Compressive properties of hollow BN nanoparticles: in-situ testing in a high-resolution transmission electron microscope

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In the last decade, there has been a great interest in the synthesis and application of boron nitride (BN) nanostructures because of their outstanding mechanical properties. Both experimental and theoretical studies show extremely high values of strength and elastic modulus for BN nanotubes, nanoribbons, and two-dimensional (2D) BN nanosheets. By contrast, the mechanical properties of another morphological type of BN structure - spherical hollow BN nanoparticles - have not been investigated in detail. However, this nanoparticles can be widely used as catalyst supports, nanocarriers for drug-delivery, additives for liquid lubricants, reinforcing phase in metal matrix composites, and UV-shielding materials.

For this study hollow spherical with an average size of 100-200 nm were synthesized by synthesized using a boron oxide-assisted chemical vapour deposition technique. Mechanical characteristics were detailed under *in situ* compression in a high-resolution transmission electron microscope. Compression tests on individual BN nanoparticle were performed in a JEM 2100 microscope (JEOL) using a depth-sensing PI 95 TEM Picoindenter (Hysitron). For in situ testing, BN were deposited onto the wedge located on the surface of Si substrate using nanoparticles suspension in isopropanol. During deformation, force-time and force-displacement curves were recorded. The compression tests were carried out using a diamond flat end conical tip with 1 μm diameter of the top circle. Samples were loaded and unloaded at a rate of 2.5 nm per second.

As a result, it was found that synthesized materials had displayed high mechanical stiffness and a large value of elastic recovery. This enables the hollow BNNPs to exhibit considerably large cyclic deformation (up to 30% of the sphere's original external diameter) and to accumulate plastic deformation of approximately 30% of the total compression strain. One possible technological application of this results is that hollow could be utilized as additives to liquid lubricants. To check it we add hollow BN nanoparticles to the PAO6 oil and test it tribological properties. Tribological tests have confirmed our hypothesis and have shown that addition of 0.1 wt.% of hollow BN nanoparticles allows to decrease the friction coefficient and wear rate from 0.1 to 0.07 and from 2.50×10^{-7} to 7.2×10^{-9} mm^3/Nm, respectively.