Electrophoretic deposition of Sr-containing mesoporous bioactive glass particles produced by spray-drying

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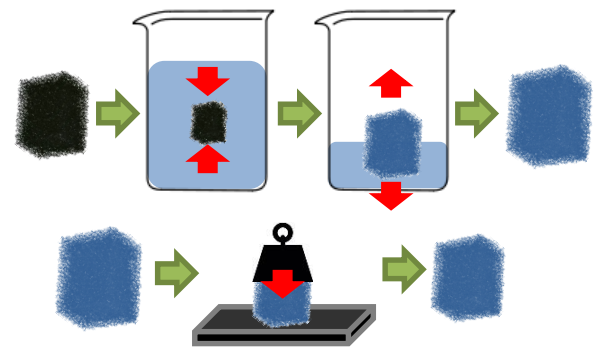
Introduction

Mesoporous bioactive glasses (MBGs) have exceptional biological and textural characteristics (high surface area, high pore volume and highly ordered mesoporosity), which allow these glasses to be successfully applied in bone tissue regeneration [1]. In this work we adopted an **aerosol-based spray-drying synthesis to** obtain MBG particles doped with **strontium (SD_Sr-MBG)**, element known for its osteogenic and bone antiresorptive properties [2]. Later these particles have been deposed by **electrophoretic deposition (EPD)** on almost **biologically inert glass-ceramic scaffolds** (SCNA; $57SiO_2$–$34CaO$–$6Na_2O$–$3Al_2O_3$ %mol.) fabricated by the polymer sponge replication method [3], in order to transfer their bioactive behavior to scaffolds and consequently to obtain an excellent solution for bone tissue regeneration.

Spray-drying synthesis of SD_Sr-MBG

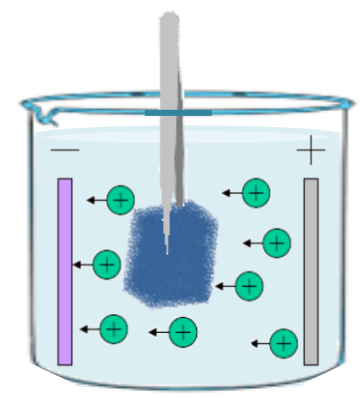
- **Pluronic P123**, used as template, is dissolved in **bidistilled water**
- Tetraethyl orthosilicate **(TEOS)** is hydrolysed under **acidic conditions** (pH adjusted to 2)
- Mixing of the two solutions
- Addition of **strontium** chloride and of calcium nitrate tetra-hydrate **(CaNT)**
- Spraying of the final synthesis solution (**pH ~ 3.5**)
- The powder is calcined in air at **600 °C** for **5 h**

SCNA scaffold preparation



- PU cubic sponges (10 x 10 x 10 mm) are immersed in a **SCNA slurry** ($57SiO_2$– $34CaO$–$6Na_2O$–$3Al_2O_3$ mol.%)
  SCNA:PVA:distilled water = 30:6:64 wt%
- The PU template is extracted from the solution and **compressed** (50 kPa for 1 s) up to **60%** in thickness along three orthogonal spatial directions 3 times.
- Scaffolds are dried at RT overnight and after treated at **1000°C** for **3 h**

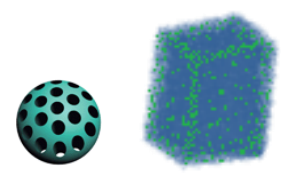
EPD process



EPD parameter	Value
Solvent	Ethanol
Dispersant concentration (TEA)	2,5 g/l
SD_Sr-MBG concentration	4 g/l
Voltage	120 V, 150 V, 180 V
Duration	5 min
Electrodes separation	15 mm
Electrodes material	Stainless steel
Electrodes dimensions (HxLxT)	40 mm x 15 mm x 0,35 mm

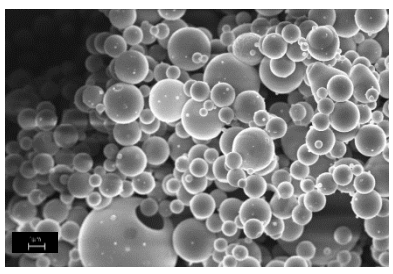
MBG particles and scaffolds characterization

- Morphological and chemical analysis (FESEM, EDS, nanoCT)
- Textural analysis (adsorption and desorption of N_2, laser diffraction and UV-VIS absorbance spectroscopy)
- Strontium release test in SBF
- Bioactivity test in SBF

