The role of the thickness and the substrate on the bioactivity of silica-based glass coatings

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INTRODUCTION

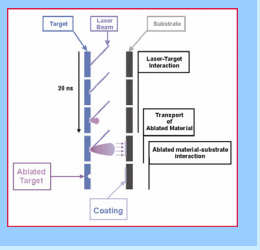
Aim

- Evaluation of the **critical thickness** of the bioactive glass coatings grown by Pulsed Laser Deposition (PLD) in order to guarantee the development of the complete bioactivity process.
- Study of the **temporal evolution** of the bioactivity process for bioactive glass coatings grown by PLD on biomorphic SiC ceramics.

Pulsed Laser Deposition Method

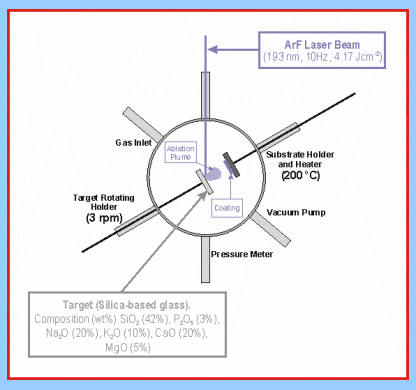
- **Pulsed Laser Deposition (PLD) is a promising technique to coat medical devices with bioactive materials.**
- **Advantages** over other techniques:
  - ❖Materials with high melting point can be deposited.
  - ❖No contamination is present.
  - ❖Coatings can be prepared in a reactive environment.
  - ❖Ability to transfer the stoichiometry of very complex materials to the coating.

Laser Ablation



EXPERIMENTAL

PLD System



Deposition of PLD bioactive coatings

SUBSTRATE	Coating Thickness (μm)	Observations
Silicon	8, 20, 30	Pure Silicon Wafers
Titanium	8, 20, 30	Medical grade Ti
Silicon Carbide	30	Eucalyptus based SiC

In vitro bioactivity tests

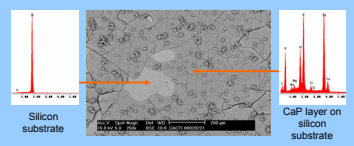
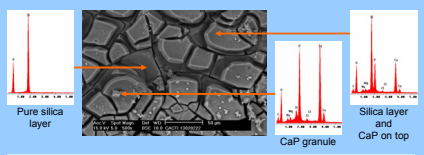
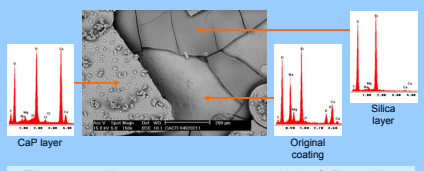
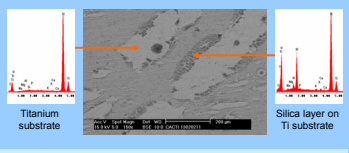
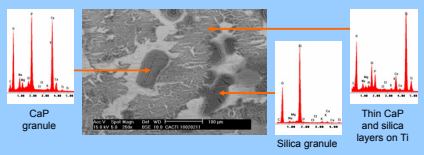
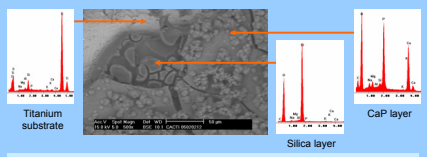
SUBSTRATE	Incubator Temperature (ºC)	SBF Volume (mL)	Immersion Time (hours)
Silicon	36.5	50	72
Titanium	36.5	50	72
Silicon Carbide	36.5	0.5	3, 18, 36, 72

Characterization Techniques

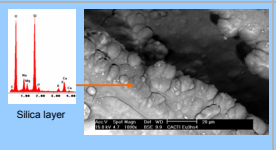
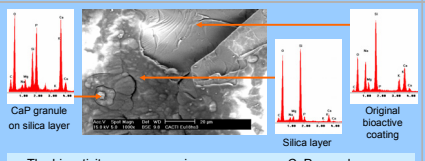
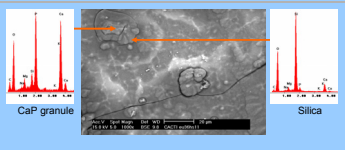
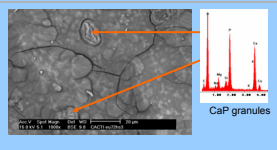
- Profilometry.
- Scanning Electron Microscopy (SEM).
- Energy-Dispersive X-ray Spectrometry (EDS).

RESULTS

Evaluation Of The Coating Critical Thickness (PLD coatings on Si and Ti substrates)

SUBSTRATE	COATING THICKNESS 8 μm	20 μm	30 μm
Silicon	 The original coating evolved to the formation of a calcium phosphate layer. No traces of silica layer were found.	 The coating was completely dissolved, the formation of CaP granules (top) on the silica layer were observed.	 The complete bioactivity process was observed: the CaP and silica layers were formed over the original coating.
Titanium	 The original coating evolved to the formation of a thin silica layer. The coating was completely dissolved in some areas.	 In some areas was observed the formation of CaP and silica granules.	 The complete bioactivity process was observed in small areas: the CaP and silica layers were formed on the titanium substrate.

Temporal Evolution Of The Bioactivity Process (PLD coatings on SiC ceramics)

SUBSTRATE	IMMERSION TIME 3 Hours	18 Hours	36 Hours	72 Hours
Silicon Carbide	 The dissolution process has already started: a thin silica layer was formed on top.	 The bioactivity process was in progress: some CaP granules were formed on the silica layer.	 The density of the CaP granules increased. The CaP layer was not completely formed.	 Even for 72 hours the bioactivity process was not complete.

- The SBF *in vitro* test was performed following the conventional criterion of Surface Area to Volume Ratio (SA/V) of 0.5 cm^{-1}.
- The biomorphic SiC is a porous material with a very high effective surface area.
- The complete bioactivity process was not observed because in these conditions the SBF volume is insufficient to promote the ion exchange, dissolution of the silica network and the CaP layer formation.

CONCLUSIONS

- Over 20 μm thick coatings are needed to observe the formation of well defined silica and calcium phosphate layers, reproducing the complete bioactivity process.
- Certain influence of the substrate on the bioactivity process was observed. The critical thickness is lower for coatings deposited on Si than on Ti substrates
- The bioactivity process was no completed because the ionic conditions in the in vitro tests were not fulfilled.
- For porous materials the conditions of the SBF in vitro tests should be carefully chosen and they are not comparable with other materials.