Atomic Layer Deposition Technology as a method allowing functionalization of the implant surfaces designed for the osteoporotic patients

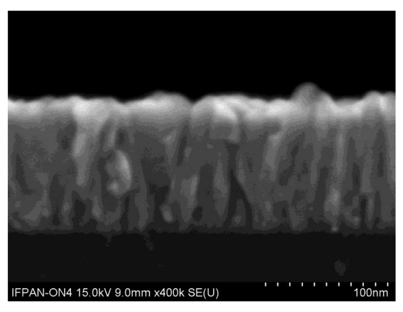
Aleksandra Seweryn[1], Krystyna Lawniczak-Jablonska, Bartłomiej S. Witkowski[1], Piotr Kuzmiuk[1], M. Ozga[1], Marek Godlewski[1]
Agnieszka Śmieszek[2], Katarzyna Kornicka-Grzybowska, Klaudia Marcinkowska[2], Mateusz Sikora[2], A. Fal[2], M. Alicka[2] Krzysztof Marycz[2,3]
[1]Institute of Physics Polish Academy of Sciences, Al. Lotnikow 32/46, 02-668 Warsaw, Poland
[2]Wroclaw University of Environmental and Life Sciences, Norwida St. 27 B, PL-50375 Wroclaw, Poland
[3]University of Cardinal Stefan Wyszynski, Collegium Medicum

BACKGROUND

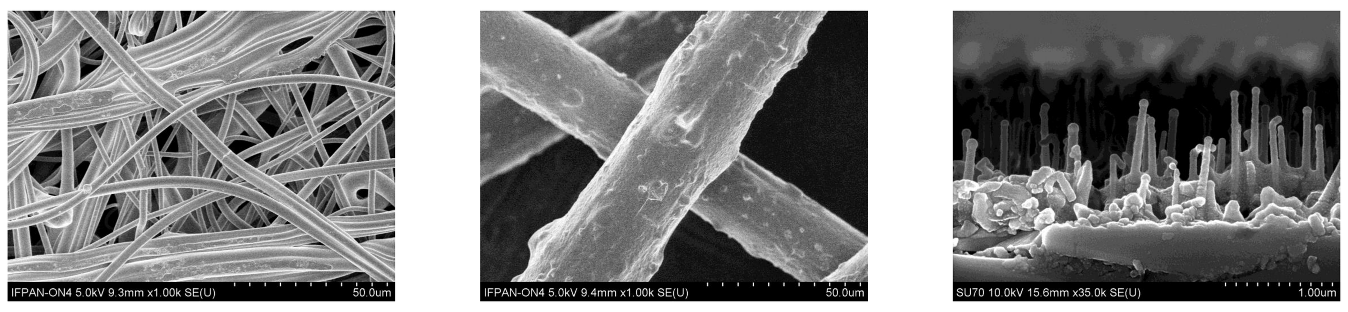
There is a great demand for the development of novel therapeutic strategies in terms of bone healing, especially when osteoporosis is considered. The bioactivity and functionality of implants can be improved by their functionalization with various coatings. Recently Atomic Layer Deposition (ALD) technology is considered as a powerful method that can be used for deposition of thin, homogenous oxide films on biomedical devices created using various substrates. We test the oxides of transition metals for their biocompatibility with osteo-cells. We have investigated zirkonium dioxide, hafnium dioxide and titanium dioxide so far. We studied the development of bone marrow stromal cells in contact with the ALD layers and observed different behaviour of such cells in relation to different oxides. The main proposal is that all the materials could support the osteogenesis.

ATOMIC LAYER DEPOSITION TECHNOLOGY

ALD technology consists in a sequential distribution of chemical compounds in a gas phase intoThe the reaction chamber. Each precursor pulse is separated with a purge phase of the chamber, whereby the precursors don't react with each other in the gas phase. The reaction occurs only on the substrate. One precursor pulse corresponds to the deposition of one atomic monolayer on the substrate. Therefore, the ALD is characterised by precise thickness control. ALD technology enables the deposition of homogeneous transition metal oxide thin films on the complex substrates.

