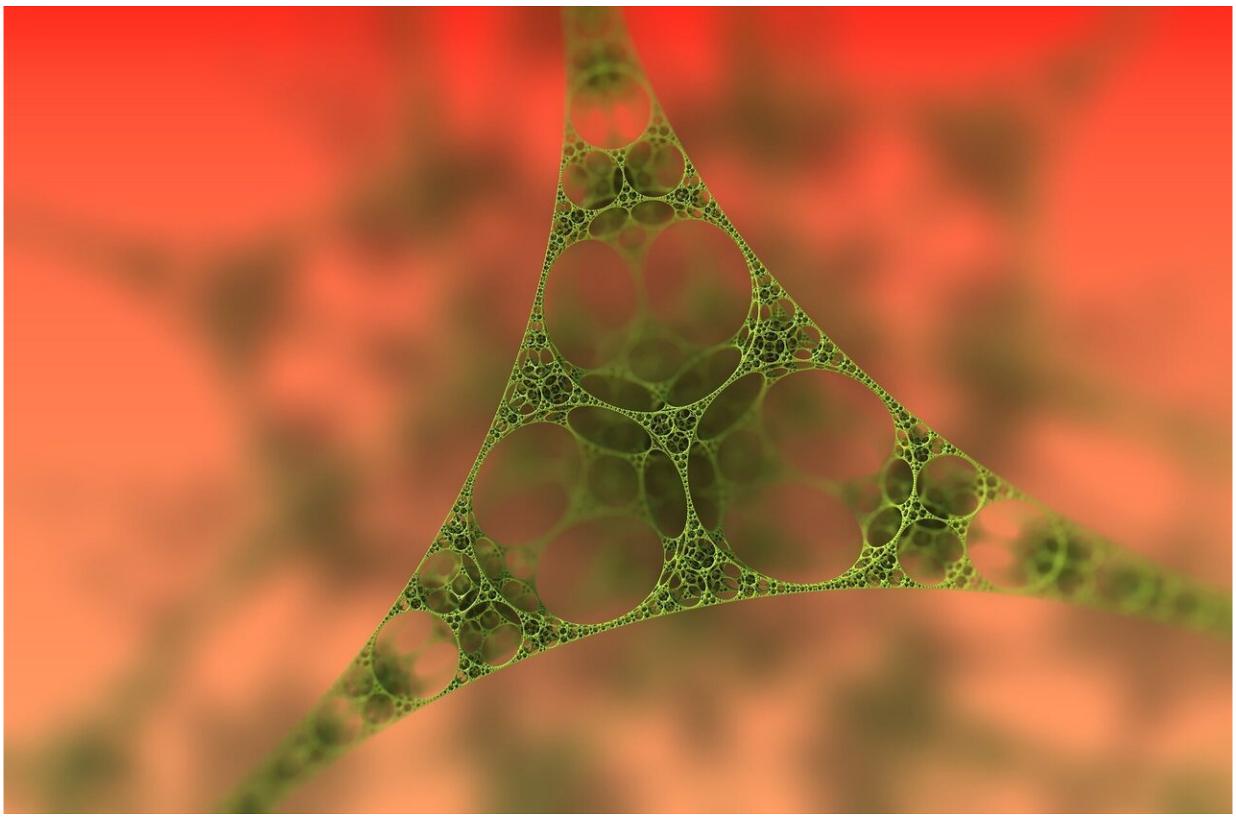

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Researchers at Wright-Patterson Air Force Base are seeking to patent a novel process for manufacturing a type of material called preceramic polymer-grafted nanoparticles, or "hairy nanoparticles" (HNP).

An HNP is a hybrid material consisting of a polymer shell bound to a solid nanoparticle core. The polymer—a chain of repeating molecules—forms the "hair" around the nanoparticle, which is roughly the size of a small virus.

Although HNPs have been around for many years, what makes this one different is the type of polymer being attached to the core particle. It is a pre-ceramic polymer, a special class of polymer used in the formation of high performance ceramic fibers and composites.

"The special polymer used in our process is what sets our work apart," said project lead Dr. Matthew Dickerson. "Researchers have made these sort of hairy nanoparticles in the past, but they've used organic polymers like polystyrene. Our polymer is different; it's inorganic because it contains silicon. It's a bit like silicones (caulk), which have a backbone of silicon and oxygen repeats, but ours has a backbone of silicon and carbon repeats."

Members of the Ceramic Materials and Processing Research Team, from left to right: Ms. Christina Thompson, Dr. Dayton Street, Dr. Kara Martin and Dr. Matthew Dickerson. Credit: U.S. Air Force photo/Karen Schlesinger

This silicon and carbon chemistry allows the polymer to convert to a silicon carbide ceramic when heated to high temperatures.

The HNPs that result from this special process will be used in the manufacture of aircraft parts made of ceramic composite material. "Ceramic composites are used for high-temperature US Air Force applications that benefit from materials that are lower in density than metals, including jet engine and hypersonic vehicle components," said Dickerson. "The HNPs we synthesized are envisioned for those type of applications."

This special hybrid material, however, is not made by simply mixing the polymer and nanoparticles together and hoping for the best. "A simple mixture would result in something like a putty or a brittle mixture," said Dickerson, "but the hybrid material we end up with flows more like molasses so it will more easily flow into a porous ceramic."

During the manufacturing of a ceramic matrix composite, the materials used to bind the ceramic fibers together shrink considerably. This shrinking results in cracks and voids that have to be refilled, or infiltrated. One of the most important requirements of the hybrid material made of the HNPs is that it must flow easily so it can infiltrate those voids.

With current state-of-the-art processes, the ceramic has to undergo several cycles (six to ten) of infiltration to attain the desired density. The novel process described in the patent application, as well as in a paper recently published in *Chemistry of Materials*, yields a material that could potentially reduce the number of infiltration cycles by about half, resulting in a more cost-effective, faster-to-produce component.

Even with the superior high-temperature properties of ceramic composites over conventional metal components, reducing their cost is key to enabling their widespread use in demanding Air Force applications.

The project was funded by the Air Force Office of Scientific Research. "This research is a major technological advancement in the synthesis of ceramic nanocomposites, said Dr. Ming-Jen Pan, Program Officer at AFOSR. "It provides unprecedented control of the nanostructure of hybrid materials. I am excited about the possibilities this discovery brings to the design and processing of future composite materials."

Additional funding was received to look at how the chemistry of the materials dictates their properties.

"This was a difficult project to do. It took almost three years to get it right," said Dickerson. "It was a real victory for Kara," he added, referring to research scientist Dr. Kara L. Martin. "Developing the chemical synthesis procedure to make these particles is very difficult. Her fresh ideas and tenacity enabled her to see the project through to success."

Provided by Air Force Office of Scientific Research

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