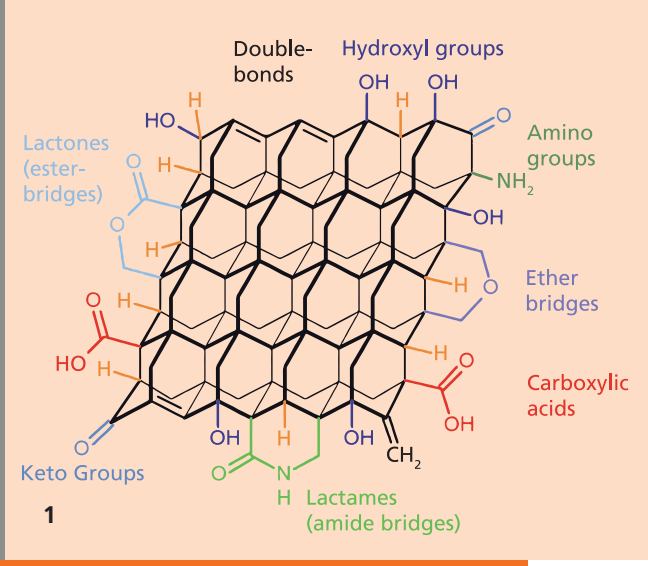

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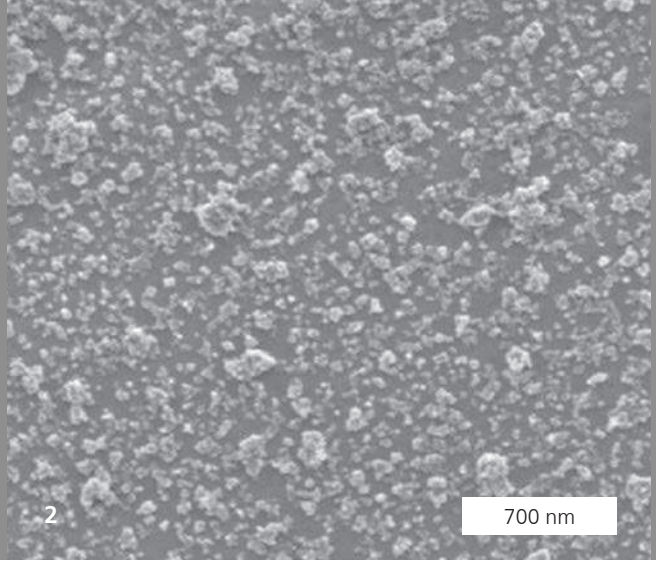

2

DEVELOPMENT OF NANODIAMOND-BASED COATINGS FOR TITANIUM ALLOY IMPLANTS

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Several million people worldwide suffer from fractures due to accidents or systemic skeletal diseases, such as diabetes mellitus. This can result in loss of bone tissue and hinder mobility. By means of implants and prosthetics, lost mobility can be largely restored.

The choice of implant is not an easy decision, since bone healing is a very complex and dynamic process. Within the first few seconds of implantation, numerous physiochemical reactions in which different organic and inorganic biomolecules are adsorbed on the surface take place. Another important factor is the biocompatibility of an implant material. The term "biocompatibility" is defined as the ability of a material to perform both structurally and functionally in a specific application with an appropriate host response.

Titanium and its alloys are normally the first choice for such applications due to their excellent mechanical properties and biocompatibility. In particular, they are the favored material for implants (osteal, dental, and coronary stents, etc.). The presence of a native oxide layer on these materials provides a certain amount of resistance to corrosion. However, in long-term use, metals have been observed to corrode, producing metal ions that diffuse into the surrounding tissue, which can induce inflammation and might lead to implant failure and repeat surgery.

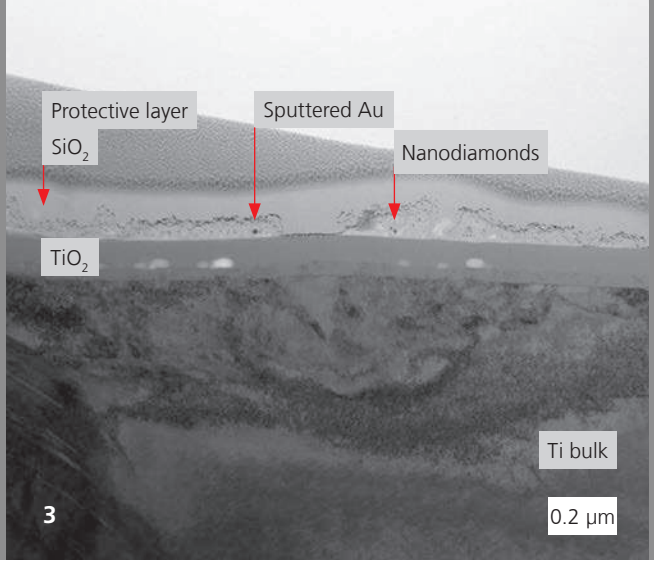
Various surface modification techniques have been used on titanium-based materials in attempts to enhance their properties.

