Nanostructured Hybrids for Tissue Engineering

Imperial College London

LONDON CENTRE FOR NANOTECHNOLOGY

Description of the Technique

- Inorganic/ organic hybrids are interpenetrating networks of organic and inorganic components that interact at the molecular scale (Fig. 1)
- Biomaterials with controlled mechanical properties and degradation rates can be synthesised by obtaining covalent bonds between the components. Silane coupling used.
- Using silica as the inorganic matrix can provide bioactivity, using enzyme degradable polymers can give controlled degradation.

Why hybrids?

- Bioactive glass is great for bone regeneration because it can bond with bone and degrade in the body releasing ions that can stimulate cells to produce healthy bone.
- Porous foams with interconnected nanoscale porosity (Fig. 2) and open macroscale porosity have been produced that can act as 3D templates (scaffolds, Fig. 3) for tissue growth, but they are brittle. Hybrids provide the solution.

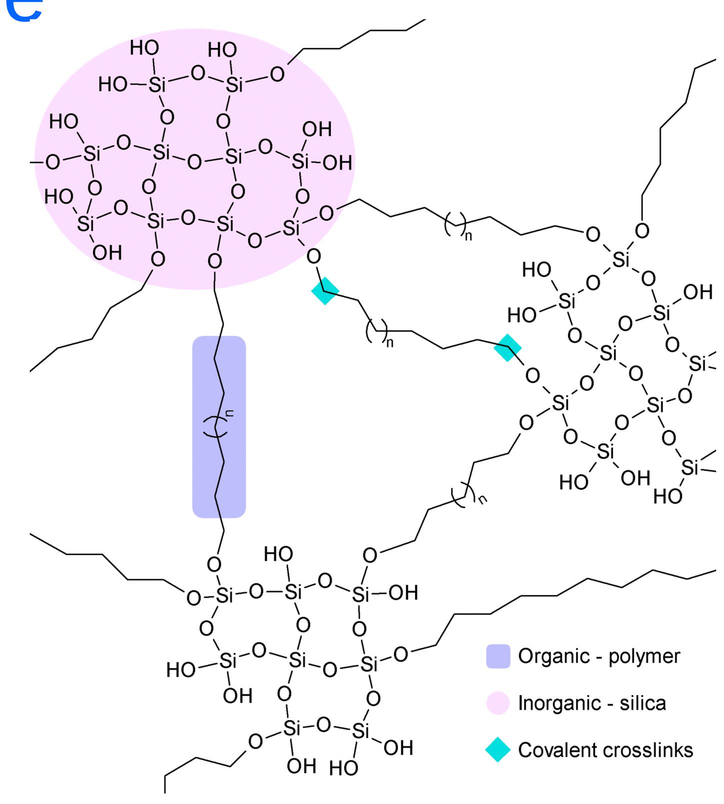


Fig. 1 Structure of a hybrid

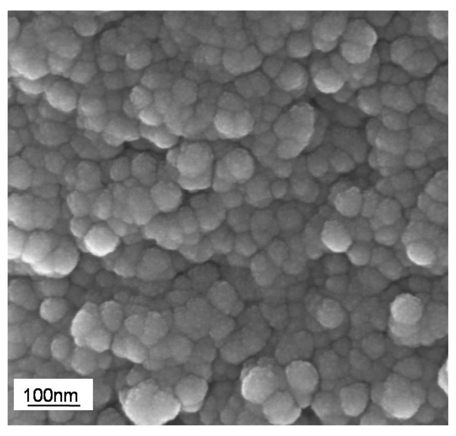


Fig. 2 SEM of sol-gel nanoporosity

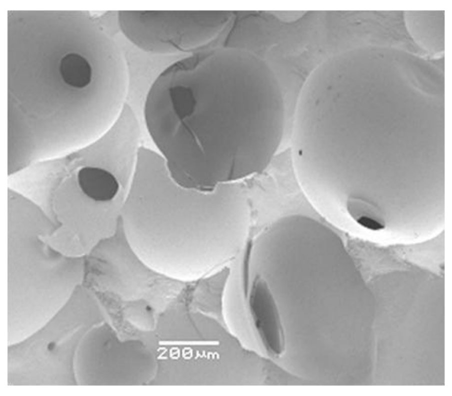


Fig. 3 SEM of bioactive glass foam

Hybrid scaffolds with controlled degradation rate

•E.g. silica/ gelatin hybrid scaffolds made by sol-gel foam process (Fig. 4)
•Control of covalent coupling dictates degradation rate.
•Hybrids degrade congruently as one material (Fig. 5)

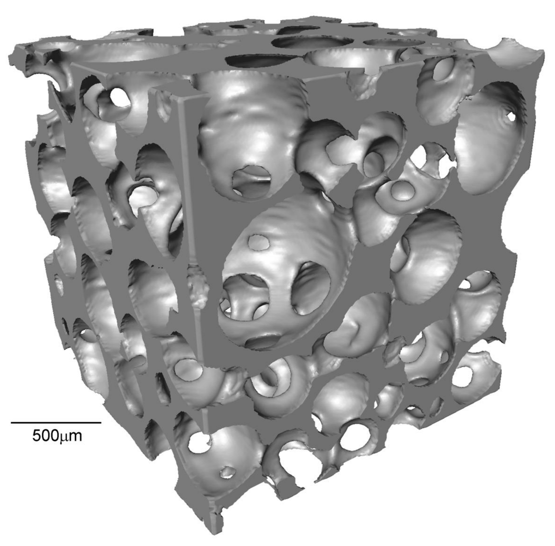


Fig. 4 Micro-CT image of hybrid foam scaffold

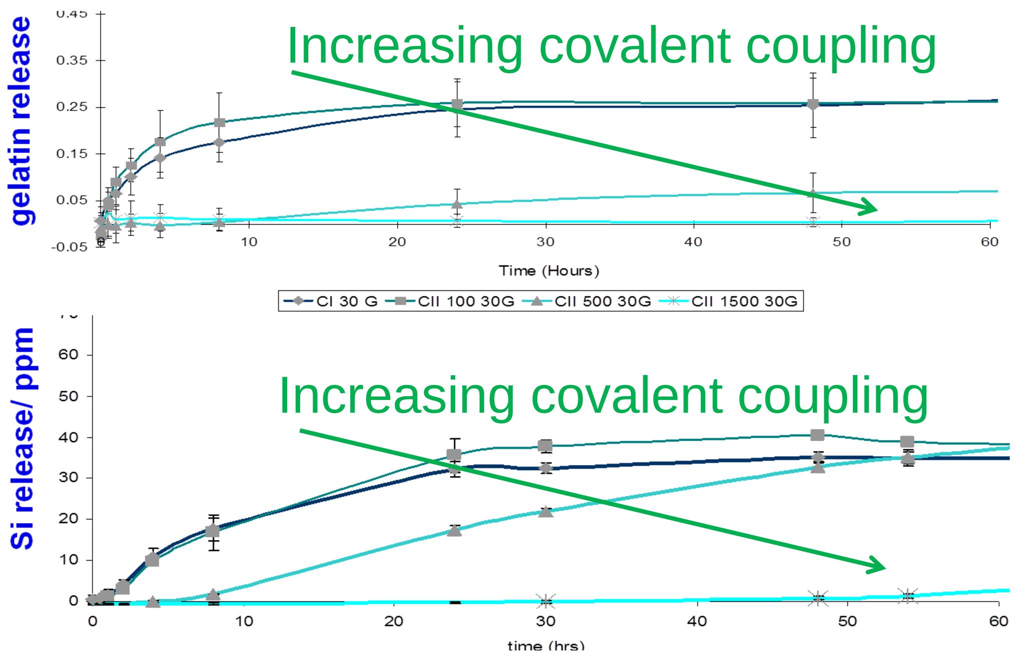


Fig. 5 Gelatin and Si release into simulated body fluid for a silica/ 30wt% gelatin hybrid with different amounts of covalent coupling

