Powder metallurgy titanium for biomedical applications

- *KOVÁČIK Jaroslav*

  Institute of Materials & Machine Mechanics, Slovak Academy of Sciences, Bratislava

- *EMMER Štefan*

  IVMA STU, Bratislava

- *MARKO Denis*

  UCM, IFBLR, Trnava

- *KULASA Joana*

  IMN, Gliwice, Poland

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Ideal biomaterial

- An ideal biomaterial is expected to exhibit properties such as a very high biocompatibility, that is, no adverse tissue response.
- Also, it must have a density as low as that of bone
- High mechanical strength and fatigue resistance
- Low elastic modulus and good wear resistance.
- It is very difficult to combine all these properties in only one material.

Is PM titanium ideal biomaterial?

Titanium

Titanium is a chemical element with symbol Ti

It is a transition metal with a silver color, low density and high strength.

It is highly resistant to corrosion in sea water, aqua regia, and chlorine.

Titanium

Attempts to use titanium for

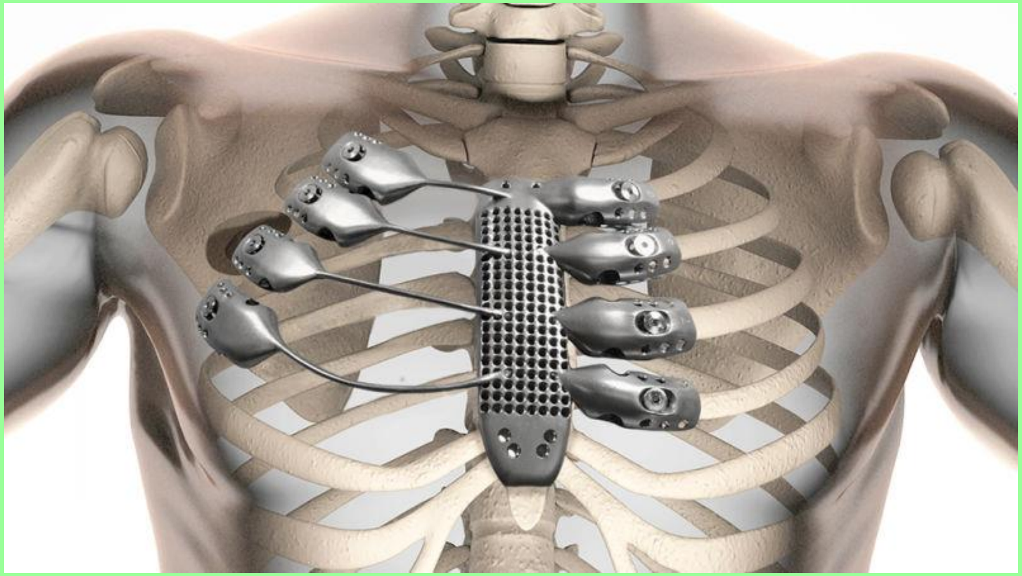
implant fabrication dates to the late 1930s.

It was found that titanium was tolerated as was stainless steels and cobalt alloys.

Titanium was found the only metal biomaterial to osseointegrate - Van Noort, 1987

Possible bioactive behaviour - Li, 1994 due to the slow growth of hydrated titanium oxide on the surface of the titanium implant that leads to the incorporation of calcium and phosphorous.

