New Generation Lightweight Nanocomposites

Prof. Valentin Rodionov[†§] and Dr. Toby Sainsbury[‡§]

† King Abdullah University of Science and Technology, Thuwal, 23955-6900, Kingdom of Saudi Arabia

‡ National Physical Laboratory, Hampton Road, Teddington, Middlesex, United Kingdom TW11 0LW

§ Nanosferix Limited

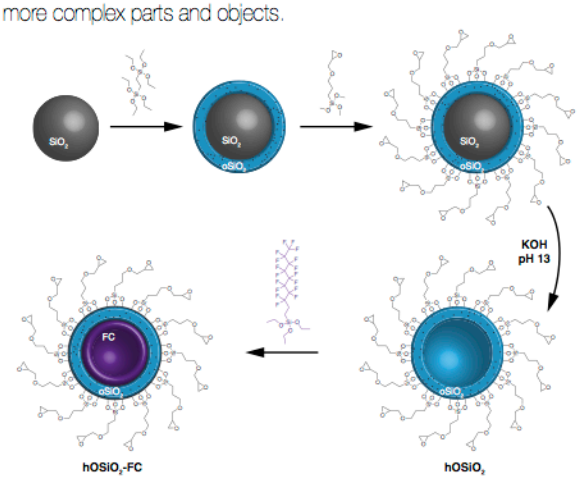
Email: valentin.rodionov@kaust.edu.sa

Materials that are tough, yet light are highly desirable for many defense applications, such as airframes, UAVs/drones, vehicle parts, and body armor. Composite materials, especially fiber-reinforced resins, are a privileged class of materials that combine light weight and extreme mechanical strength.

A variety of substances have been applied as interphase agents between reinforcing fibers and resins in composites. Silica nanoparticles are commonly used for improve the compressive properties and stability of composite materials. However, a high weight loading of SiO_2 (> 10 wt.%) is commonly needed. This leads to an undesirable increase in the weight of the composite due to the high density of silica.

A need exists for additives that could improve the mechanical properties of the resin and prevent fiber delamination without penalizing the weight of the composite. We solve the problem by using suitably functionalized hollow silica or organo-silica nanoparticles as interphase agents. These particles are remarkably light, yet they have many of the same beneficial properties as the traditional SiO_2-based interphase agents. Blending in as little as 0.1 wt % of one of our nanoparticle formulations have increased the ultimate strength of common aerospace resins by up to 100%.

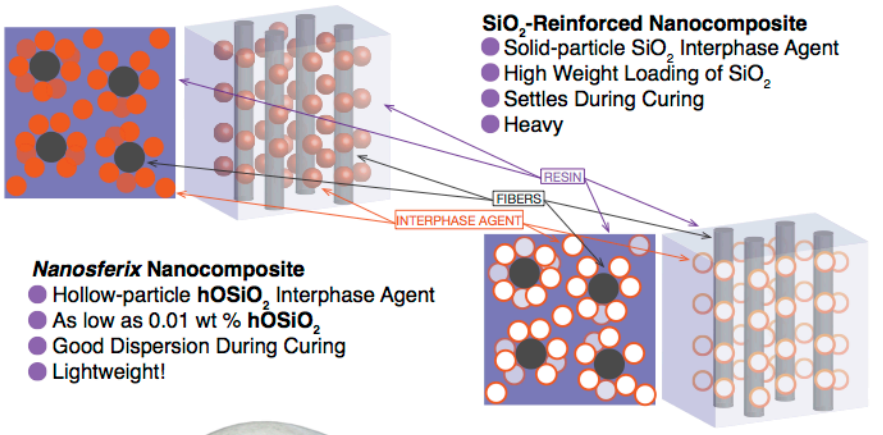
Nanosferix technology offers a drop-in replacement for existing interphase agents in carbon fiber and similar composites. Materials prepared with the use of our hollow-particle interphase agent can be up to 20% lighter than the materials currently on the market. Furthermore, better dispersibility of our interphase agent allows easier curing procedures, and simplifies manufacturing of more complex parts and objects.



The **hOSiO$_2$** and **hOSiO$_2$-FC** materials are synthesized under mild, environmentally friendly conditions.

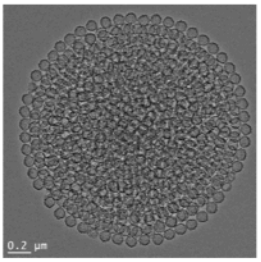
Military Applications

- **Aerospace:** Aircraft and Drones
- **Battlefield Protection:** Armor and Vehicles
- **Power Systems:** Insulation for Cryogenic Tanks

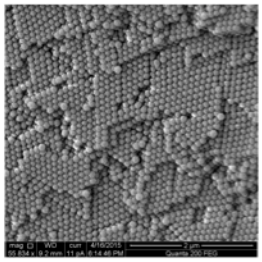


SiO_2-Reinforced Nanocomposite
- Solid-particle SiO_2 Interphase Agent
- High Weight Loading of SiO_2
- Settles During Curing
- Heavy

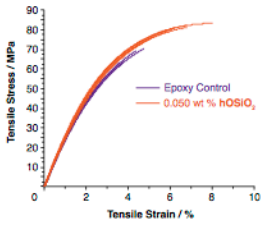
***Nanosferix* Nanocomposite**
- Hollow-particle **hOSiO$_2$** Interphase Agent
- As low as 0.01 wt % **hOSiO$_2$**
- Good Dispersion During Curing
- Lightweight!



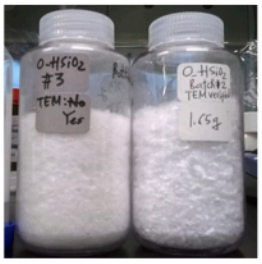
Transmission Electron Microscopy (TEM) image of the **hOSiO$_2$** material. The nanoparticles are hollow.



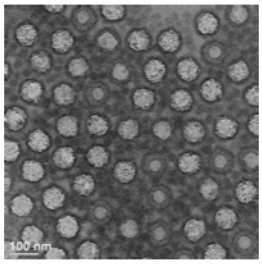
Scanning Electron Microscopy (SEM) image of the **hOSiO$_2$** material. Uniform particles assemble into a superlattice.



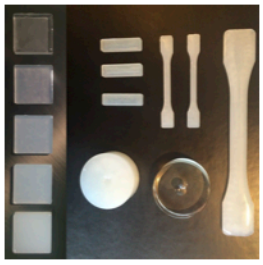
Stiffening effect of Nanosferix particles. Adding just 0.050 wt % to a commercial epoxy resin dramatically improves ultimate strength and toughness.



Bulk **hOSiO$_2$** material. The density of the free-flowing powder is ~0.1-0.2 g/mL.



TEM image of the ultra-thin section of epoxy-**hOSiO$_2$** composite. The nanospheres remain hollow when embedded into the resin.



Nanosferix composite material test articles: polyurethane (left) and epoxy (right). Loading of Nanosferix particles varies from 0.01 to 0.1 wt %.

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