ADVERTISEMENT FEATURE

Improving the mix for better control of nanocomposites

A NEW ELECTROSTATIC ADSORPTION assembly method promises to release the potential of nanocomposites by bringing a greater precision to the manufacturing process.

Nanocomposites made from powders have the potential to revolutionize materials science and usher in a new era of advanced functional materials. But while there have been many advances in nanocomposites, Hiroyuki Muto and his assistant, Wai Kian Tan, of Toyohashi University of Technology in Aichi prefecture, Japan, believe that they have yet to come close to fulfilling their full promise.

ITS PRECISION ALLOWS MATERIALS TO BE DEPOSITED JUST WHERE THEY ARE NEEDED

"A lot of material scientists are trying to make many new nanostructures, but the potential of nanocomposites is still to be realized because conventional powder-mixing methods and suspension-based techniques are inadequate for achieving precise structural formation," explains Muto.

The problem boils down to a lack of control over nanoparticles — mechanical mixing of nanopowders often results in the nanoparticles agglomerating, thereby producing larger structures or an inhomogeneous mixture, which affects the desired properties. For example, agglomeration can mean more material is needed to form electrically conductive pathways in ceramics and polymers. "Nanoparticles have a strong tendency to congregate, and no amount of stirring can cause them to disperse," explains Muto, who is a professor at the university's Institute of Liberal Arts and Sciences. What is needed is a technique that can achieve a much higher level of control over the positioning of nanoparticles in composite materials.

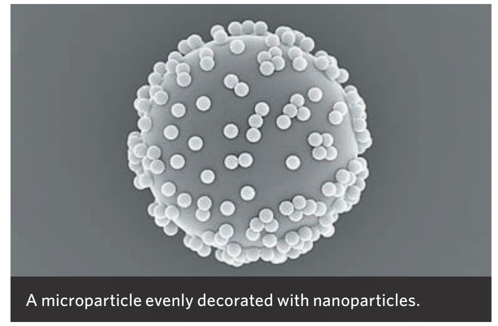
That is exactly what a

Hiroyuki Muto (left) and a student using an electrostatic adsorption assembly method for making nanocomposites.

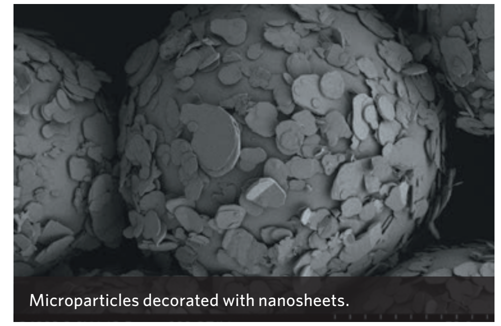
novel electrostatic adsorption assembly method developed by Muto's laboratory offers. A bottom-up fabrication technique, it employs a simple powder metallurgy process to fabricate advanced nanocomposites. Specifically, it involves modifying the surfaces of additive nanoparticles and primary microparticles with polyelectrolytes. It's a simple but very effective concept: imparting opposite charges to the two types of particles prevents the nanoparticles from agglomerating, while causing them to attach to the larger particles. This in turn allows greater positioning control of the additive nanoparticles on the primary (larger) particles.

3D PRINTING USING CERAMIC COMPOSITES

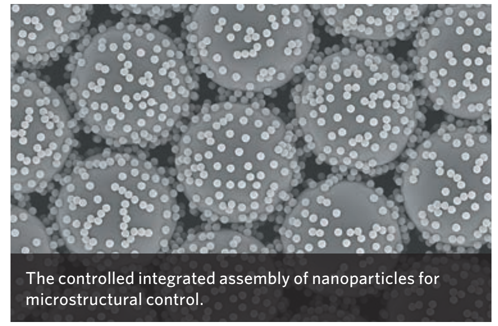
While three-dimensional (3D) printing can be done using a wide range of materials, including polymers, resins and metals, 3D printing of ceramics is still in its infancy. One of the main reasons is that ceramic powders have poor light absorption at laser wavelengths used for precise 3D printing. The electrostatic adsorption assembly method can overcome this problem by evenly decorating ceramic particles with laser-absorbing nanomaterials. In a recent study, Muto and his team developed composite particles that exhibit good near-infrared absorption properties with huge potential



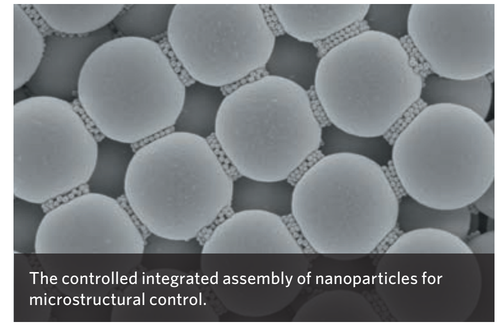
A microparticle evenly decorated with nanoparticles.