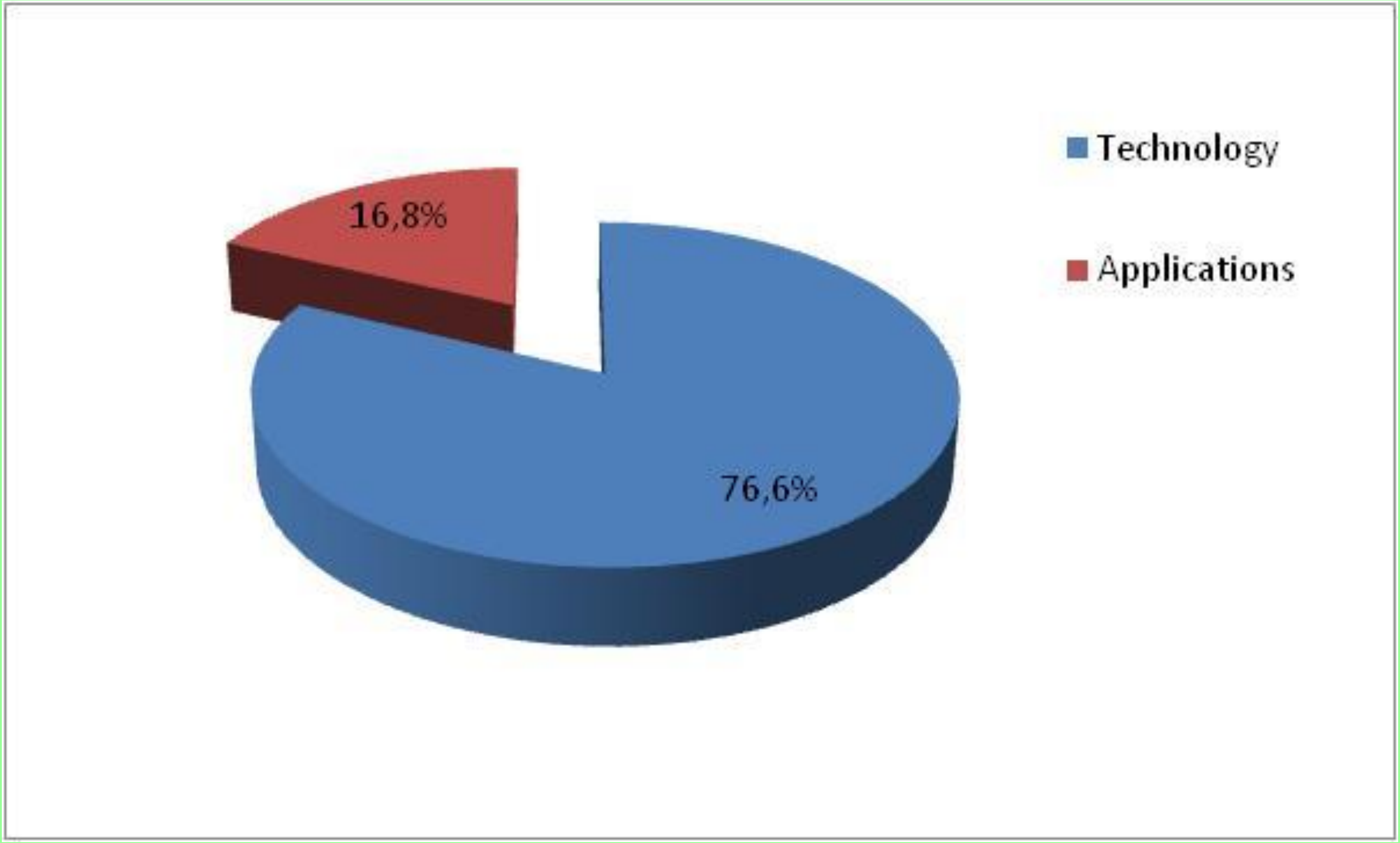
Titanium



2015:

54-year-old Spanish man received the world's first 3D-printed chest prosthetic made from titanium powder.

The Proceedings of the 13th World Conference on Titanium, held in August 2015 at San Diego, California, USA



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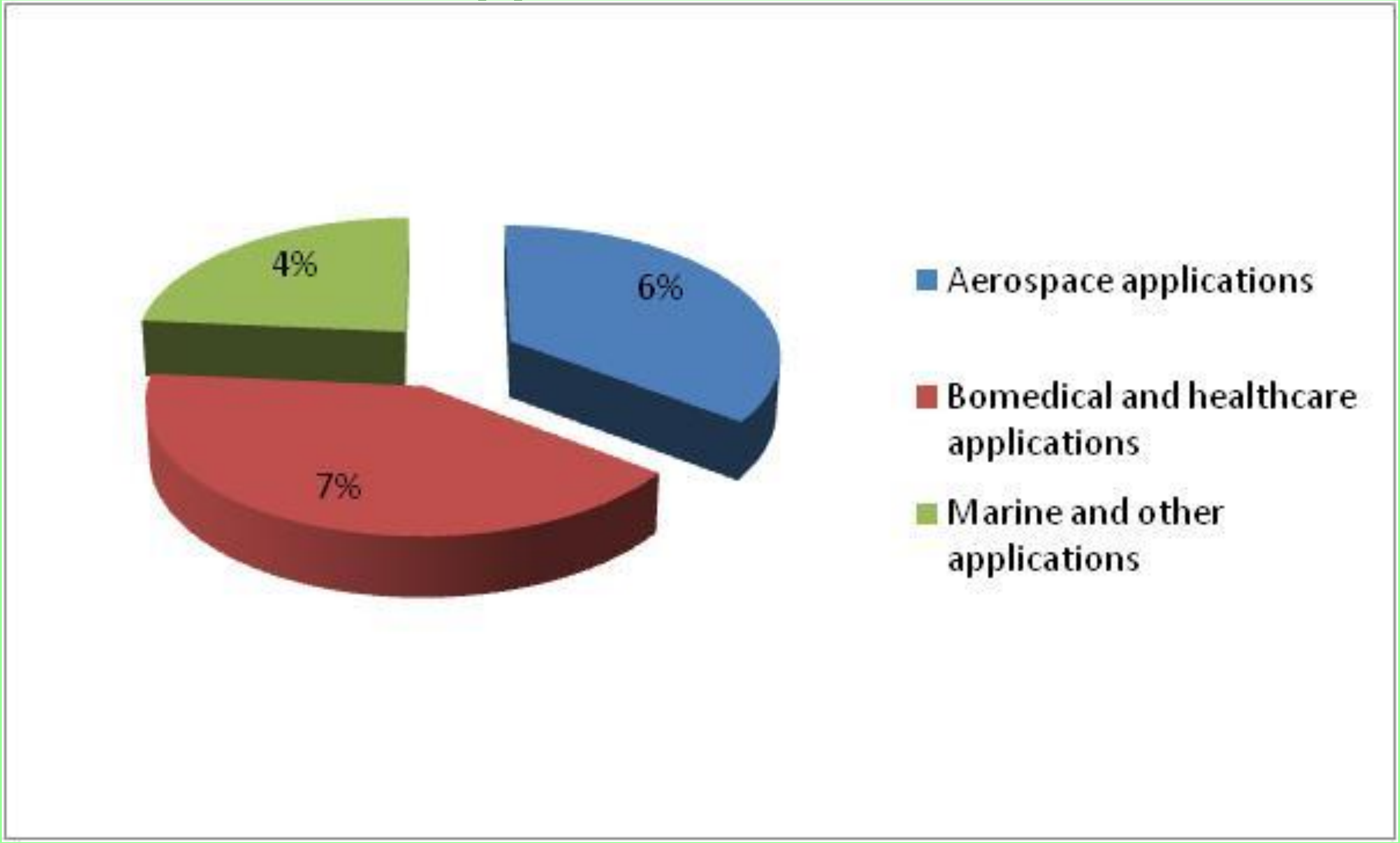
Applications – 17%



PM Titanium

Scientists all over the world are looking for

decreasing of base material cost using powder metallurgy (PM) technologies (low cost powder, additive manufacturing, microwave consolidation, etc.)

and also for decreasing high fabrication cost using new technologies (coatings, laser welding, laser sintering of 3D parts, etc.)

