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# **Electrochemical elaboration and investigation of Nitinol** surfaces covered with tantalum, carbon nanotubes and phosphonic acid self-assembled monolayers

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## General context: **Ti-based biomaterials**

Titanium and its alloys constitute very interesting platforms for dental and osseous biomedical applications thanks to their low density, high fatigue strength, corrosion resistance, ... More particularly, the Nitinol (NiTi) alloy (Ni 56%, Ti balance) is well known for its excellent shape memory and superelasticity of certain alloying elements (Ni in NiTi, Al and V in TiAl6V4 ...), long-term degradation and weak osseointegrative properties remain problematic features.

One solving approach stands in the formation of a thin tantalum coating on NiTi surface by an electrodeposition (EDP) process in ionic liquids media: Ta, with its very passivating oxide layer, is highly resistant to corrosion, biocompatible and bioactive, has good radio-opacity ... Additional barrier effect can be brought by the further self-assembly of alkylphosphonic acid monolayers [1,2].

Multiwalled carbon nanotubes (MWCNTs) can also be incorporated to form a composite Ta-based coating on NiTi owing to their ability to improve the mechanical properties of the implant. They can also specifically interact with osteoblasts and osteoclasts and promote the bone regeneration process by mimicking the structure of collagen fibers and favor the formation of an hydroxyapatite layer. Composite Ta-CNTs layers are prepared according a two-step electrochemical process, first through the electrophoretic deposition (EPD) of phosphonate-modified MWCNTs on NiTi, than through the Ta electrodeposition on the NiTi/MWCNTs platforms [3].

## Ta electrodeposition and alkylphosphonic acids self-assembly on NiTi



## **MWCNTs electrophoretic deposition** and Ta electrodeposition on NiTi



 $\Rightarrow$  Specific electrochemical responses on CV and SECM curves.



Potential (mV/SCE)

## **Conclusions and perspectives**

- Electrochemistry is used for both elaboration and characterization of protective and functional surface coatings on Nitinol substrates with a high level of versatility and precision.

- The considered approaches lead to highly homogeneous, nanostructured and adherent tantalum-based layers.

- Such organic-inorganic hybrid films are therefore strongly believed to constitute sensitive platforms for further osseointegrative purposes (nucleation of hydroxyapatite, adhesion-proliferation of osteoblasts and osteoclasts).

#### References

[1] A. Maho, J. Delhalle, Z. Mekhalif, Study of the formation process and the characteristics of tantalum layers electrodeposited on Nitinol plates in the 1-butyl-1-methylpyrrolidinium bis(trifluoromethylsulfonyl)imide ionic liquid, *Electrochim. Acta* 89 (2013) 346-358. [2] A. Maho, F. Kanoufi, C. Combellas, J. Delhalle, Z. Mekhalif, Electrochemical Investigation of Nitinol/Tantalum Hybrid Surfaces Modified by Alkylphosphonic Self-Assembled Monolayers, Electrochim. Acta 116 (2014) 78-88.

[3] A. Maho, S. Detriche, G. Fonder, J. Delhalle, Z. Mekhalif, Electrochemical Co-Deposition of Phosphonate-Modified Carbon Nanotubes and Tantalum on Nitinol, ChemElectroChem (2014) in press.

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