Lotus leaf and fake diamonds lead to better orthopaedic implants

by CHUCK BROWN

Inspiration often comes from unexpected places.

Just ask UNMC's Fereydoon Namavar, Sc.D.

In the case of a coating he designed for orthopaedic implants, the scientist – who worked on NASA's Mars Rover, Star Wars and optical communications projects before entering the world of biomedical research 10 years ago – found inspiration in his mother-in-law's jewelry case and the leaves of the lotus flower.

One day a few years back, Dr. Namavar listened as his mother-in-law shared how much she liked her cubic zirconia jewelry – except for one thing that bothered her.

"When it would get wet, it would fog up," said Dr. Namavar, professor and director of the nano-biotechnology laboratory in the UNMC Department of Orthopaedic Surgery.

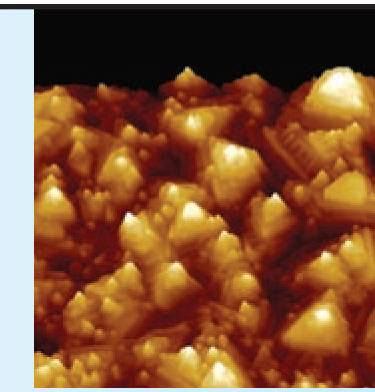
While bad news for his mother-in-law, this was an epiphany for Dr. Namavar.

A common issue with implants is wear and tear because joint surfaces rub together. This can lead to repeat surgeries, as well as send an unhealthy mix of wear particles into a person's blood stream.

The wear and tear happens, in part, because surfaces used on orthopaedic implants are too soft and lack the ability to stay wet.

With orthopaedic implants, ideally, it is important that one of the two contact surfaces be wettable, while the other is hydrophobic or rejects water, Dr. Namavar said. He needed opposites, a Yin and a Yang.

"If both were wet, the surfaces would stick together and drastically increase friction," Dr. Namavar said. "But, when you have these opposites together, you have lower friction and smoother motion on the surface."



ATOMIC FORCE MICROSCOPY IMAGE OF CUBIC ZIRCONIA SHOWING PYRAMIDAL NANOSTRUCTURES WITH SIZES RANGING FROM 130 TO 210 NANOMETERS.

Dr. Namavar's ears immediately perked up when his mother-in-law complained about how cubic zirconia fogs up when wet.

"I knew I had my substance," he said. "I thought, 'here is a material that could be hard and also seems to be able to stay wet.'"

In other words, cubic zirconia might work just as well in a hip joint as it does in a gold tennis bracelet.

As he designed his implant coating, Dr. Namavar wanted to alter the properties of cubic zirconia to attain maximum wettability.

The cubic zirconia would provide the Yin (wet) to his existing model, the lotus leaf, the Yang (dry).

The lotus leaf is considered a symbol of purity in many cultures because of its self-cleaning properties.

"When a drop of water hits a lotus leaf, it rolls off the surface, washing away dirt and dust," Dr. Namavar said. "This is because the lotus leaf is water resistant, or hydrophobic."

Hydrophilic (wettable) and hydrophobic properties of substances are actually flip sides of the same coin and thus identical at a nanostructure level, he said.

As a result, Dr. Namavar decided to alter the physical properties to mimic the hydrophobic lotus leaf to make his coating super-hydrophilic or more wettable.

To alter the cubic zirconia, Dr. Namavar uses a technique called ion-bombardment, during which he exposes a substance to a large amount of ions – atoms that have gained an electrical charge by losing an electron.