Fraunhofer IKTS in cooperation with the "Biomaterial Innovation for Medicine and Technology" working group of Max Bergmann Center for Biomaterials at TU Dresden perform surface modifications of titanium-based materials for such metal-based biomedical applications with detonation nanodiamonds.

Detonation nanodiamonds (DNDs) are carbon-based nanoscale materials with excellent properties. Besides displaying typical diamond properties, such as high thermal conductivity and extreme hardness, these nanoparticles possess different functional groups on their surfaces resulting from the purification process performed after detonation synthesis. These functional groups allow biological and chemical tuning of nanodiamonds for use in various fields. Nanodiamonds have proven to be non-toxic and biocompatible in-vivo, making them favorable candidates for biomedical applications.

Methodology and mechanism

DNDs are first chemically functionalized with (phosphate) anchor groups known for their great affinity with titanium oxide surfaces. The functionalized detonation nanodiamonds are then immobilized and incorporated into the titanium oxide surface through the electrochemical process of anodic oxidation performed to increase the oxide layer thickness. The hydrostatically stable phosphate group structure supports the formation of monolayers and bilayers. This phosphate-based coordination leads to nanodiamond-to-titanium oxide layer binding with a strength that could not be achieved via electrostatic or hydrogen bridging.

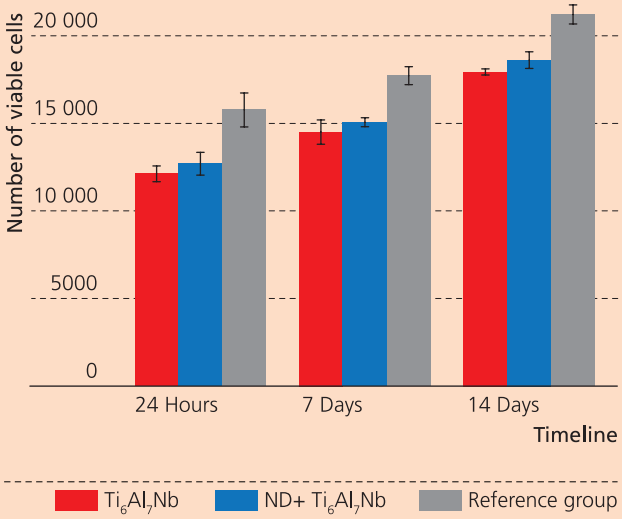


3

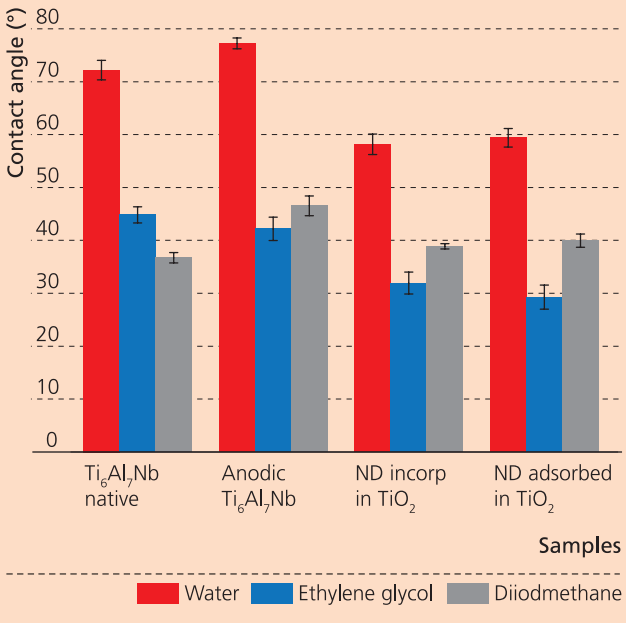
Effects of using nanodiamond-based coatings

- Biocompatibility: improvement in surface wettability and surface energy; improvement in hydrophilicity associated with the increased biocompatibility
- Cellular response: increase in cell adhesion, proliferation, and no cytotoxicity
- Corrosion resistance: improvement in corrosion resistance based on capacitive behavior and high impedance values, particularly at lower frequencies (nanodiamond-coated titanium-based material)
- Improvement in wear resistance and strength
- Formation of a barrier layer preventing diffusion of metal ions into surrounding tissues

Cytotoxicity assessment



Contact angle measurements



Services offered

- Biochemical surface modification of nanodiamonds
- Surface modification of titanium and other valve metals for a variety of applications (aerospace, industrial, and biomedical)
- Antimicrobial coatings

1 *DND structure.*
2 *SEM image of DND on TiO_2.*
3 *STEM image.*

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