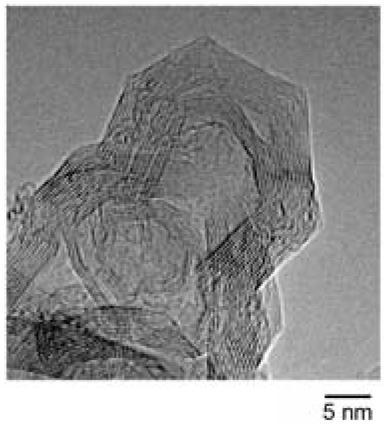
Tribological Behavior of Nano-Onions in Krytox 143AB Evaluated

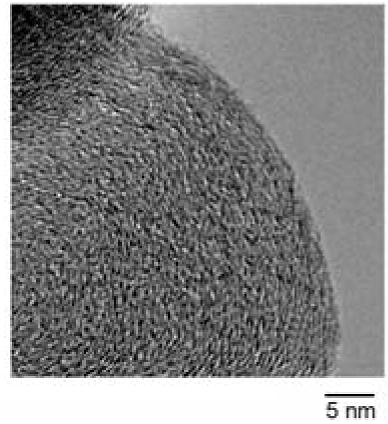
Nanoparticles have been developed over the past 10 years and have found several applications. This work presents the use of carbon nano-onions as a potential oil additive for aerospace applications. Researchers at the NASA Glenn Research Center tested lubricant lifetimes in ambient air and ultrahigh vacuum and characterized the breakdown products of the friction and wear. These carbon nanoparticles can provide adequate lubrication very similar to that of graphitic material when run in air.

Soot represents one of the very first nanostructured materials, although it has rarely been considered as such. Changes in the carbon nanostructure, resulting in increased graphitic layer plane length, correlate with reactivity loss. Upon heating spherically shaped nanometer-sized carbon black in the absence of oxidant, graphene sheets form, and the initial soot particle templates the growth of a graphitic particle into what is best described as a “sphere” with many flat sides having a hollow interior. Because there are no edge sites, these polygonal graphitic particles, or “nano-onions,” are relatively resistant to oxidation.

Graphite is used as a solid lubricant because of its stability at moderately high temperatures. However, the temperature at which graphite oxidizes rapidly is strongly influenced by surface area. With the size of particles typically employed in lubrication, a great amount of thermal stability is lost because of size reduction either during preparation or during lubrication of contacting parts. Therefore, we have undertaken a study of the lubricating ability of graphitic nano-onions (ref. 1).

A spiral orbit tribometer (ref. 2) simulates an angular contact bearing. Lubricant allows the system to operate in the boundary lubrication regime. The ball rolls and pivots in a spiral and is maintained in orbit by a guide plate. The force the ball exerts on the guide plate is used to determine the friction coefficient. A suspension of nano-onions in Krytox oil was evaluated at room temperature under ultrahigh vacuum or in air at Glenn as part of our ongoing efforts in aeronautics research.





Transmission electron microscope pictures. Left: Nano-onion. Right: Carbon black.

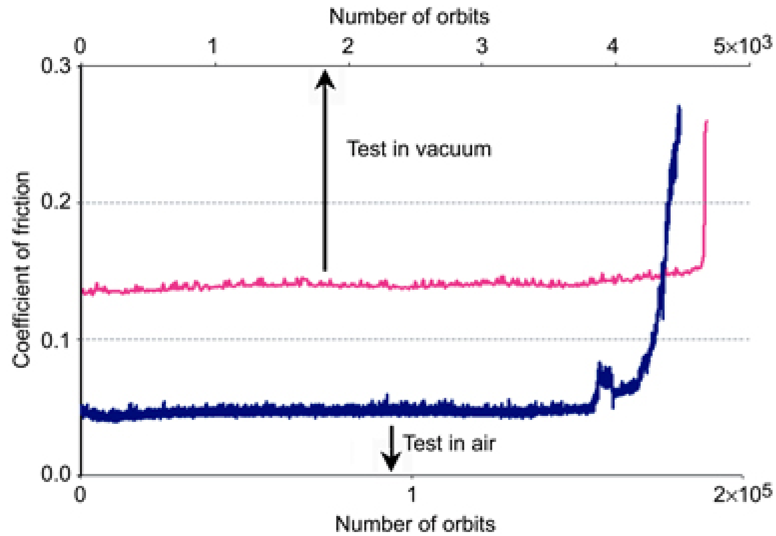
High-resolution transmission electron microscope images of the nano-onions (see the left photograph) and carbon black (see the right photograph) indicate that the structure of the material changed significantly upon graphitization. In these images, the dark lines indicate the graphene sheets of carbon atoms and the white lines are the spacing between sheets. The analyses of both the nano-onions and carbon black in air indicate high-purity materials.

Raman spectroscopy is often used to characterize graphite and graphitic materials (ref. 3). The spectra obtained from the nano-onions indicate a highly ordered material considerably different from the starting carbon black. The Raman spectrum of the degradation products resembles the starting carbon black, indicating that the nano-onions are consumed during use.

NORMALIZED LIFETIMES OF KRYTOX 143AB WITH NANO-ONIONS FOR DIFFERENCE CONDITIONS

Tribological conditions	**Normalized lifetime, orbits/µg**
Vacuum	55
Ambient air	3830

For tests conducted in ultrahigh vacuum at room temperature, the nano-onions do not improve the lifetime, or change the friction coefficient, of this perfluoropolyether (PFPE) oil. The normalized lifetime (number of orbits performed before failure per microgram of lubricant employed) was calculated. Tests conducted in ambient conditions; however, showed a very low friction coefficient with a long lifetime. Furthermore, the failure was more “progressive” than the one observed in vacuum. Examples of friction traces and the lifetimes obtained are given in the following graph and in the table.



Friction coefficient for tests run in vacuum (upper scale) and in air (lower scale).

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