Surface modification of powder metallurgy Titanium by chemical diffusion of Mo for biomedical applications

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Abstract

Titanium and its alloys are the preferred metallic material nowadays for **biomedical prosthesis** for bone substitution. The alloys more extensively used nowadays for these purposes are **Ti6Al4V** and **pure Ti**, depending on the type of prosthesis or implants, although other alloys like **Ti6Al7Nb** are also used. Extensive investigation is followed in the development of **beta alloys** and the use of **porous materials or surfaces** to reduce the elastic modulus. In this study, the **Molybdenum** is introduced because of its **β-stabilizing character** that modifies the **microstructure of titanium from α to α+β**, creating a graded composition and microstructure. **Varying the thermochemical conditions** (temperature, time atmosphere, activator agent) it is possible to change the depth of the layer and its characteristics. The study is carried out on **Ti samples produced by powder metallurgy (PM Ti)** due to the potential of this technique to reduce the cost of the Ti components. Both **sintered and green samples** are used as substrates to compare the layers obtained by different methods and to understand the influencing parameters to achieve reproducible surfaces. As a result an open porosity is formed at the surface in addition to the compositional change that would be beneficial for cell adhesion.

Motivation

Titanium as biomaterial [1]

Advantages

- High corrosion resistance
- Good mechanical properties
- Biocompatibility

Stem *TwinSys* (Ti6Al4V) [2]

Maintaining these:

Stem *SCS/SCL* (Ti6Al7Nb)

Knee system *Balansys Mathys* (TiNbN)

Needs

- Better wear resistance
- Lower Young modulus
- Osseointegration

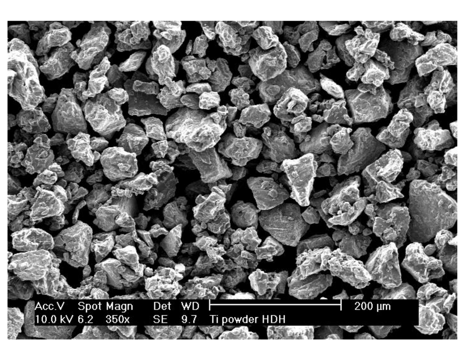
In order to improve these:

Ti + **β-stabiliser (Mo, Nb, V)**

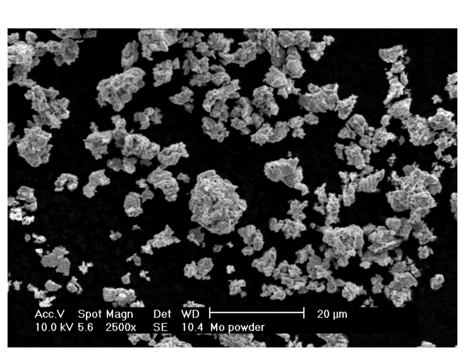
Experimental details

Materials

SEM microestructures of the starting powders



Ti powder (<75 µm)



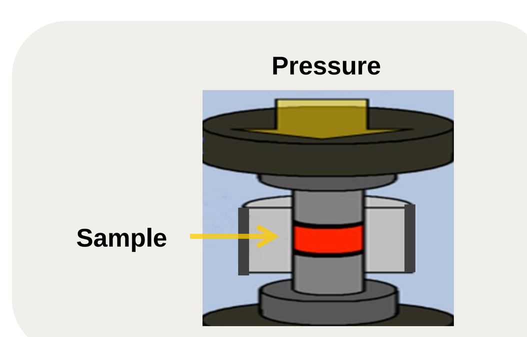
Mo powder
Mean particle size: 1-2 µm

Characterization

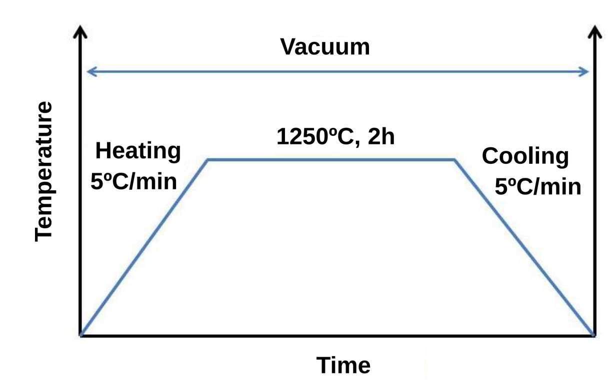
XRD
SEM/EDS

Processing by POWDER METALLURGY [3]

