Corrosion behaviour of Ti and Ti reinforced by addition of ceramic particles obtained by combination of Colloidal and Powder metallurgy techniques

Universidad Carlos III de Madrid

GTP GROUP OF POWDER TECHNOLOGY

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CSIC colloidal processing

Motivation

Need to increase the wear resistance of Ti maintaining corrosion behaviour

Addition of fine ceramic particles to Ti: Al_2O_3, ZrO_2, Y_2O_3

Restrict grain growth during sintering
Enhance sintering behaviour
Increase hardness
→ Finer microstructure ✓ Denser material ✓ **Could increase wear**

Difficulty of good particle dispersion
Could affect corrosion behaviour
→ Use of colloidal techniques ✓ **Study of corrosion**

Objective

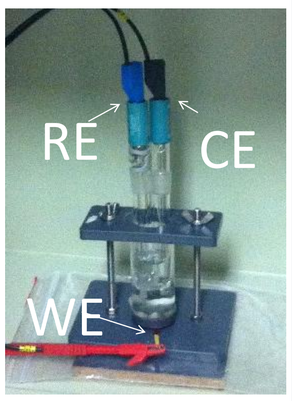
To study the corrosion behavior of titanium composites reinforced with alumina, zircona and ytria and the comparison with Ti without reinforcement to evaluate the influence of the ceramic particles added and the processing technique

Techniques

EIS (Electrochemical Impedance Spectroscopy) in an aggressive saline aqueous solution (3.5 wt.% NaCl).

Electrochemical cell set-up

Reference electrode (RE):
Ag/AgCl/KCl sat. (0,197 mV vs NHE)
Counter electrode (CE): Pt
Working electrode (WE): sample (0,28 cm^2)
Electrolyte: 3,5 %wt. NaCl



Potenciostat AUTOLAB PGSTAT302N (Echo Chemie)
Sweeping frequency: 100 kHz – 10 mHz
Amplitude: ±10 mV

Immersion time: **4, 24, 48, 72 hours; and 7, 15 and 30 days.**

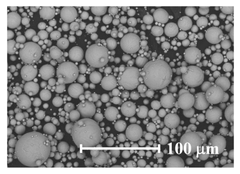
Conclusions

(1) The combination of **PM and colloidal techniques** allowed obtaining a final part with **less porosity and more fine and homogenous microstructure** than that obtained with conventional PM.
(2) EIS results showed that **Ti10** and all the **composites behaved better** in the aggressive saline solution than Ti45. **The porosity seems to have higher influence than the presence of ceramic particles.**
(3) The **equivalent circuit** proposed for the EIS test showed that the **oxide layer formed is not enough to protect** the all surface of the samples.
(4) SEM micrographs confirmed the **absence of pits** and the formation of a thin and discontinuous oxide layer in Ti45, Ti with Al_2O_3 particles and Ti with ZrO_2.

Processing

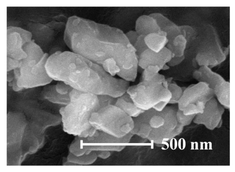
Colloidal techniques + powder metallurgy

POWDERS

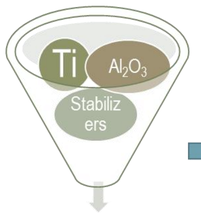


Ti elemental (Ti 45)
Dv50= 29 µm,;
Dmax= 45 µm,
O_2= 0,336 % wt

(Ti 10)
Dv50= 10 µm
O_2= 0,216 % wt



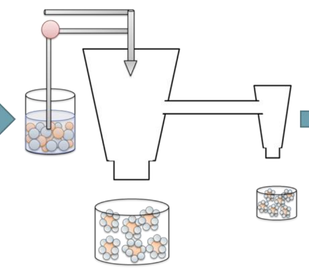
Al_2O_3
Dv50= 0.4 µm

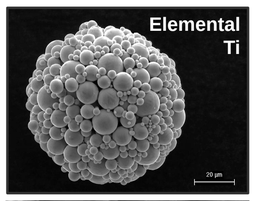


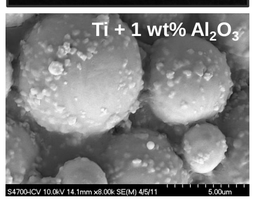
Stable and homogeneous aqueous suspension

Ti 50%vol+1wt% Al_2O_3
1% wt stabilizer (PAA)
2% binder (PVA)

SPRAY-DRY

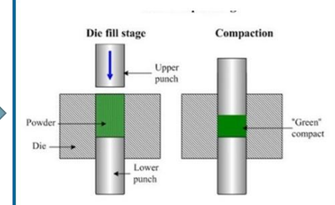






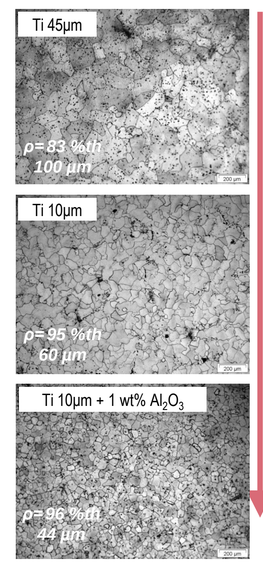
Materials prepared
Elemental Ti:
T145, Ti10
Ti10 + 1wt% Al_2O_3
Ti10 + 1wt% ZrO_2
Ti10 + 1wt% Y_2O_3