Bioactive Tough Hybrids

•Important to have high strength and resistance to cyclic loads (toughness), which is illustrated by high strain to failure (Fig. 8).
•Calcium is needed for bioactivity and can be introduced into the inorganic (e.g. by calcium alkoxides) or organic components (Fig. 9).
•Synthetic polymers with specified functional groups are being developed with Dr J. Weaver.

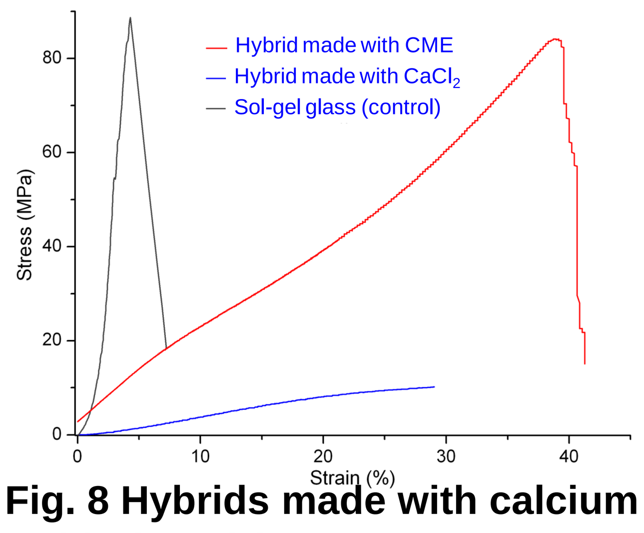
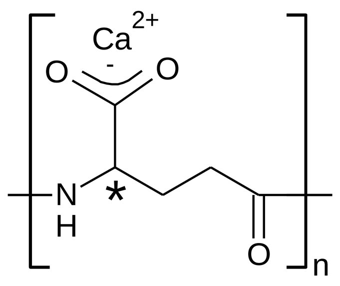


Fig. 8 Hybrids made with calcium alkoxide (CME) have same strength as a glass but with improved toughness



Ca-poly-γ-glutamic acid

Fig. 9 –NH and –COOH groups are used to functionalise polymers with coupling agents but can also be used to chelate Ca.

Vascularisation using Tissue Engineering

•Large scaffolds need blood vessels for successful bone regeneration
•Blood vessels can be grown in the scaffolds *in vitro* prior to implantation so they will connect with host vessels after implantation.
•This is done by seeding stem cells and endothelial cells inside a gel.

