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Nanojewels made easy

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Butterfly wings, peacock feathers, opals and pearls are some of nature's jewels that use nanostructures to dazzle us with color. It's accomplished through the way light reaches our eyes after passing through the submicroscopic mazes within these materials.

The seemingly effortless way that nature creates this effect is now rivaled by a rapid and simple method developed through a collaboration of researchers from North Carolina State University (NCSU), Arizona State University (ASU) and the Universidad Complutense de Madrid (UCM).

Professor Orlin Velev and graduate student researcher Vinayak Rastogi in the Department of Chemical Engineering at NCSU have shown how colloid chemistry methods originally used to form particle aggregates from nanoparticles can be used to quickly make particles with dazzling colors simply by letting a suspension of nanoparticles dry on a superhydrophobic surface.

Superhydrophobicity is a property of a material that repels water like ducks' feathers or lotus leaves. It has been used commercially in textiles, coatings and building materials.

The basic idea behind the process is akin to stacking round fruits or vegetables in a supermarket produce bin in high, neat rows to keep the produce from falling to the floor as customers pick them out. Doing this with nanoscale particles of different sizes leads to opalescence, since some colors of light are reflected differently depending on the size of the holes between the nanoparticles and the angle from which they are viewed.

Normally, carefully arranging the nanoparticles in neat rows requires a complex series of steps with oily solvents and water mixtures requiring extensive washing afterwards to remove the solvents.

Now, with the help of researchers at ASU, this process has been made as simple as placing a drop on a superhydrophobic surface and letting it dry for one to two hours.

The researchers call these one- to two-millimeter particles "nanojewels."

Velev and Rastogi of NCSU developed the method with help of several colleagues, including: Manuel Marquez, an adjunct professor in the Harrington Department of Bioengineering in ASU's Ira A. School of Engineering, and Antonio Garcia, a professor in the bioengineering department and director of the Laboratory for Personalized Molecule Measurement; and professors Sonia Melle and Oscar Calderon in the School of Optics at UCM.

Rastogi's presentation at the 82nd American Chemical Society Colloid & Surface Science Symposium on June 18, 2008 titled "Synthesis of Light-Diffracting Colloidal Crystal Assemblies from Microspheres and Nanoparticles in Droplets on a Superhydrophobic Surface" and a paper just published in the journal *Advanced Materials* (published Online: July 28, 2008), authored by these researchers, describes how for the first time superhydrophobic surfaces are shown to play an important role in making new materials.

In the paper, they describe how different nanoparticles of various sizes can produce "nanojewels" of various colors that display different optical properties.

"These nanojewels can potentially find application in photonics, drug delivery, special coatings, sensors and microfluidics," Velev explains.

Indeed, many researchers around the world are working on ways to make similar two-dimensional and three-dimensional photonic crystals to fabricate light-emitting diodes, optical fibers for communications, submicroscopic lasers, ultrawhite pigments, antennas and reflectors, and optical integrated circuits.

The biggest stumbling blocks in making these materials is finding ways of making photonic crystals with uniform properties in very large quantities and in minimizing imperfections in structure that reduce the quality of the final product.

This new process is certainly easy to replicate to make large quantities, and superhydrophobic surfaces lead to structures that naturally form ordered structures.

Superhydrophobic surfaces allow nanojewels to be created from a single drop of water containing nanoparticles, because of several effects.

First, the drop stays in the shape of a ball because water does not spread on it while the nanoparticles are held in the drop due to the surface tension of water.

Compared to drying the drop in air, which is a fast evaporation process that causes the water in the drop to distort and flow, the drop gently dries on the superhydrophobic surface. This lets the nanoparticles get as close to each other as possible, swirling in a slow circular motion until all of the water evaporates.

When nanoparticles of two different sizes are used in the same drop, the smaller ones move to the surface of the drop while the bigger ones stay in the middle. This is because the smaller ones have more Brownian motion and are elevated to the surface with the water molecules that are subsequently evaporating at the surface, leaving all of the nanoparticles behind to form the nanojewels.

"Besides the dazzling look of these nanojewels, the most exciting thing about this work is that it opens up many interesting possibilities in quickly and inexpensively making new materials with nanoparticles", Marquez says.

"By understanding how different particle sizes determine the colors produced, these nanojewels can be designed for applications in optical communication systems," Melle adds.

As more nanoparticles and nanostructures come into the marketplace, technologies that can quickly assemble the structures so that their unique size and properties can be employed in new devices will be important to the growth of nanotechnology and related industries.

Source: Arizona State University

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