PM Titanium

Partial dentures and crowns : SLS by EOS

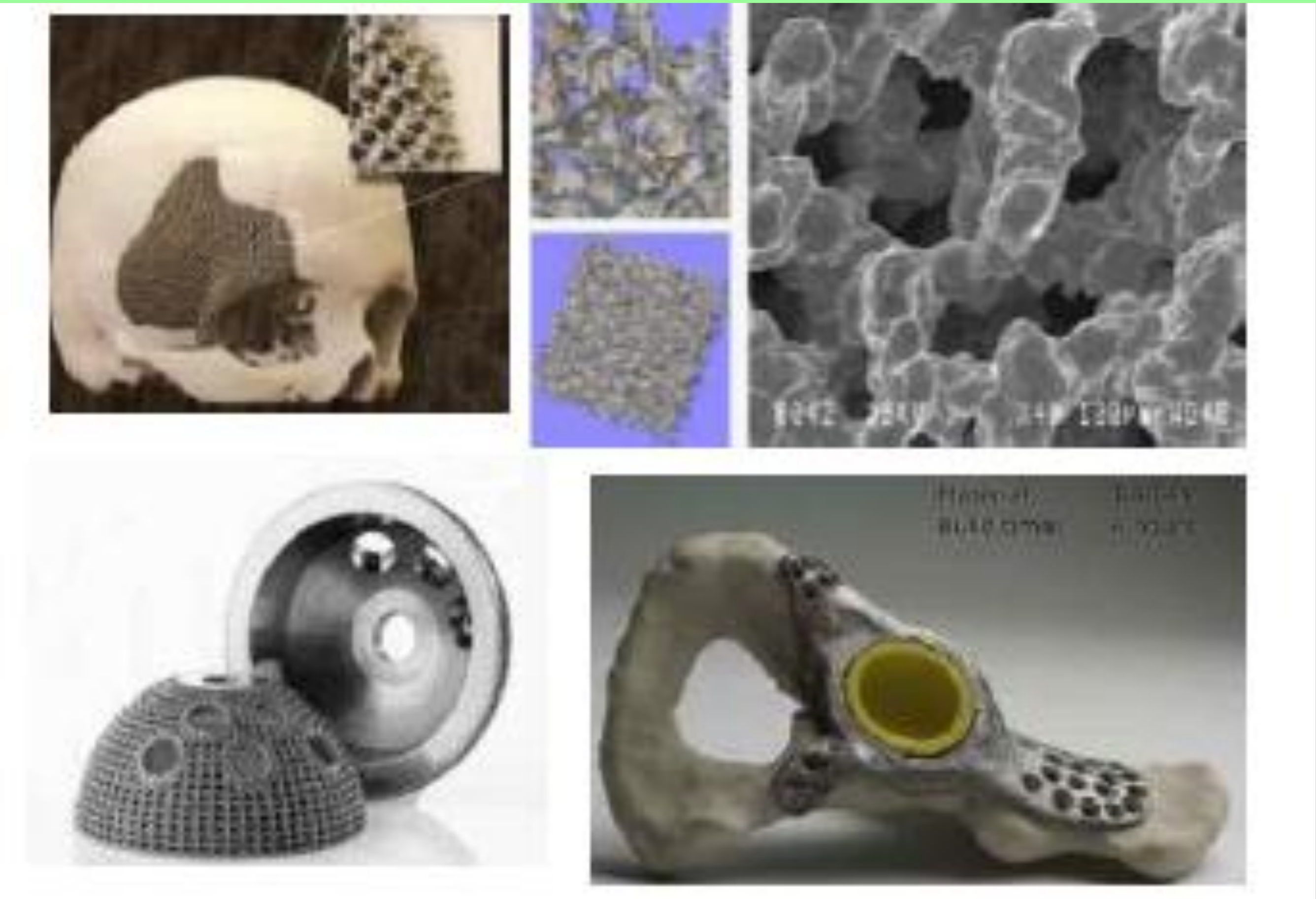
Selective laser sintering_

PM Titanium

Titanium jaw prosthesis: SLS by LayerWise

Selective laser sintering_

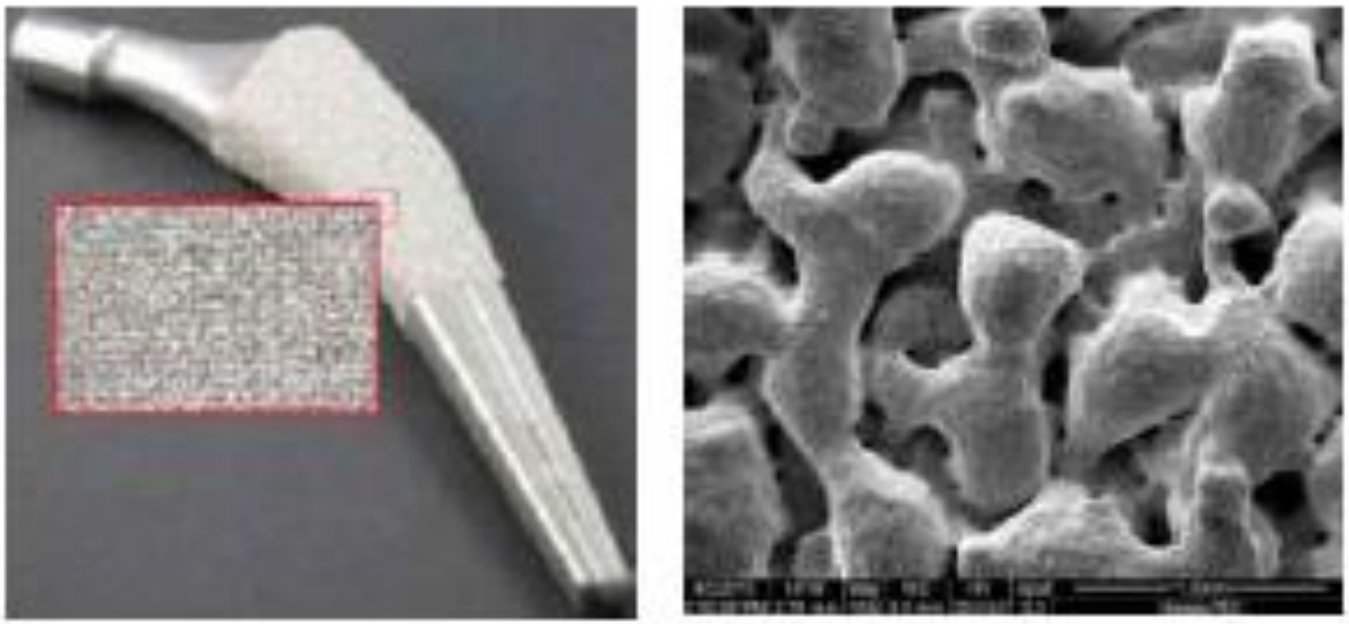
PM Titanium



Acetabular cups and prostheses: EBM by Arcam

Electron beam melting

PM Titanium



Hip joint replacement : DMT by Insstek

