Biomimetic Nanostructured Coating for Environmentally Preferable Dry Machining

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Environmental Problem

Machining involves several processes that use power-driven machine tools (such as lathes, milling machines, and drill presses) with a sharp cutting tool to mechanically cut metal, wood, or plastic. The temperature of both the cutting tool and the part are decreased during the machining process by the use of cutting fluids, which are expensive, can be toxic, and produce a significant waste stream. More than 100 million gallons of cutting fluid are used each year in the United States, and responsible handling of waste fluid is needed to avoid contamination of water bodies and groundwater. Coatings for cutting tools can be an effective approach to help address this problem. However, standard coatings use a multilayer configuration in which the soft phases wear out early in the machining process, leaving the hard phases exposed. Therefore, this configuration cannot provide efficient lubrication throughout the tool life.

SBIR Technology Solution

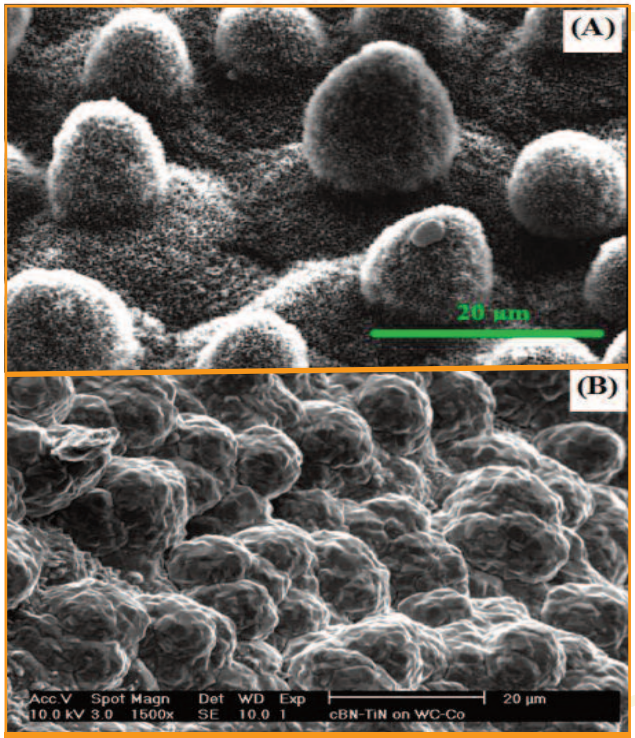
With support from EPA's Small Business Innovation Research (SBIR) Program, NanoMech developed an innovative nanostructured coating for cutting tools that includes a hard phase comprised of cubic boron nitride (cBN) and titanium nitride (TiN) and a soft phase that uses polytetrafluoroethylene (PTFE) or molybdenum disulfide (MoS_2). Based on the principles of biomimicry, the patented coating has the hard phase deposited in a nodular textured structure similar to a lotus leaf's surface, and the soft phase in the micro-reservoirs surrounded by the micro-nodules. This surface morphology acts as a lubricant delivery system at the machining interface, refreshing the contact surface with lubricants, thereby reducing friction and resulting wear and enhancing tool performance. The coating is synthesized using a hybrid manufacturing process that represents the next generation coating process beyond traditional vapor deposition processes. Tribological testing of the coating demonstrated a lower coefficient of friction and a better resistance to wear than the benchmark, which combines the hard and soft phases in a layered structure.

The coating, called TuffTek®, can improve tool life 300 percent compared to conventional physical vapor deposition (PVD) titanium aluminum nitride (TiAlN) coatings by combining exceptional wear resistance and toughness. Polycrystalline cubic boron nitride (PcBN) compact tools are costly, brittle, and are available in limited geometries. cBN coatings have been sought for a long time as they could offer a solution to these issues, but they have proven difficult to deposit. NanoMech's patented coating process has solved this problem. TuffTek® also does not require polishing after coating, and this provides additional cost savings and environmental protection because no chemicals have to be used or disposed.