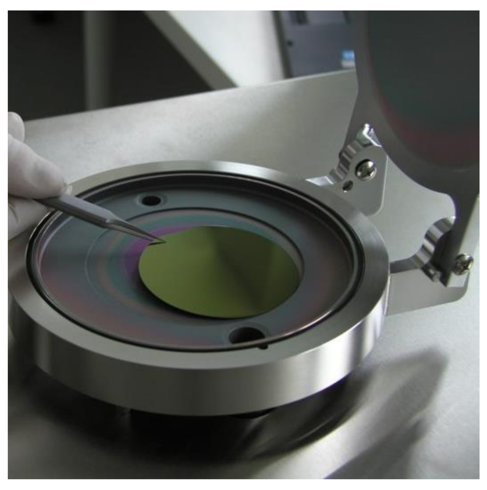


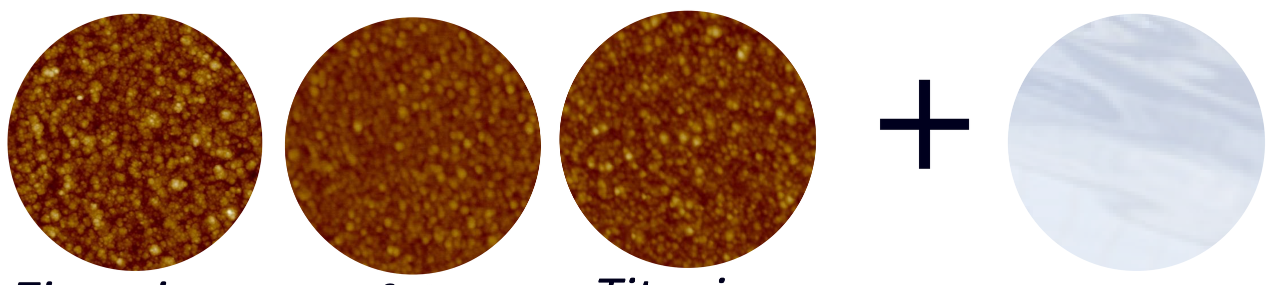
Precise thickness control (ZnO film)



Deposition on the 3D surfaces (ZnO film on the cotton and nanorods.

EXPERIMENT

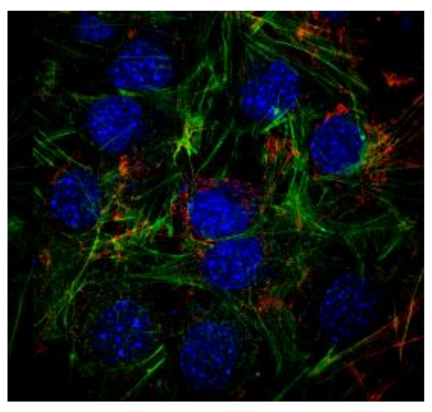




Zirconium dioxide | *Hafnium dioxide* | *Titanium dioxide* | *Cover slip*

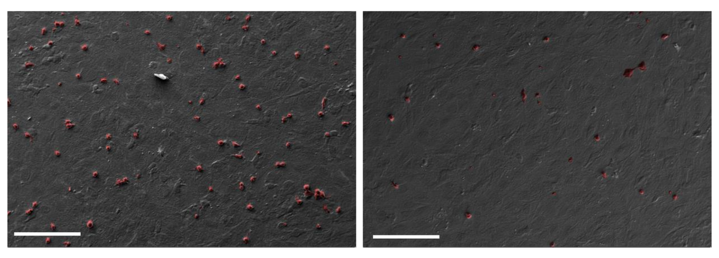
We test the oxides of transition metals for their biocompatibility with osteo-cells. We have investigated zirkonium dioxide, hafnium dioxide and titanium dioxide obtained by ALD technology. We studied the development of bone marrow stromal cells in contact with the ALD layers and observed different behaviour of such cells in relation to different oxides.

