New Nanotechnology Solid Lubricants for Superior Dry Lubrication

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Abstract

This paper presents a new commercial breakthrough for advanced anti-friction materials based on unique inorganic nanospheres that can be used as dry lubricants, coatings, and for impregnating parts. The new material reduces friction and wear significantly better than other layered solid lubricants and is especially useful in self-lubricating, maintenance-free, and oil-free applications of the types encountered in aerospace markets.

The material, NanoLub™, is the world's first commercial lubricant based on spherical inorganic nanoparticles. NanoLub's particles have a unique structure of hollow nested spheres (see photo) of about only 0.1 micron in diameter. (the size in the picture – 40- 50 nm)

This paper presents tribological evaluations of tungsten and molybdenum disulphide NanoLub™. The material reduces friction and wear under conditions that are especially relevant for space such as ultra-high vacuum, UV radiation, and high loads. Suitable applications could include rotors, bearings, robots, planetary rovers, space vehicles and transport devices.

Extensive testing by a number of independent groups clearly shows that these special nanoparticles improve considerably the tribological properties of different contact pairs in comparison to other solid lubricants.

Introduction

The recent interest in nanoscale science and technology has lead to largte efforts to develop new strategies for the synthesis of nanomaterials of a controlled size and shape at commercially competitive prices. Numerous possible applications have been postulated for these new nanomaterials, but simple analysis shows that their use is closely related to reduced manufacturing costs.

Nanomaterials are likely to be applied in important niches in various technologies, like ultra-strong nanocomposites, and as additives to various materials like lubricants.

Common solid lubricants are layered compounds like graphite, molybdenum disulfide (MoS_2), and tungsten disulfide (WS_2). Their layers slide past each other to reduce friction. Layered compounds are not without their drawbacks however. The edges of the layers are chemically reactive, causing them to slowly decompose, break apart, and bind to the metal surface. The relative large size of the layered platelets prevents them from entering the pores of metal parts and thus they tend to accumulate and stick on the surface. These factors ultimately diminish their lubricating ability causing the metal parts to grind against each other and wear down. Thus, there is a need for smaller, more stable solid lubricants.

We have found that certain inorganic compounds like MoS_2 and WS_2 that normally occur as flat platelets can be synthesized into nanospheres. The new nano-sphere structures are several times smaller than the typical layered form of the compound. In addition, each particle consists of a number of progressively smaller concentric spheres (like an onion) nested one within the other. The diameter of the nanoparticles is on the order of 100 nm (about a thousand times smaller than the diameter of a human hair). These nanoparticles, due to their special size, shape, chemistry, and structure, have unique and beneficial properties that are not possible with conventional size materials, making them attractive for many commercial applications.

Fig. 1 is a high-resolution electron microscope photo of a typical multi-walled nanosphere. The clearly visible concentric spheres are a result of the special synthesis conditions.

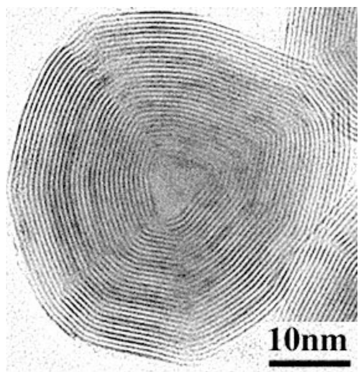

Fig. 1: IF nanoparticle

The structure of each shell resembles the geodesic dome design of Buckminster Fuller and are thus termed 'fullerenes'. Up until this discovery it was thought that fullerenes could only be made with carbon atoms. Our group was the first to show that certain inorganic (i.e., non-carbon) compounds could also be synthesized into fullerene-like structures, hence the name inorganic fullerene, or IF, nanoparticles.

Results

Thin films of IF nanoparticles were deposited on metal substrates, either in the pure form, or embedded in electroless coatings. They were found to confer low friction and wear to the substrate, even under very high loads, ultra-high vacuum, and in a humid atmosphere. The IF films are strongly adhered to the substrate as evidenced by their ability to significantly reduce friction at very high loads in ultra-high vacuum.

Similar beneficial effects were observed for anti-friction polymeric coatings loaded with IF nanoparticles. We have developed methods for excellent dispersion of the nanoparticles in the polymer and their de-agglomeration to individual particles homogenously distributed.

Ceramic materials are very ionic and consequently they are rather tough and brittle, notoriously known for exhibiting very poor tribological behavior. This poor behavior can be also attributed to the high surface roughness of ceramic materials. When rubbed against another surface, asperities of the rough ceramic surface detach, and small wear debris are formed, which scratch and damage the mating surface leading to its rapid deterioration. The surface of an alumina wafer was coated with a thin dry layer of IF-WS2 nanoparticles which was stressed under pressure applied by the reciprocating action of a ceramic ball. The added IF nanoparticles were found to decorate the irregularities and scratches on the surface of ceramic materials. shows the results of a tribological experiment with Si3N4 ball and a flat alumina wafer. Here an order of magnitude reduction of the friction coefficient is obtained by adding the IF-WS2 to the interface in comparison to conventional lubrication with oil. Furthermore, almost no wear incurred to the ceramic ball that was rubbed against the alumina surface with IF dry coating. Contrarily severe wear damage occurs to the surface of the ceramic ball lubricated with oil only. This remarkable behavior could be potentially very useful for machine parts in the aerospace industries.

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