CONTROL OF ORDERED/DISORDERED POROUS STRUCTURES IN SiO_2 MONOLITHS AND SiO_2/TiO_2 COMPOSITES FOR APPLICATIONS IN BONE TISSUE ENGINEERING

A. Hertz, E. Pignotti, I.J. Bruce
Department of Biosciences, University of Kent, Canterbury CT2 7NJ, UK
a.hertz@kent.ac.uk

Introduction. Implant preparation for guided bone regeneration has recently shown an increase of interest mainly due to major progresses in the field of biomaterials and tissue growth. In this context, a wide range of bone substitute materials have been studied [1] viz. organic polymers [2], hydroxyapatite-based ceramics [3] and bioactive glasses [4]. Materials which mimic bone structure, bone composition or present specific surface chemistry seem suitable for bone replacement/repair applications. Especially, materials with macroporous structures have been observed to promote cell infiltration, bone growth as well as vascularization [6]. Surface roughness and micro/mesoporosity have also been demonstrated to promote apatite nucleation and cell attachment on implant surface [6-9]. Consequently, novel porous inorganic materials have been developed [1, 12-14].
Our work focuses on the production of biocompatible material which can be easily tailored in terms of its porosity and composition to achieve suitable structures and bioactivity.

Method. SiO_2 and SiO_2/TiO_2 monolithic materials have been prepared by compaction and sintering of various porous silica powders and titania nanopowders/nanowires and have been proved to be non toxic in vitro. Powders used in this study have been selected mainly for their surface properties eg. both SiO_2 and TiO_2 present hydroxyapatite nucleation abilities and for their porous structures eg. mesoporous and/or macroporous structures.
SBA-15 mesoporous and polystyrene-templated (PST) macroporous silica powders have been synthesized by TEOS (tetraethylorthosilicate) hydrolysis/polymerization and self-organized surfactants and/or polystyrene bead have been used as templates. Silica powders as well as titanium dioxide nanopowder were mixed together in various ratios and compacted at between 10 and 150 MPa. The obtained pellets were sintered at 500 or 700°C.

Results. This study highlights the influence of powder processing on monolith structure characteristics. The effect of the shaping process on the monolith properties were measured using density calculation, N_2 adsorption/desorption, XRD and SEM.
Specific surface area and pore volume have been observed to decrease when compaction pressure or sintering temperature increase for all monolith compositions. In particular, SBA-15 mesopore size decreased with an increase of compaction pressure (Fig. 1a) which was correlated with an increase of pore wall thickness (Fig. 1b). In addition, an increase of sintering temperature tends to reduce SBA-15 pore volume whilst pore size slightly decreases (Fig. 2a) and wall thickness remains unchanged (Fig. 2b). These behaviours have been linked with pore disappearance and material shrinkage. This study has finally demonstrated that SiO_2/TiO_2 composite densities are mainly dependant of compaction pressure and TiO_2 percentage. Actually, compaction pressure and TiO_2 percentage increases tend to increase monolith density.

Conclusions and Prospects. In conclusion, biocompatible SiO_2 and SiO_2/TiO_2 monolithic bone implant with tailored meso- and/or macro-porosity can be easily prepared by adjusting simple parameters such as composition, compaction pressure and sintering temperature. Especially, pore characteristics and monolith densities can be modified and controlled.
These materials are non toxic in vitro and could be suitable for in vivo bone regeneration. In vitro bioactivity is still under evaluation and the effect of materials structure on bioactivity will

be brought to light shortly. In-vitro (hydroxyapatite nucleation in SBF and osteoblast cell adhesion/proliferation) and in-vivo characterizations will be carried out to complete this study. Finally, investigations on monolith surface functionalization by organic molecules and their loading with proteins or specific drugs will be considered to modify materials surface properties, to improve monolith bioactivity and to enable in situ drug delivery.

References

[1] A Hertz, IJ Bruce, Nanomedicine, **2(6)** (2007) p. 899-918
[2] H-y Cheung, K-t Lau, T-P Lu, D Hui, Composites Part B, **38** (2007) p. 291-300
[3] M Vallet-Regi, JM Gonzalez-Calbet, Progress in Solid State Chemistry, **32** (2004) p. 1-31
[4] JR Jones, LM Sehrenfried, LL Hench, Biomaterials, **27** (2006) p. 964-973
[5] QZ Chen, ID Thompson, AR Boccaccini, Biomaterials, **27** (2006) p. 2414-2425
[6] S Ni, J Chang, L Chou, J. Biomed. Mater. Res., **76(A)** (2006) p. 196-205
[7] AJ El Haj, MA Wood, P Thomas, Y Yang, Pathologie Biologie, **53** (2005) p. 581-589
[8] M Tanahashi, T Matsuda, J. Biomed. Mater. Res., **34** (1997) p. 305-315
[9] M Vallet-Regi, L Ruiz-Gonzalez, I Izquierdo-Barba, J Gonzalez-Calbet, J. Mater. Chem., **16** (2006) p. 26-31
[10] J Coreño, A Martinez, A Bolarin, F Sanchez, J. Biomed. Mater. Res., **57** (2001) p. 119-125
[11] ID Xynos, AJ Edgar, LDK Buttery, LL Hench, JM Polak, Biochemical and Biophysical Research Communcations, **276** (2000) p. 461-465,
[12] SA Bagshaw, Chem. Commun. (1999) p. 767-768
[13] I Izquierdo-Barda, L Ruiz-Gonzalez, JC Doadrio, JM Gonzalez-Calbet, M Vallet-Regi, Solid State Sci., **7** (2005) p. 983-989
[14] T Sen, GJT Tiddy, JL Casci, MW Anderson, Microporous Mesoporous Mater., **78** (2005) p. 255-263

Figures:

Fig. 1. Evolution of (a) N_2 ads/des. pore size distribution (in volume) and (b) small angle XRD profiles depending on compaction pressure.

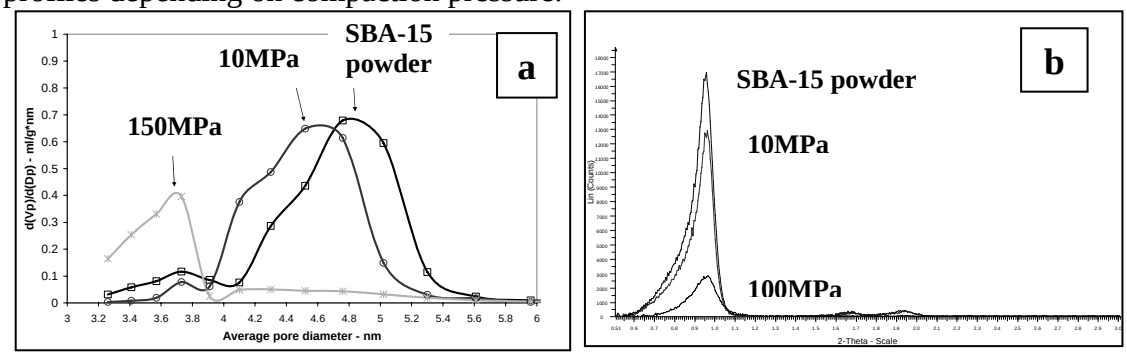

Fig. 2. Evolution of (a) N_2 ads/des. pore size distribution (in volume) and (b) small angle XRD profiles depending on sintering temperature.