BIOCOMPATYBILITY OF THE ALD COATINGS

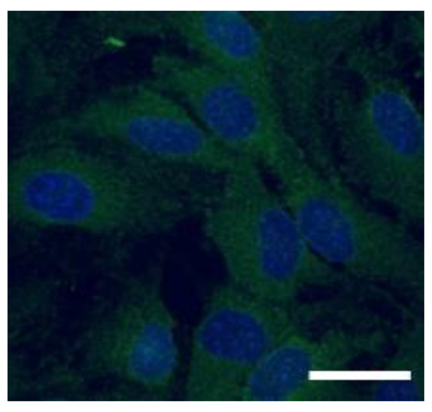


Zirconium dioxide improved mitochondrial metabolism of bone forming cells

Titanium dioxide | *cover slip*

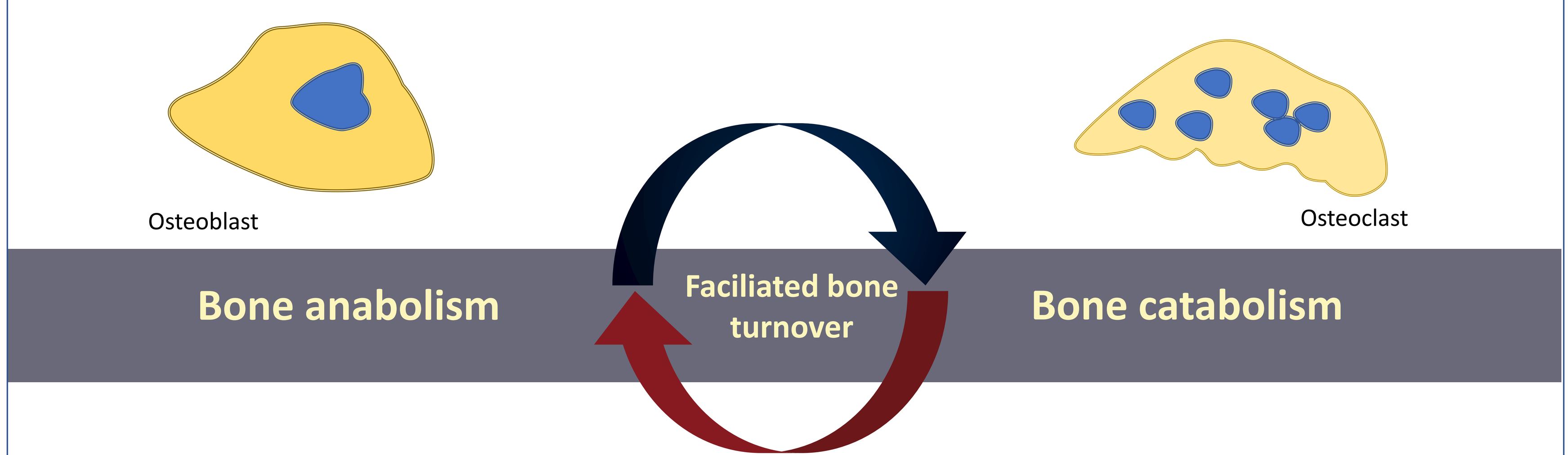


Titanium dioxide decreased invasion of osteoclast cells (red colour)



Hafnium dioxide increased expresion of bone markers, including transcription factor Runx-2 (green colour)

CONCLUSION



ALD coatings:

- Regulate interactions between bone cells
- Enhance expression and production prooosteogenic markers (mRNA, miRNA, proteins)
- Promote bone homeostasis

CONTACT

Group of Technology of Oxide Nanostuctures
Division of physics and technology of wide-band-gap Semiconductor nanostructures.
aseweryn@ifpan.edu.pl godlew@ifpan.edu.pl

Marycz's Lab Reg-Med-Lab Group
Leading Research Team
Department of Experimental Biology
agnieszka.smieszek@upwr.edu.pl krzysztof.marycz@upwr.edu.pl

Institute of Physics Polish Academy of Sciences
Wrocław University of Environmental and Life Sciences