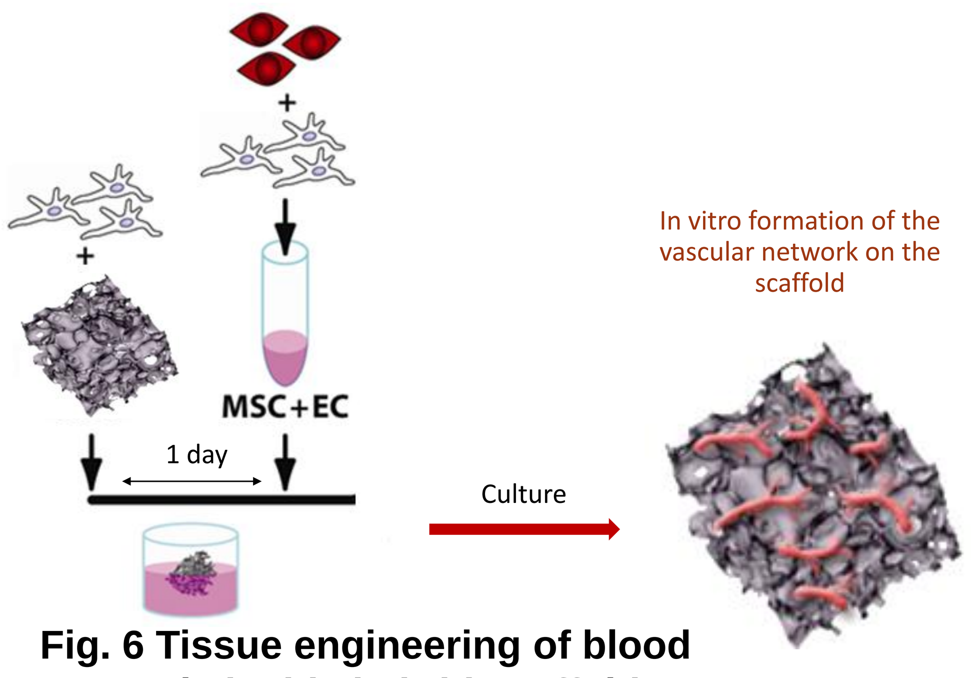


Fig. 6 Tissue engineering of blood vessels inside hybrid scaffolds

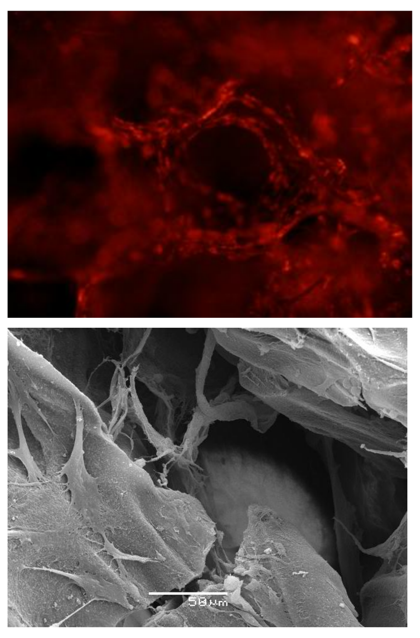
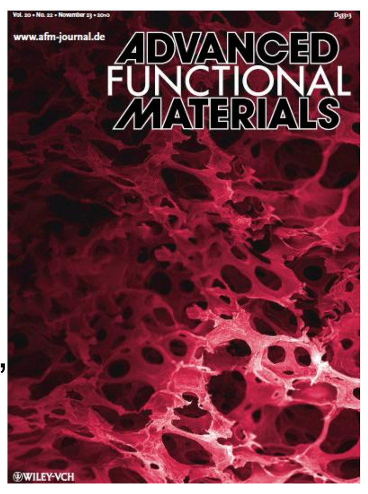


Fig. 7 Fluorescence and SEM images of vessels grown *in vitro*

Key Publications

1. Poologasundarampillai, G., Yu, B., Kato, H., Jones J. R., Kasuga, T. “Electrospun silica/PLLA hybrid materials for skeletal regeneration” Soft Matter. In Press, , DOI:10.1039/C1SM06171B.
2. Valliant, E. M., Jones, J. R. “Towards softer materials for synthetic bone graft applications: hybrid materials” Soft Matter, 2011: 7 (11): 5083 – 5095.
3. Mahony, O., Tsigkou, O., Ionescu, C., Minelli, C., Hanly, R., Ling, L., Smith, M. E., Stevens, M. M., Jones, J. R. “Silica-gelatin hybrids with tailorable degradation and mechanical properties for tissue regeneration”, Advanced Functional Materials, 2010: 20: 3835-3845. Cover page.
4. Poologasundarampillai, G., Ionescu, C., Tsigkou, O., Hill, R. G., Stevens, M. M., Smith, M. E., Jones, J. R. “Synthesis of bioactive class II poly(γ-glutamic acid)/silica hybrids for bone tissue regeneration.” Journal of Materials Chemistry, 2010: 40: 8952-8961.



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