Diamonds are a Scientist's best Friend: Research into Building Better Small Machines

July 14 2005

Do diamonds really last forever? That's the hope of University of Wisconsin-Madison researchers who are trying to solve the problems associated with building extremely small machines and having them withstand the test of time, wear and tear.
The problem is that these machines are so small - microscopic or smaller - that their moving parts cannot be assisted by lubricants; instead, they have to function in a dry state, like a car with no oil.
A really, really small car with no oil.

"They no longer behave in the same way as they do at the macro-scale, where materials may be far stronger, have more power to catalyze chemical reactions, be more optically responsive, and more," says Robert Carpick, associate professor of engineering physics. "That is why it is very interesting to study the fundamental physics of nanoscale materials and also to try to utilize these unique properties for real applications."

An example of a real application includes the tiny sensors in cars that sense rapid deceleration and deploy airbags.

Carpick and his colleagues - including collaborators from Argonne National Laboratories - recently published research that is integral to better understanding the issues facing the engineering of both micro- and nanoelectromechanical systems, called MEMS and NEMS. The paper, published in the journal Advanced Materials, explored a material made by their Argonne collaborators, ultrananocrystalline diamond (UNCD) and, in particular, its structure and surface chemistry.

"When you consider fabricating devices with sliding and rotational motion, you need to consider the structure and surface chemistry of the materials at the location of contact, called a tribological interface," Carpick explains.

It's this issue of tribology - the study of friction, lubrication and wear of moving parts - that's particularly interesting when considering MEMS and NEMS. Just because small machines can be made doesn't mean that they can be made to work well and not wear down the researchers say.

Due to the vast knowledge of its use in microscale fabrication, the material of choice has traditionally been silicon. But because silicon does not respond well to uses that require repetitive sliding or rolling, the machines made from it fail. Two solutions to the problem include improving silicon's wearability or finding a new material. Carpick is putting his money on a new material: diamond.

The published study reported on data taken exclusively at the Synchrotron Radiation Center, an electron storage ring located at UW-Madison that uses the light produced by electrons whizzing around a basketball court-sized ring to conduct spectroscopy - a method that uses electrons kicked out of the sample by this light like knocking bricks out of a wall - to analyze the bonding configuration of materials like diamond in detail.

"To our surprise, we found that the structure and surface chemistry of the diamond at the tribological interface is worse than the original diamond. We found that at the tribological interface, the surface is more graphitic in nature," explains Carpick. "This would be bad news for a MEMS device."

The solution offered by Carpick and his colleagues is to coat the surface of the diamond by removing the graphite and attaching hydrogen to the remaining pure diamond. This forms a strongly bonded "atomic cap" to the surface. Like putting varnish on a wooden table, the diamond surface becomes sealed and the diamond becomes water repellent, a critical feature for a machine that runs without lubrication.

"This means, if one wishes to build MEMS or NEMS devices from UNCD, then we have shown a way to minimize friction and adhesion, and this will help us to develop more reliable, robust (and) long lasting MEMS devices," Carpick notes.

The next step for Carpick includes a collaborative effort with UW-Madison physics Professor Gelsomina "Pupa" de Stasio, who has developed world-renowned spectroscopy methods at the Synchrotron Radiation Center. The team has been awarded a $480,000 grant from the United States Air Force Office of Scientific Research to tackle the issue of wear and tear on these thin diamond films and to answer the question of whether diamonds can truly last forever - or at least a really long time.

Published in Advanced Materials [April 2005, Volume 17, Issue 8 , Pages 1039 - 1045]; A. V. Sumant, D. S. Grierson, J. E. Gerbi, J. Birrell, U. D. Lanke, O. Auciello, J. A. Carlisle, R. W. Carpick; "Toward the Ultimate Tribological Interface: Surface Chemistry and Nanotribology of Ultrananocrystalline Diamond"

Source: University of Wisconsin-Madison

Citation: Diamonds are a Scientist's best Friend: Research into Building Better Small Machines (2005, July 14) retrieved 25 April 2024 from https://phys.org/news/2005-07-diamonds-scientist-friend-small-machines.html