DMT 3D metal printing technology

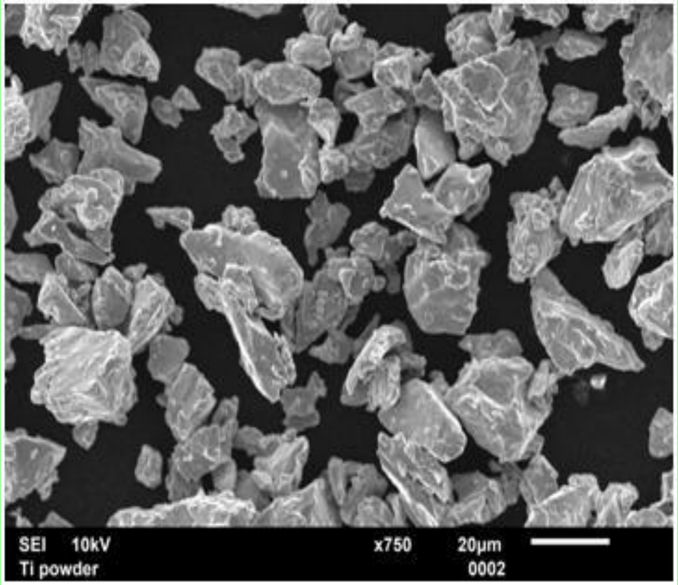
PM Titanium

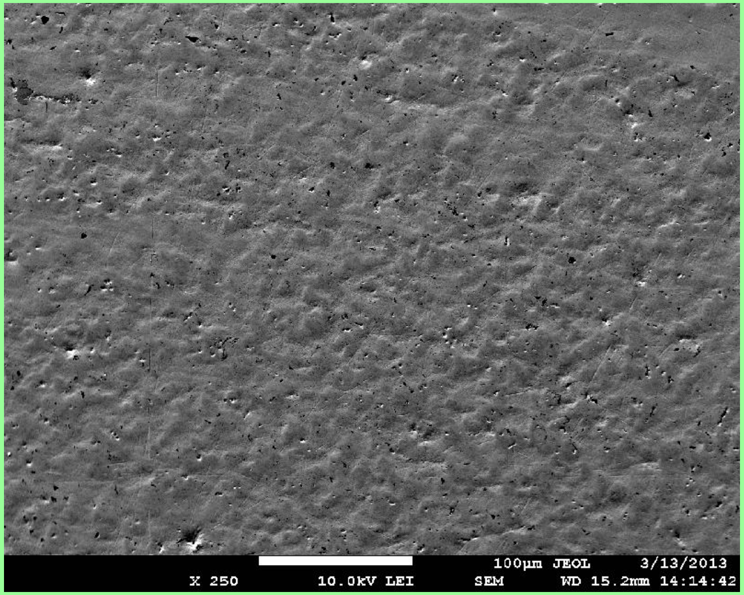
in Slovakia?

PM Titanium

VEGA project 2/0158/13

“Investigation of Ti and Ti alloys compacts prepared by powder metallurgy methods,”





PM Titanium

VEGA project 2/0158/13

metallurgical technology of preparation of Ti samples

forging and direct hot extrusion.