Commercialization Information

TuffTek® is currently sold in the commercial market to automotive and other manufacturing industries. The technology was called "coating's holy grail" by *Cutting Tool Engineering* (October 2008).

Depending on the customer's need, TuffTek® can offer surfaces with or without lubricants. Although it was designed to coat cutting tools and serve manufacturing industries, the coating technology is useful for other applications as well, including dies and molds. TuffTek® can be used for wear-resistant coatings on machine parts, which represents another market opportunity. In addition, NanoMech's nanoparticle coating platform technology can be applied in biomedical, military, and electronics arenas. Development in those areas is underway based on



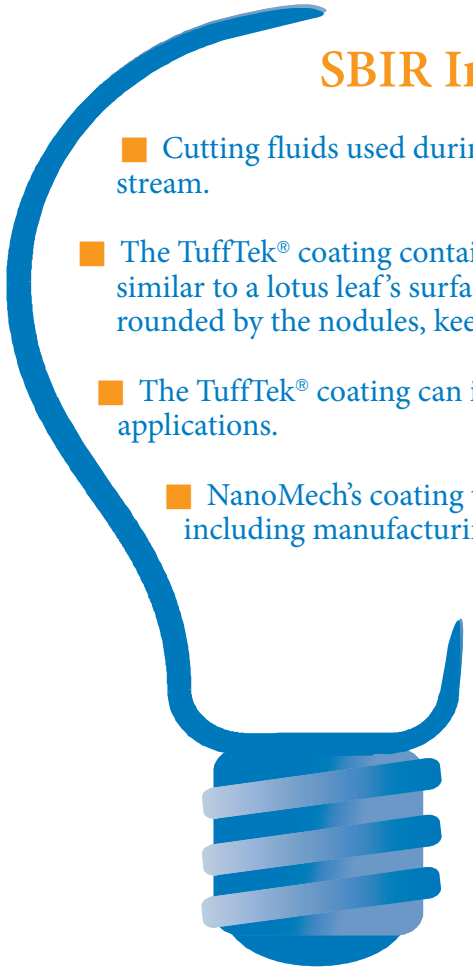
(A) Typical surface morphology of a lotus leaf;
(B) Representative surface features of a TuffTek® - coated cutting tool insert

funding from other government agencies and commercial partners. NanoMech can take pre-synthesized nanomaterials, integrate them into a product, and bind them efficiently.

NanoMech's technologies have created jobs in manufacturing with salaries of $60-70 K. Overcoming the technical barriers to develop an alternative method for cBN coating deposition has given NanoMech an opportunity to gain a significant competitive advantage in the nanomanufacturing market.

Company History and Awards

NanoMech, Inc., operating since 2002, is a privately held company. In 2008, the company began manufacturing and sale of the TuffTek® coating for cutting tools. NanoMech has more than 20 employees, and in addition to TuffTek®, manufactures its Guard-In-Fresh nanoparticle-based additive for imparting antimicrobial action (e.g., to polymers and fabrics), and NanoGlide® a nanoparticle-based lubricant additive. The company has received several awards for its innovative products and processes, including Frost & Sullivan's 2005 Award for Excellence in Technology in the field of Advanced Coatings, Surface Technologies, and Spray Coatings; the R&D Magazine Micro/Nano 25 Technologies of Tomorrow Award naming NanoMech's cBN coatings among the 25 best micro- and nanotechnologies of 2006; and a Recognition of Excellence in Innovation Award from the U.S. Under Secretary of Commerce for Technology in 2007.



SBIR Impact

- Cutting fluids used during the machining process create a hazardous waste stream.
- The TuffTek® coating contains the hard phase deposited in a nodular structure similar to a lotus leaf's surface, and the soft phases in the micro-reservoirs surrounded by the nodules, keeping the contact surface refreshed with lubricants.
- The TuffTek® coating can improve tool life by 300 percent or more in certain applications.
- NanoMech's coating technology has applications in numerous markets, including manufacturing, biomedical, electronics, and military.
- NanoMech has successfully marketed TuffTek® coatings to cutting tool manufacturers and users in the automotive and other manufacturing industries.