Uniaxial pressing 600 MPa



Sintering 1250 ºC, 2h Vacuum 10^{-5} mbar



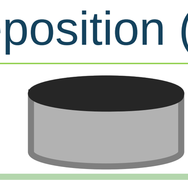
Layer deposition techniques for the surface modification (coatings)

Substrates

- **Green** (ρ=3.7325g/cm³) 82.82%
- **Sintered** (ρ=4.3030g/cm³) 95.47%

- Slurry deposition
- Spraying of a stable aqueous suspension of Mo microparticles
- Electrophoretic deposition (EPD)

More homogeneous and uniform



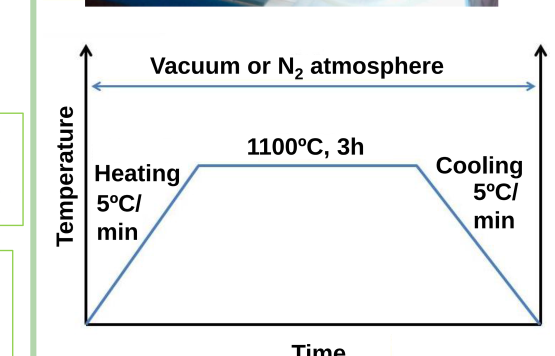
Thermochemical treatments on the surface

Coated Substrates

- **Green** → **Cosintering**
- **Sintered**

Diffusion of Mo element by **vacuum sintering** at **1100 ºC, 3h**

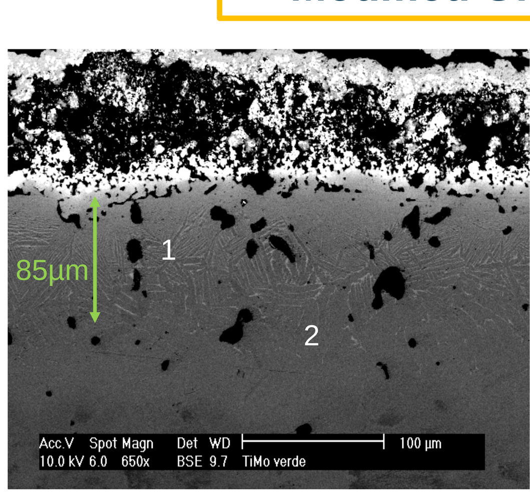
Diffusion of Mo element **activated by NH_4Cl** by **sintering in N_2** atmosphere at **1100 ºC, 3h**



Results

SEM microstructures and EDS of samples modified by Mo

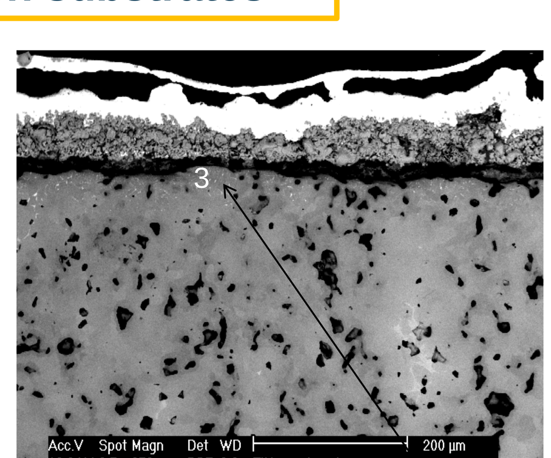
Modified Green substrates



Green Ti substrate Mo (slurry coating)

