SOLAR SINTERING OF TITANIUM FOAMS WITH A FRESNEL LENS

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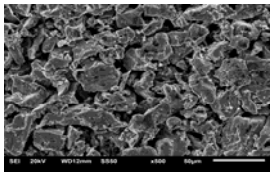
ABSTRACT

The main objective of this work has been to assess the feasibility of using a low cost solar installation, consisting in a Fresnel lens, for the sintering of commercially pure titanium (cp-Ti) foams. Fresnel lenses are an effective tool to use in surface engineering because of the advantages such as low-cost, light-weight and high optical efficiency. Titanium foams are suitable in biomedical engineering, for example to process scaffolds for bone tissue engineering, due to their mechanical properties, low density, high chemical resistance and excellent biocompatibility. In this work cp-Ti foams have been processed using a powder metallurgy technique based on the space holder method. NaCl crystals were used as space holders in order to prepare the foams. Different weights of NaCl were added to Ti powder to get a final porosity in the range of 60-80%. Heating rate during sintering process was adjusted with a shutter which controlled the incident solar radiation that gets to the lens. Sintering with different heating times were evaluated but in any case tests were completed in less than 30 minutes. Solar heating activated the sintering process, so that solar sintering of Ti foams in the Fresnel lens required a much shorter time than using a classical heating system.
Solar sintered foam samples were characterized by SEM microscopy, density measurements were obtained using Archimedes' method and image analysis and Young's modulus and mechanical strength were determined from a compression test. Results fulfil the requirements for scaffold applications in tissue engineering.

Foam Preparation by Space Holder Method

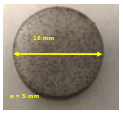
Mixing → Pressing → Debinding → Removal of space holder → Solar sintering

Powder c.p.Ti | **Space holder** NaCl | **Binder** PVA



Size c.p.Ti: < 53 µm

Size NaCl: 200-600 µm



Green sample after uniaxial pressing (300MPa)

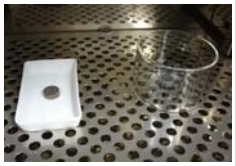
Open cell Ti foam with different porosities were prepared using NaCl as space holder (60-70-80 % vol NaCl).

DEBINDING
2 h at 100ºC + 2 h at 400ºC

REMOVAL OF SPACE HOLDER

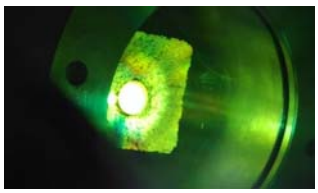
Distilled water: 18 h at 80ºC

Heating at 100ºC for 2 h



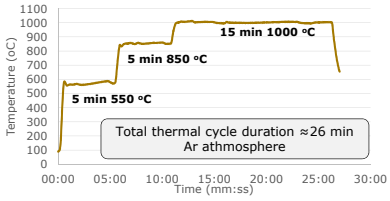
+ Distilled water 2 h at RT

Solar Sintering

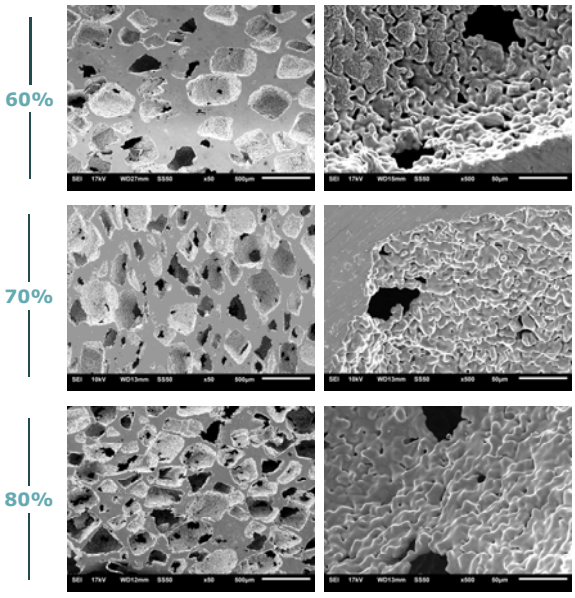


60% 70% 80%

Fresnel lenses located at the University of Castilla-La Mancha (ETSII-UCLM, Ciudad Real) and CENIM-CSIC are 900 mm in diameter and concentrates 2644 times the direct solar radiation.



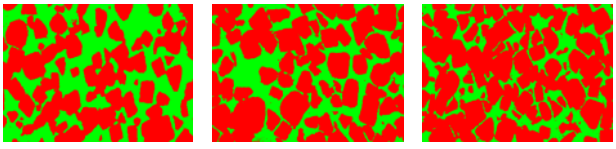
SEM Characterization



SEM micrographs showing sintering of Ti foam with macropores (from the space holder) and micropores (from the powder metallurgy method)

Complete sintering and uniform distribution of open and interconnected porosity is achieved

Porosity Analysis

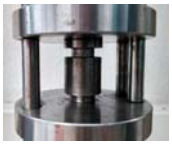


60% 70% 80%

Designed Porosity	Archimedes' Porosity		Image Analysis Porosity
	Total	Interconnected	
60%	54,5%	52,7%	58,0%
70%	65,4%	64,7%	65,3%
80%	76,4%	74,7%	72,1%

Total and interconnected porosity is slightly lower than space holder content due to shrinkage during the sintering process.

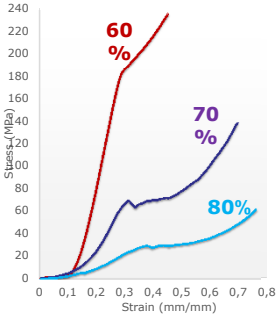
Mechanical Properties



Compression resistance is measured through testing 3 foams of each type. A high sensitivity general testing machine equipped with a motion inverter mechanism is used.

σ_{pl} (MPa)	60%	70%	80%	Cortical bone	Spongy bone
Mean	190,9	68,8	30,0	110-210	<10
Std Deviation	8,8	1,1	2,4		

Results successfully fulfil the requirements for scaffold applications in tissue engineering.
A relationship between compressive properties and porosity is observed. Porous Ti with 54%-77% porosity has potential for bone implant applications.



References

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