Producing Incompatible Functional Materials by fusing High Molecules and Inorganic Nanoparticles

-- The development of super-hybrid materials --

A project team led by Professor Tadafumi Adschiri at WPI Advanced Institute for Materials Research (WPI-AIMR), Institute of Multidisciplinary Research for Advanced Materials, and New Industry Creation Hatchery Center, Tohoku University, has developed a technology of interface control on the molecular or nano level between polymers and nanoparticles. The new technology helps develop incompatible functions at the same time, such as processability of polymers, and properties of inorganic materials including a high refractive index and high thermal conductivity. The project has been conducted with the aid of New Energy and Industrial Technology Development Organization (NEDO.)

Super-hybrid materials are incompatible functional materials that maintain and develop both properties of high molecules and ceramics. Polymers have processability, transparency, and flexibility. Ceramics have various properties including a refractive index, high-thermal conductivity, a high dielectric constant, ultraviolet and infrared ray absorption, fluorescence, and an electromagnetic property. When polymers and ceramics mix, the mixture usually loses processability and transparency just as clay. It has seemed to be impossible to maintain and develop each property at the same time.

Polymers and ceramics are like oil and water. They cannot mix at the nano size or on the molecular level although it is possible at the micrometer size. Each interface has an effect on the overall function, which deteriorates each property. A key to a solution to bring out each property is a technology to control interface between polymers and inorganic nanoparticles.

The group led by Professor Adschiri has developed a technology to synthesis organic-inorganic hybrid nanoparticles to whose surface organic molecules bind. The group has focused on that organic molecules and inorganic molecules form uniform phase, and that water molecules serve as catalyst in supercritical water as a reaction field. The newly synthesized hybrid manoparticles are a key to the production of super-hybrid materials because they have organic molecules on the surface to be dispersed in high concentrations into organic solvent or polymers. The new technology has been developing in collaboration with Japan Chemical Innovation Institute (JCII,) and continuous synthesis at 0,1 t/year has been successful.

The JCII team has achieved high thermal conductivity while maintaining formability by using the above technology. The new technology synthesizes organically-modified boron nitride nanoparticles and alumina nanoparticles, and disperses them in high concentration in resin. A size of power device and semiconductor material has been smaller, and those power output has been increasing. Heat value per unit volume has also been increasing significantly, and to promote heat release performance is an important function of devices. The new technology has been developed to help high thermal conductivity by high filling, and particle array by shearing. The team has succeeded in improving thermal conductivity to 35W/m/K at a maximum from several W/m/K and in maintaining 300℃ heat resistance. The new technology is expected to contribute to application to power generator, electric vehicle, and hybrid vehicle, and to reducing emissions of CO2.

The JCII team has also developed hybrid materials that maintain processability and flexibility of high molecules while dispersing titania and zirconia with a high refractive index in high concentrations into high molecules. The newly developed materials also maintain transparency while developing a high refractive index. The project team has developed two-stage polymerization method that is Tohoku University's original technology, and produced compatible inorganic monomers, which brought about high refractive index of 1.7 and more than 90% of light transparence.

Ten chemical companies involved in the project has started to develop high thermal conductivity film materials and high refractive index materials for application. They have tried to further develop a technology to scale up a process of supercritical synthesis. The new technology can be a new industrial infrastructure, and expected to be applied to various fields including flexible antireflection film, highly processable lens materials, LED sealant, and optical memory materials.

The above technology has been presented at SuperGreen 2009, an international conference organized by Professor Tadafumi Adschiri, at Sakura Hall on Katahira campus, Tohoku University through October 15 to October 17, 2009.

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