Microparticles decorated with nanosheets.



The controlled integrated assembly of nanoparticles for microstructural control.



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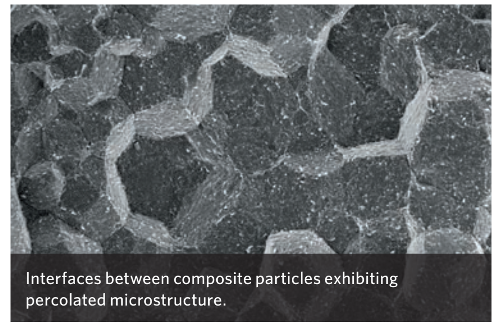
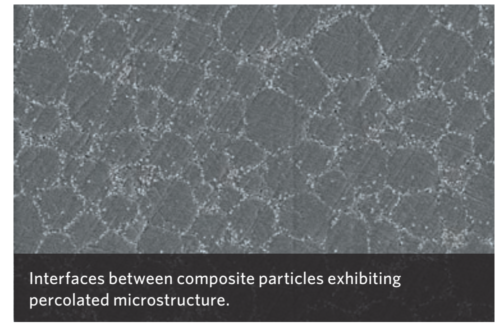


Interfaces between composite particles exhibiting percolated microstructure.



Interfaces between composite particles exhibiting percolated microstructure.

for 3D printing technology through direct selective laser sintering.

Another example of an application that involves tailoring the optical properties of a material is the fabrication of infrared filters made from a polymer composite. These filters are transparent at visible-light wavelengths but exhibit an infrared-shielding effect, making them ideal for applications such as the windscreens of vehicles and energy-saving windows. Muto's team fabricated the filters using the electrostatic adsorption assembly method by incorporating indium tin oxide (ITO) nanoparticles within a matrix of poly(methyl methacrylate) (PMMA). The level of infrared shielding it provides can be controlled by varying the amount of the ITO nanoparticles.

SAVING RESOURCES WHILE BOOSTING FUNCTIONALITY

The technique efficiently uses materials and resources, in line with the 12th Sustainable Development Goal of the United Nations, namely Responsible Consumption and Production. Its precision allows materials to be deposited just where they are needed, minimizing the use of natural resources, while offering enhanced functionality. An excellent example of this is the fabrication of electrically conductive ceramics or polymers through incorporating conductive carbon nanotubes. Conventional techniques require large quantities of carbon nanotubes because of the problem of agglomeration. In contrast, the electrostatic adsorption assembly method enables formation of a conductive path using a mere 0.01% by volume of carbon nanotubes —roughly ten times less than conventional techniques.

Muto's team has demonstrated the potential of their technique for composite material design by using it to realize controlled assembly of different materials in various structures including nanosheets, whiskers and fibres. These composite materials are highly promising for a range of applications such as selective laser sintering, transparent composite ceramic films with controlled optical properties and renewable energy technologies.

REALIZING NANOPOWDERS' FULL POTENTIAL

Muto and his team are excited about the potential of the electrostatic adsorption assembly method to turn around some previously disappointing results in nanocomposite materials. "Trying to use conventional processes to manufacture products containing nanoscale additives often leads to products that fail to live up to expectations," notes Muto. "Conventional processes effectively become counterproductive when nanoscale additives are involved." Despite the rapid advancement of technologies such as additive manufacturing, a limiting factor to their widespread application is the inability to realize precise powder integration technology that can produce various composites on nano- and microscale levels. In many cases, Muto notes, the problem is that, when a nanopowder is used, it becomes challenging to control the composite's microstructure. "Our electrostatic adsorption assembly method enables good control over the final microstructure formation," he says. "Our goal is to show that conventional material processes can be improved by using this kind of technique." ■

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