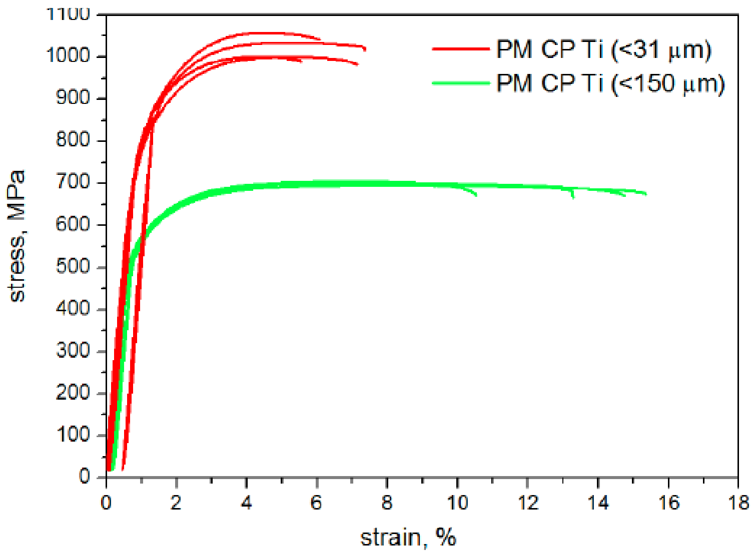
has been optimized with respect to the resulting mechanical properties of the material.

PM Titanium

Mechanical properties

Table 1 The mechanical properties of PM CP Ti (<150 μm) and PM CP Ti (<31 μm). $YS_{0.2}$ – offset yield strength, UTS – ultimate tensile strength and ε – the true elongation (obtained from the tensile tests), and E – Young`s modulus (obtained from DMA).

Powder size (μm)	Oxygen content (wt.%)	$YS_{0.2}$ (MPa)	UTS (MPa)	ε (%)	E (GPa)
< 150	0.21 ± 0.01	512 ± 11	701 ± 4	13 ± 2	99 ± 0.5
< 31	0.54 ± 0.03	768 ± 20	1024 ± 27	6 ± 1	100 ± 0.1



PM Titanium

Veneric tests for dental implants are ongoing

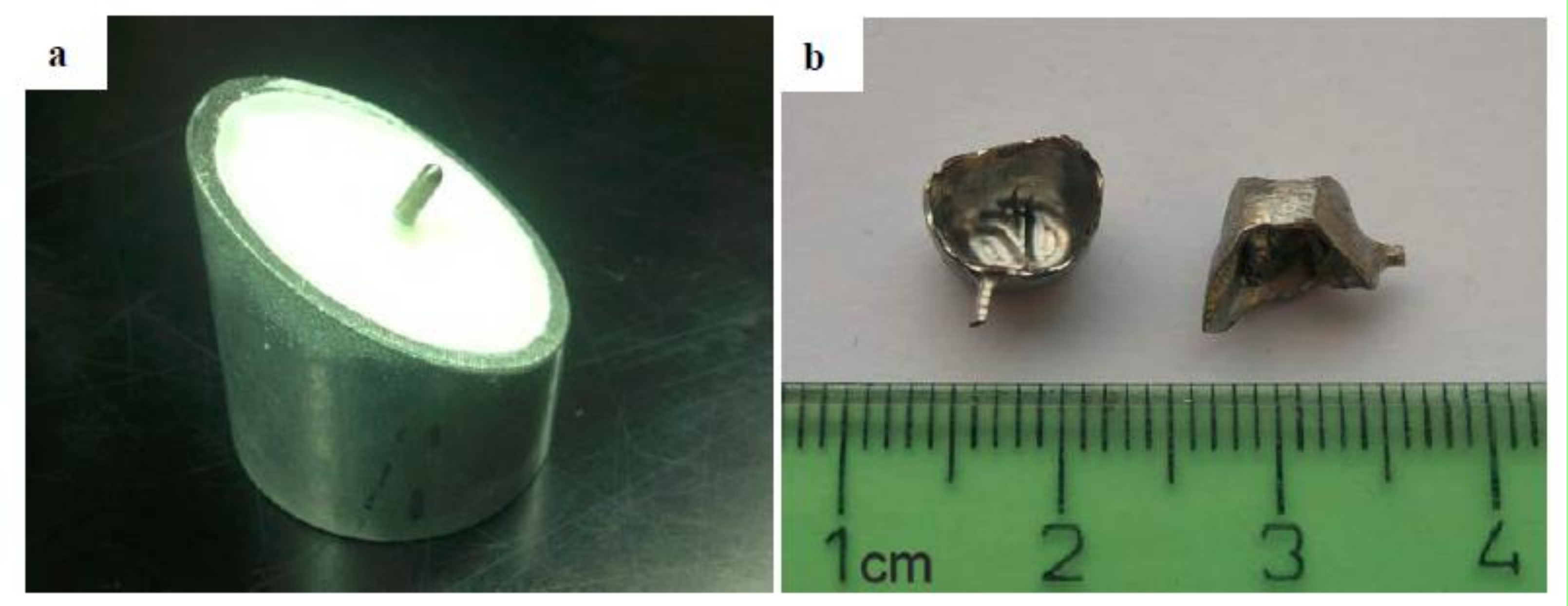
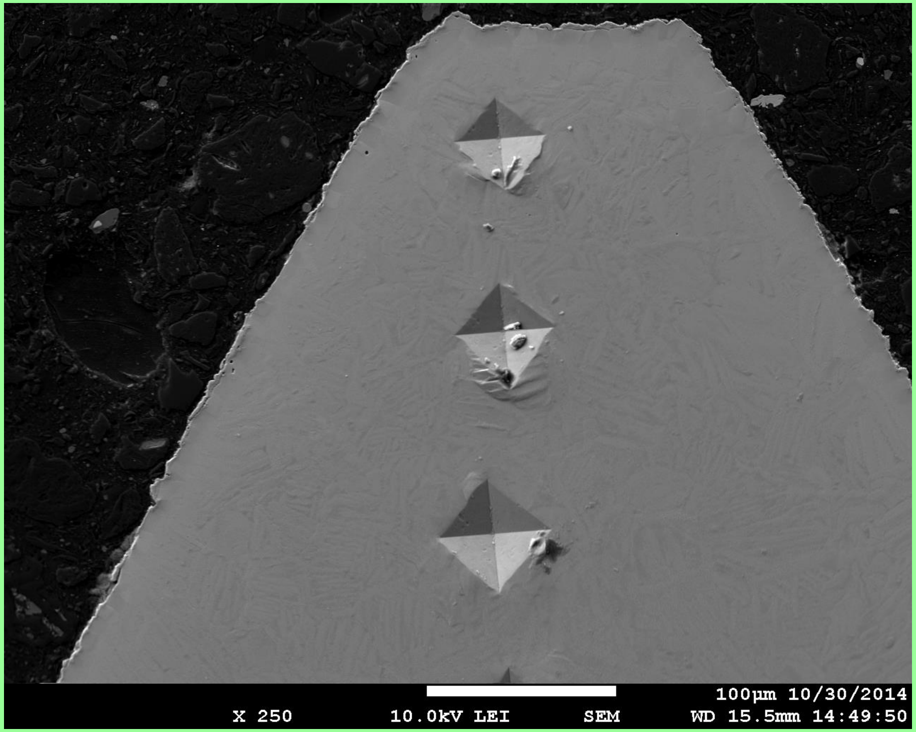