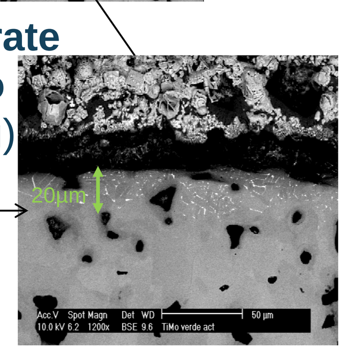
1	Wt (%)
Mo	8.89
Ti	91.11

2	Wt (%)
Mo	1.60
Ti	98.40

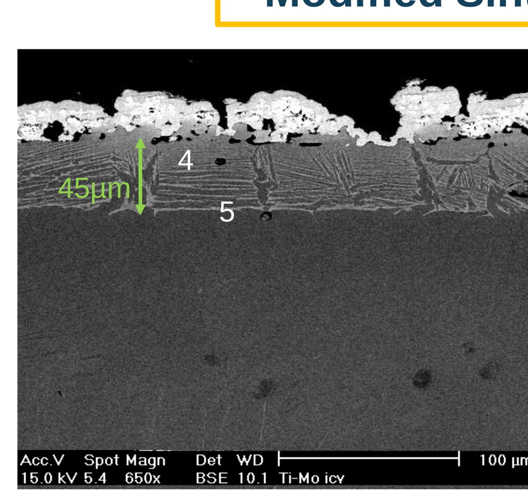


Green Ti substrate activated Mo (slurry coating)

3	Wt (%)
Mo	3.01
Ti	96.99



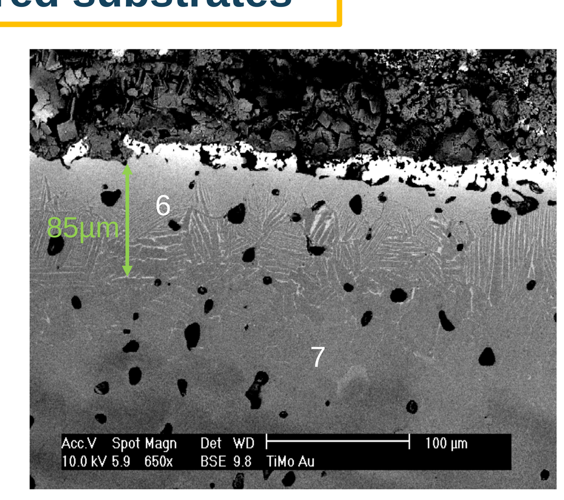
Modified Sintered substrates



Sintered Ti substrate Mo (spray coating)

4	Wt (%)
Mo	7.00
Ti	93.00

5	Wt (%)
Mo	4.10
Ti	95.90

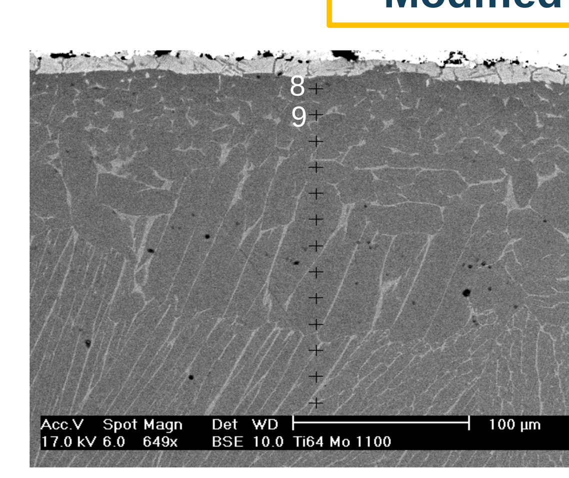


Sintered Ti substrate Mo (slurry coating)