UNIAXIAL PRESSING



SINTERING
✓ **1100 ºC**
✓ **30 min**
✓ **Vacuum (10^{-5} mbar)**

Reduced sintering temperature and time



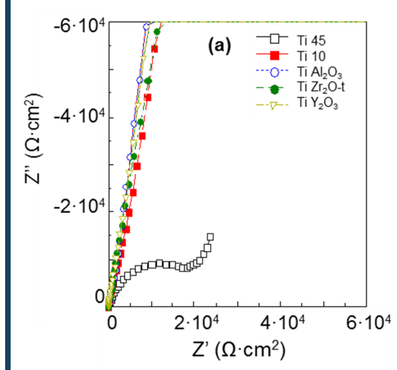
Decreasing grain size and increasing hardness

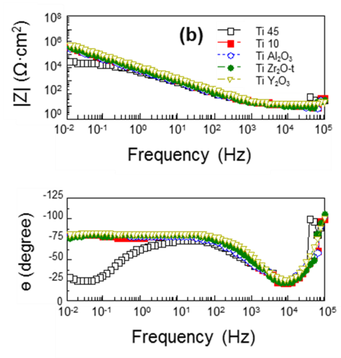
Dense granules
High packing of particles
Size distribution: 30 – 300 µm
Homogeneous dispersion of ceramic particles
High compressibility

Results

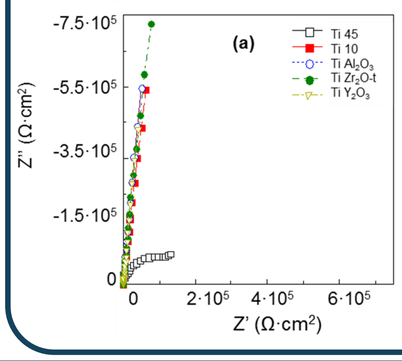
Electrochemical Impedance Spectroscopy (EIS)

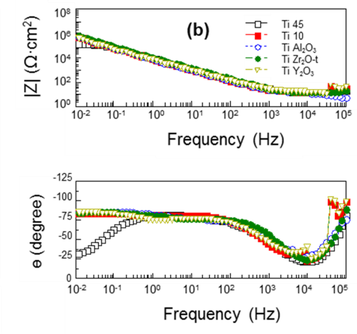
4 hours



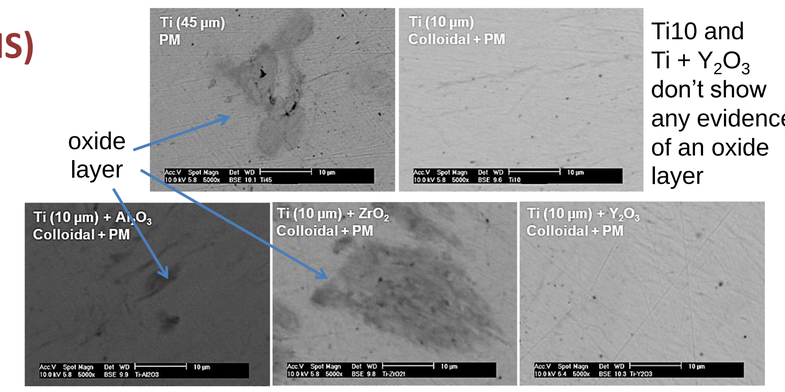


30 days





SEM (after 30 days EIS tests)

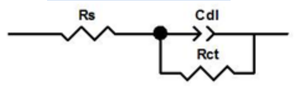


Ti10 and Ti + Y_2O_3 don't show any evidence of an oxide layer

No evidence of pitting corrosion

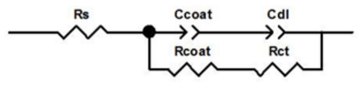
Equivalent circuit

1 time constant



Ti10 and composites

2 time constants



Ti45

R_s : resistance of the electrolyte
C_{dl} : cte phase element of double layer
R_{ct} : charge transfer resistance
C_{coat} : cte phase element oxide layer
R_{coat} : resistance oxide layer

The addition of ceramic particles do not decrease the corrosion behaviour of elemental Ti processed by colloidal techniques and PM, and it is one order of magnitude higher than elemental Ti processed by conventional PM

ACKNOWLEDGEMENTS:
Authors acknowledge funds provided by Spanish Government (programme MINECO, ref. MAT2012-38650-C02-01) and regional government of Madrid (programme MULTIMAT-CHALLENGE, ref. S2013/MIT-2862).

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