Fig. 5 Fatigue testing set up: implant shaped specimen embedded in a supporting PMMA resin structure (a) and CNC machined dental crowns (b) fabricated from PM CP Ti (<150 µm).

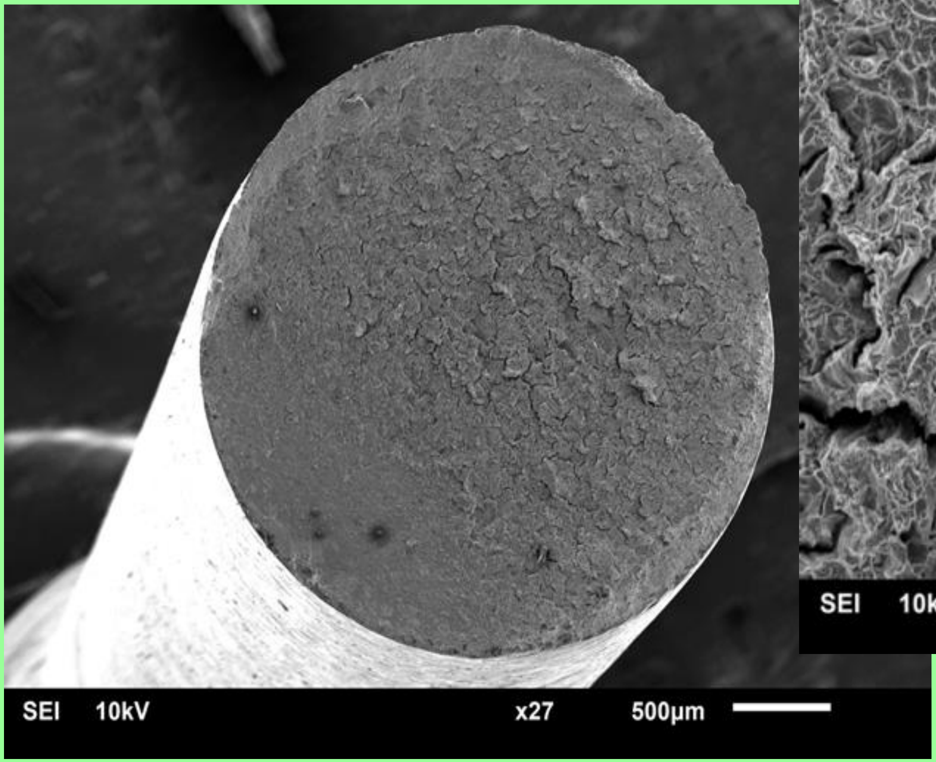
PM Titanium

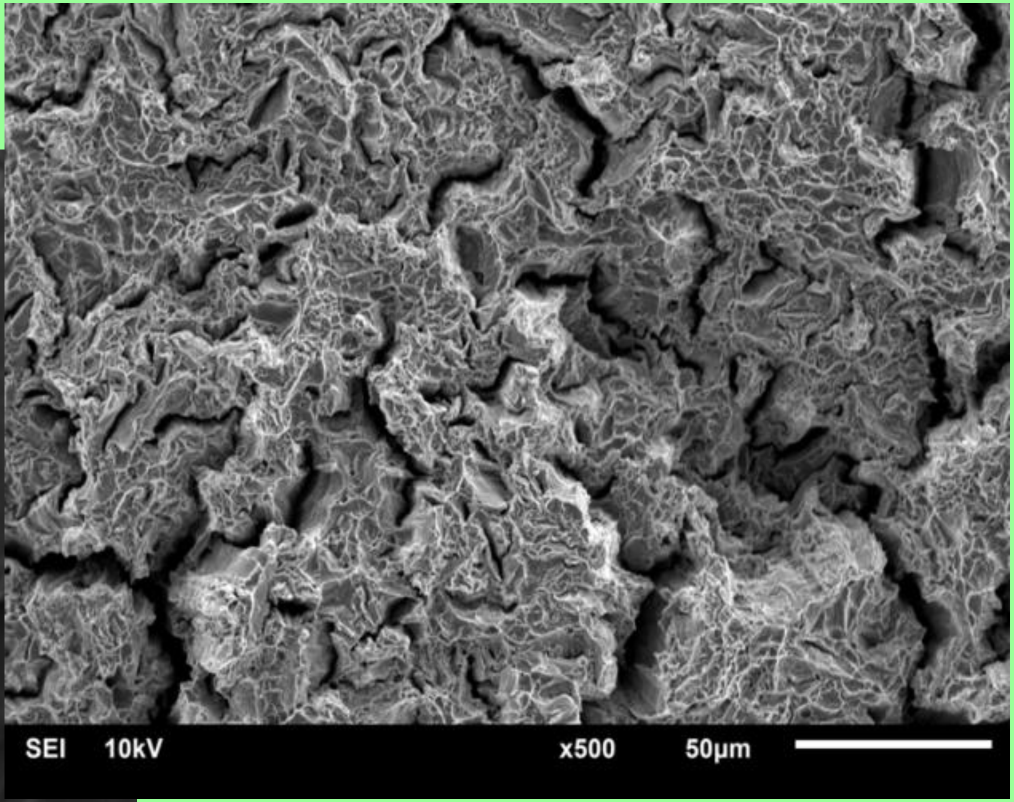
Solar furnace nitrided surface of PM sample with microhardness measurement - significant increase of hardness