6	Wt (%)
Mo	10.69
Ti	89.31

7	Wt (%)
Mo	2.06
Ti	97.94

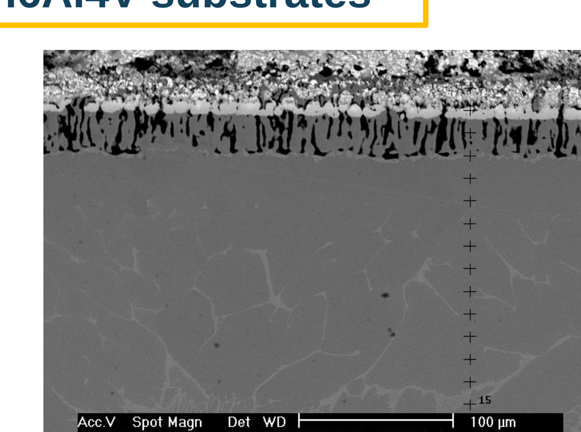
Modified Ti6Al4V substrates

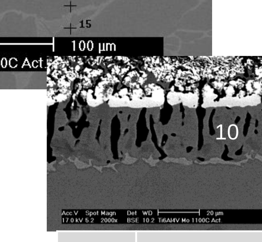


Ti6Al4V substrate Mo (slurry coating)

8	Wt (%)
Mo	11.12

9	Wt (%)
Mo	1.01

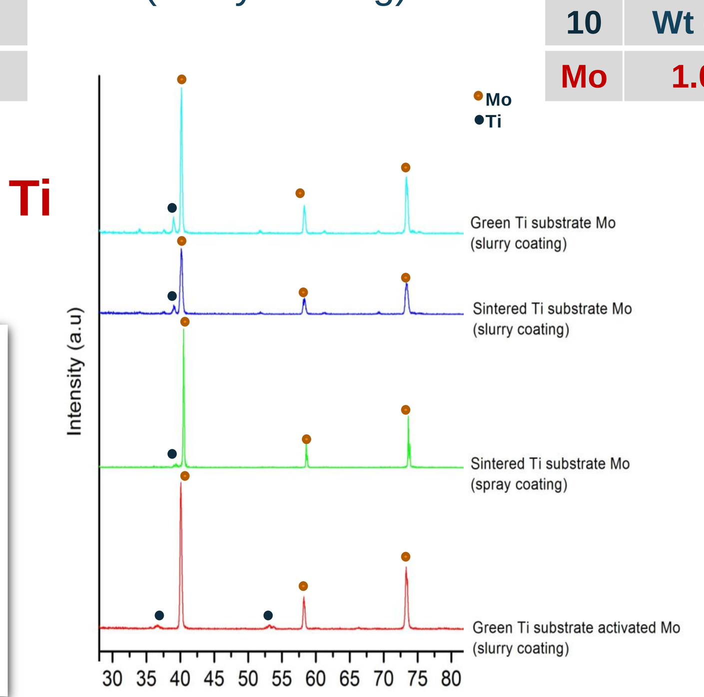




Ti6Al4V substrate Activated Mo (slurry coating)

10	Wt (%)
Mo	1.00

DRX of modified Ti samples by Mo



Summary

Different surfaces (green and sintered) modified by three coating deposition techniques have been characterized, showing a diffusion area of between 40 µm and 85 µm with clear microstructural changes. In the case of Ti substrates, the diffusion of Mo inwards, forms a gradient layer of α+β microstructure, with higher amount of Mo content on the surface. The activator used does not provide improvements on the surface. However, in the case of Ti64alloy, the presence of activator compound provides an interesting porous surface besides a Mo layer.

Work in progress

- Microindentation tests to determine the hardness and the elastic modulus.
- Corrosion, wear and tribocorrosion tests to have a deeper knowledge of the new modified samples.
- Same procedure with niobium element as a diffuser, as well as with Ti6Al4V as a substrate.

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[1] M. Geetha, A.K. Singh, R. Asokamani, A.K. Gogia, Ti based biomaterials, the ultimate choice for orthopaedic implants – A review, Prog. Mater. Sci. 54 (2009) 397– 425.
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ACKNOWLEDGEMENTS:
Authors acknowledge funds provided by Spanish Government (ref. MAT2012-38650-C02-01) and regional government of Madrid (programme MULTIMAT-CHALLENGE, ref. S2013/MIT-2862).