IIT Hyderabad Researchers Developing New Eco-Friendly Technologies

Early detection of premature failure or malfunctioning prosthetic implants without surgery can help avoid reverse surgery, a remedial measure more expensive and painful than first time surgery.

(L-R) Dr. Saket Asthana, Head Professor, Advanced Functional Materials Laboratory, Physics Dept, IIT-H, with his student Krishnarjun Banerjee.

Indian Institute of Technology Hyderabad Researchers are developing new technologies for bio-compatible implants that will enable early detection of malfunctions through non-invasive monitoring and diagnosis. Early detection of premature failure or malfunctioning prosthetic implants without surgery can help patients avoid reverse surgery, a remedial measure more expensive and painful than first-time surgery.

A huge number of knee, hip, and other bone replacements are conducted in India and across the world every year. The replacements are done mostly on patients aged above 60 years. While the expected durability of the implant is up to 20 years, early failure is observed and sometimes, even immediate failure of the implant is also noticed.

This happens due to the lower hardness of the implant and its reaction with the body fluid and organs. The common solution to detect the premature failure of the implant is reverse surgery, which is more expensive and painful than first-time surgery.

IIT Hyderabad Researchers are working towards early detection of malfunctioning implant without surgery, which can solve this problem. For this purpose, a biocompatible implant with sensing property and high hardness will be the best choice.

The piezoelectric/ferroelectric material can detect the change in mechanical energy due to its dimensional change during the functional period. To avoid reverse surgery an eco-friendly and hard ferroelectric material can be an effective choice as an implant instead of other available ceramic or steel-based implants.

IIT Hyderabad Researchers have shown that reducing particle sizes of the ferroelectric material results in improvements in mechanical properties without compromising on their electric characteristics, making them suitable for biocompatible implants. Their work has recently been published in the Journal of American Ceramic Society.

The study is being led by Dr Saket Asthana, Head Professor, Advanced Functional Materials Laboratory, Department of Physics, IIT Hyderabad. His team is studying lead-free ferroelectric ceramics for use in orthopedic implants.

Speaking about the practical applications of his Research, Dr. Saket Asthana said, "Most importantly, this eco-friendly material is synthesized by normal solid state reaction method instead of sophisticated technique, which may reduce the cost of processing of this material. This finding can show the pathway of using this kind of ceramics in prosthetic applications; the piezoelectric property makes them detectable from outside, which enables non-invasive monitoring and diagnosis. An extensive research in collaboration with medical team is necessary to come with real time and practical application of these materials".

According to its property, the supplied mechanical energy through the physical activities is converted to the electrical energy, and by detecting this, the abnormality and/or duty of the implants are diagnosed. The IIT Hyderabad study shows that the different grain size vastly controls the mechanical properties of the ferroelectric material, which effects its hardness. The researchers from this laboratory found that reducing the grain sizes of lead-free Na 0.5-x Rb x Bi 0.5 TiO 3 to 0.50 μm results in considerable improvements in hardness without loss of ferroelectric properties. In addition, they have established the biocompatibility of this family of ceramics.

Ceramic-based materials such as alumina and zirconia are being considered for biomedical structural applications such as prosthetics and implants in orthopedics and dentistry. Despite inherent strength, toughness and fatigue resistance of conventional ceramics, implant strategies using these materials face difficulties due to poor biological interaction between the ceramic and biological tissues. This can result in complications such as aseptic loosening and infection.

There are some classes of materials such as piezoelectric and ferroelectric materials that can generate an electrical potential in response to mechanical stimulus. Use of such materials in prosthetic applications is attractive because the mechanical loading of bones and joints during human movement can generate an inherent electric potential, which can provide the stimulation for bio-integration of the prosthetic device.

Elaborating on this, Dr. Asthana said, "Piezoelectric and ferroelectric ceramic materials have the potential to be used in prosthetic implants, but the benefit of electrical stimulation is offset by poor mechanical properties like hardness and toughness".

He adds that many piezoelectric materials contain lead, which is toxic and is banned by most countries in the world. There is thus, a quest for lead-free piezo and ferroelectric ceramics for a range of applications, including biomedical. The improvement of mechanical properties of lead-free ceramics without compromising on the ferro/piezoelectric properties has been challenging.

Dr. Asthana's team meets this challenge through materials engineering; the researchers reduce the particle sizes of lead-free ferroelectric powders before compacting them into solid items to improve the mechanical properties of the ceramics. "We have chosen lead-free relaxer ferroelectric materials that have permanent dipole moments in the nanoscale", says Dr. Asthana.

The researchers found that reducing the particle sizes of Na0.5-xRbxBi0.5TiO3 to one thousandth of a millimeter results in considerable improvements in hardness without loss of piezoelectric properties. In addition, they have established the biocompatibility of this family of ceramics.

The researchers find another benefit of using this kind of ceramics in prosthetic applications - the piezoelectric property makes them detectable from outside, which enables non-invasive monitoring and diagnosis.

Many orthopedic surgeons prefer ceramic implants over traditional metal-and-plastic implants because deterioration of metals and plastic within the body can lead to the gradual buildup of debris in tissues, leading to serious aftereffects. The use of piezoelectric ceramics in implant applications is an emerging field and Dr. Asthana's research provides a launch pad for future developments in this area.

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