PM Titanium

Partial problem to solve – fatigue: Fractured surface of PM sample





PM Titanium

APVV project SK-PL-2015-0003

“Wear resistant and electrically conductive composite coatings on non ferrous metals”

PM Titanium

APVV project SK-PL-2015-0003

TiB2 composite coatings deposited on Ti and Ti alloy substrates by electro spark deposition

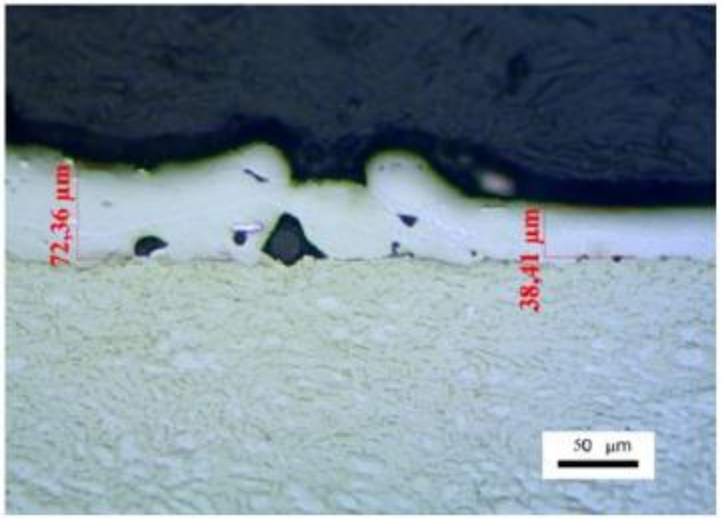


Fig. 5 TiB_2 layer on Ti6Al4V at 40V

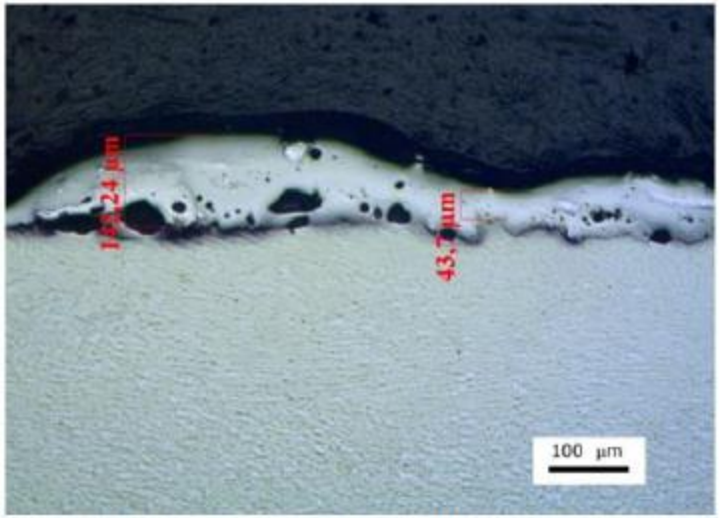


Fig. 6 TiB_2 layer on Ti6Al4V at 60V

PM Titanium

the wear resistance of the substrate-coating material was significantly improved in comparison with substrate material.

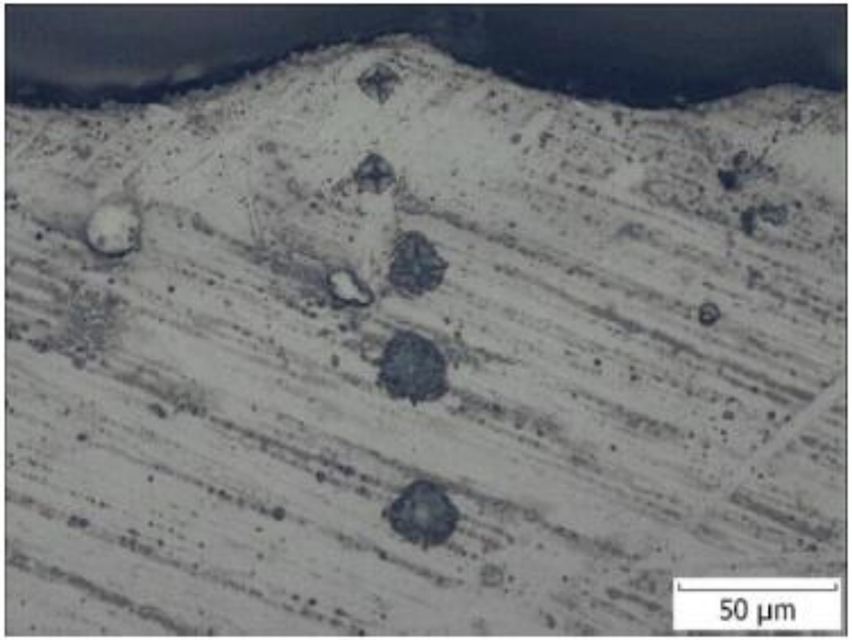


Fig. 9 Microhardness of TiB_2 deposited on Ti6Al4V at 40V and 10 deposition runs. The hardness values from top to bottom are: 1016, 951, 470, 347 and 355 MHV0.1