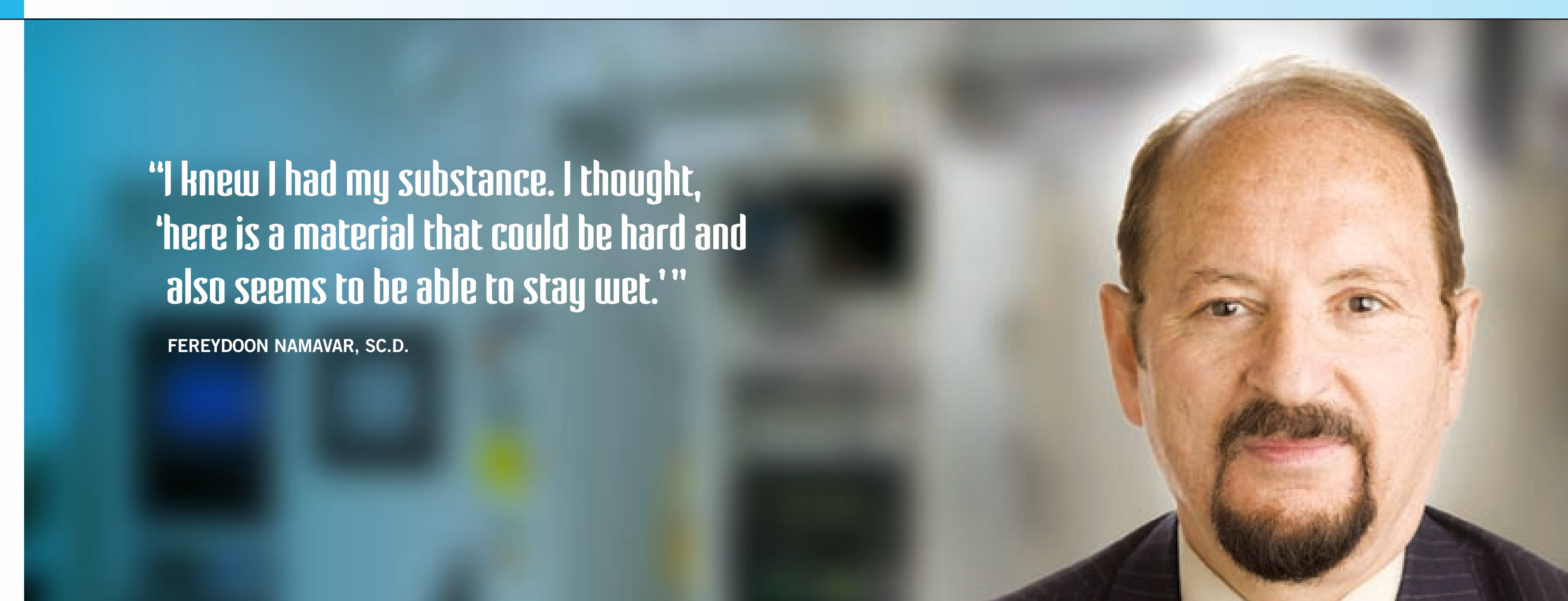
Dr. Namavar's team uses a special ion beam assisted deposition (IBAD) process to enhance the zirconia's hardness and ability to stay wet. They are one of the few research teams at an academic instititUion in the country that uses the IBAD process.

"Utilizing billions of energetic ions as an ionic hammer, we have forged nano pyramidal structure films possessing combined properties of super-hardness and complete wetting behavior," Dr. Namavar said.

With his coating made of altered pure cubic zirconia, Dr. Namavar knew he had created a harder, wettable substance that stands to improve the life of orthopaedic implants.

By altering the hydrophilic (wettability) properties of these novel materials, Dr. Namavar also created a substance that bones like to grow on.

Tests done in collaboration with John Jackson, Ph.D., associate professor, pathology and microbiology, and Graham Sharp, Ph.D., professor, genetics, cell biology and anatomy, have shown that bone stem cells actually attach to and grow on Dr. Namavar's coating.



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"It seems that our pyramidal nano-structures have a charge distribution, which the cells find hospitable," he said. "This was an unexpected development and one we were thrilled to encounter."

Dr. Namavar and his team plan to do tests on animal models.

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Dr. Namavar said his work has been aided by strong support from Kevin Garvin, M.D., chairman of the department of orthopaedic surgery, and Hani Haider, Ph.D., an associate professor of orthopaedic surgery.

Collaborations have been important to his work, Dr. Namavar said. A grant from the Nebraska Research Initiative has allowed him to work with Barry Li Cheung, Ph.D., of the chemistry department at the University of Nebraska-Lincoln, and Renat Sabirianov, Ph.D., and Wai-Ning Mei, Ph.D., of the physics department of the University of Nebraska at Omaha.

THOMAS GUSTAFSON, INTERN, PREPARES THE ION BEAMS ASSISTED DEPOSITION (IBAD) SYSTEM THAT PRODUCES THE NANOCRYSTALLINE COATING.

Dr. Garvin said Dr. Namavar's coating could prove particularly important as the health care system faces a surge in the elderly population, which will lead to more implant surgeries.

"By making implants last longer, this coating could make life better for patients and physicians alike," Dr. Garvin said.

"Patients, of course, may be able to avoid the discomfort and inconvenience of multiple surgeries, which also would take stress off a system that already is overburdened."