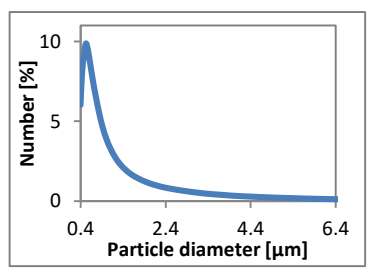


Results and discussion

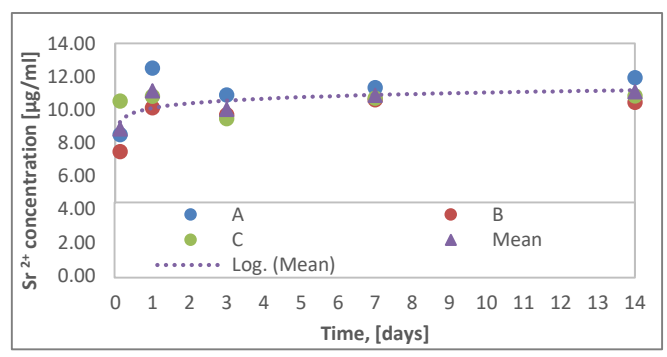
SD_Sr-MBG particles



FESEM image: particles have a perfect **spherical shape.**



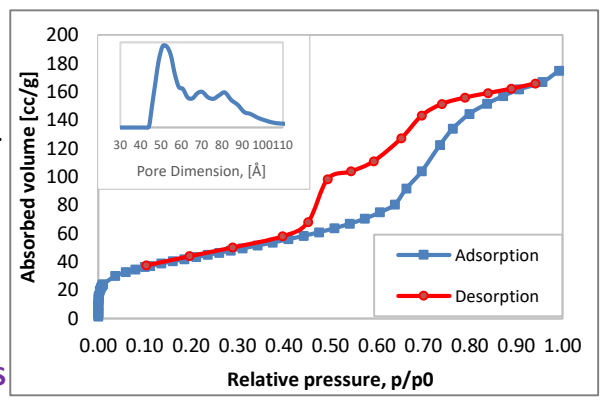
Most of particles have diameter **below 2 µm.** Few reach 5 µm.

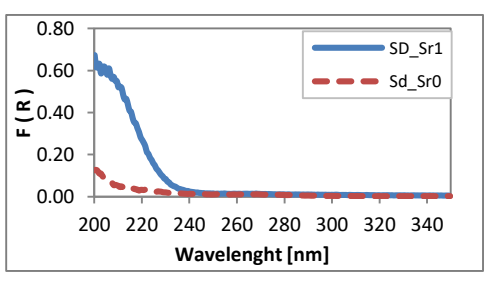


Strontium release: presence of an initial **burst release**. Final concentration of **11 µg/ml** ➡ osteogenesis [4]

- **IV type isotherm**
- Surface area of **153 m^2/g**.
- **Pore size** distribution **between 4** and **10 nm**.

➡ The sample is **MESOPOROUS**



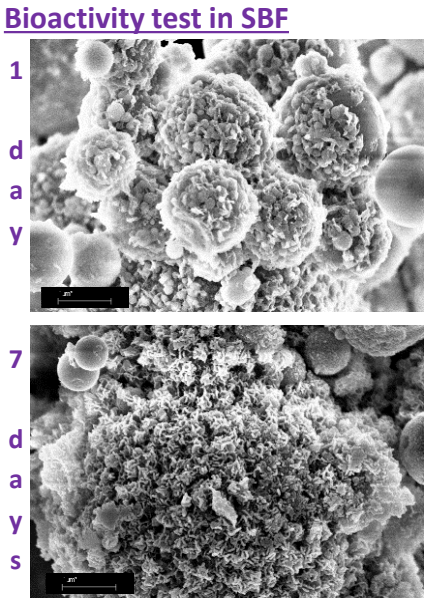


- **No peak** in the VISIBLE region

➡ SD_SrMBG is **white**

- **Peak** at **200 nm** due to strontium

Bioactivity test in SBF

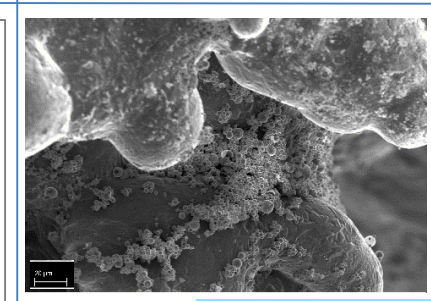


Fast bioactive behavior:

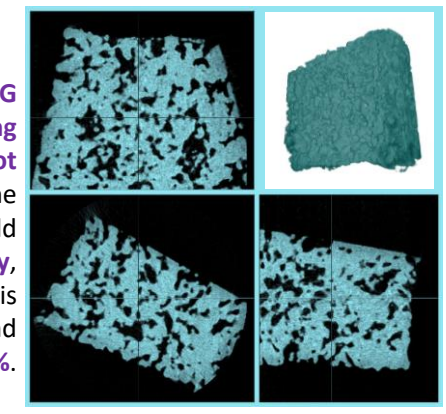
- **After 1 day:** numerous **hydroxyapatite aggregates**.
- **After 7 days:** particles **completely covered** by a HA layer.
- **pH** always under value **7.8**

➡ value optimal for osteoblasts [5]

SCNA scaffold + SD_Sr-MBG

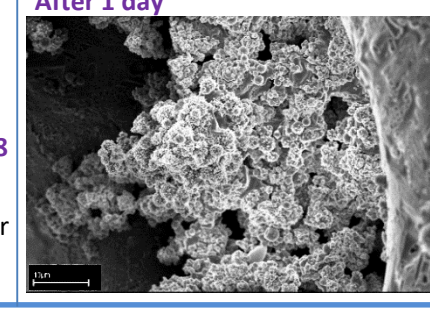


Abundant deposition on the pore wall, but not homogeneous. Best result at **150 V**.



MBG coating does not occlude the scaffold **porosity**, which is around **30%**.

Bioactivity test in SBF
After 1 day



Numerous **HA aggregates**.

➡ Scaffolds acquire a **fast bioactive behaviour**

Conclusions

MBGs synthetized with aerosol-based spray-drying process and doped with strontium have **excellent textural properties and a bioactive behaviour**. After electrophoretic deposition, they maintain these properties and consequently they **improve the bioactivity of SCNA scaffolds**, which initially are almost biologically inert.
In this way we demonstrate that it is possible to obtain a **successful construct** for bone tissue engineering with both **excellent regenerative and mechanical properties**.

Acknowledgement

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www.mozartproject.eu

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