PM Titanium

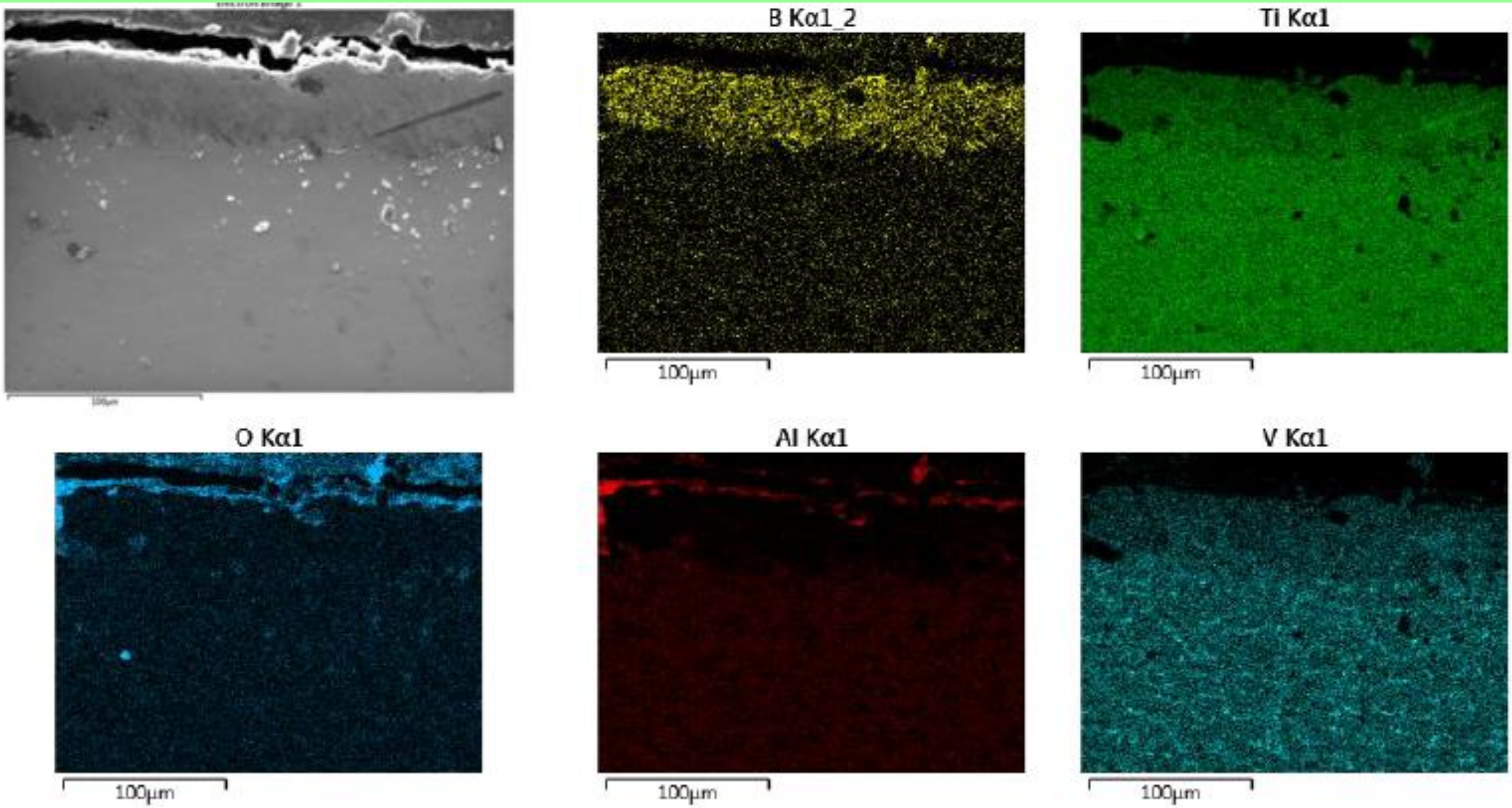


Fig. 8 Element map of TiB_2 deposited on Ti6Al4V at 20V – 10 deposition runs

Conclusions

During last 5 years PM Ti materials were successfully developed in Slovakia with possibility to be used in biomedical and health applications.

Biocompatibility of some materials was already tested in cooperation with University of Zagreb, Croatia.

Furthermore, Ti-Mg and Ti-TiC composites are further developed for dental and biomedical applications using powder metallurgical methods.

Conclusions

The way how to control final porosity of Ti samples during sintering of Ti powders via changing of sintering parameters was studied.

Using these results it will be possible to address better the issue of the elastic modulus mismatch between titanium and bone.

Finally electro spark deposition method was successfully used for deposition of hard wear resistant TiB_2 coating layers on Ti and Ti6Al4V substrate thus increasing their wear resistance and thus improving their suitability for biomedical applications.

Thank you for attention

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