Bob Newport

"Researchers are developing a material that promotes the growth of new bone"

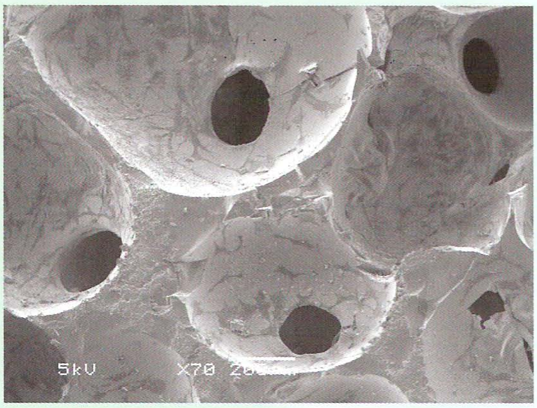
BIOACTIVE GLASS: A LOOK INSIDE

Average life expectancy in the Western world has increased dramatically with better nutrition and improvements in medical care. To allow people to remain active, and to contribute to society for longer, the need for new materials to replace and repair worn-out and damaged tissues becomes ever more important.

All present-day orthopaedic implants lack some important characteristics of living tissues. Therefore, one strategy is to shift from the replacement of tissues to the regeneration of tissues. A research collaboration in the UK is developing a bioactive glass that promotes the growth of new bone. When made into the correct shape to replace a piece of missing bone and glued into place in the body, the simple, porous calcium-bearing silicate acts as a scaffold for new bone tissue to form. The glass gradually dissolves in the body over a period of several months, and as it does so, it releases calcium which triggers the deposition of hydroxyapatite, the mineral component of bone.

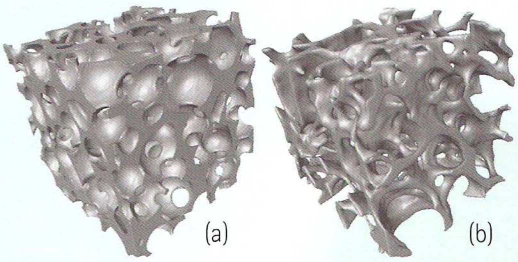
The glass is being tested for future facial reconstruction, and the next goal is to make a stronger material suitable for the regeneration of load-bearing bones. However, to take the work further, it is vital to understand exactly how the glass behaves at the atomic level when immersed in body fluids.

Neutron diffraction is a key component in a broader methodology aimed at understanding the properties of biomaterials in terms of their atomic-scale structure. The role of calcium has been recognised as critical for both the stability of the glass and its bioactivity, but no direct and quantitative study of the environment of the calcium atoms in these glasses had been undertaken.



Human bone cells cultured on a bioactive glass scaffold

Credit: J. Jones *et al*, *Biomaterials*, 2007, **28**, 1653



Computer images of (a) a typical scaffold used in this study, and (b) human trabecular bone

ISOTOPIC SUBSTITUTION

We carried out neutron diffraction on a sample of glass synthesised using natural calcium, and also on a sample enriched in a calcium isotope (^{44}Ca) which scattered the neutrons differently. The idea was to use the difference in the diffraction patterns to pick out the calcium atoms, and calculate their positions in relation to those of the other surrounding atoms. This was the first time that the complex and subtle contribution of the calcium to the structure of this material had been revealed. The same isotopic substitution method was later employed to reveal details of the dissolution process, and the re-deposition onto the residual glass surface, of the calcium-based mineral constituents characteristic of bone.

We uncovered a similar atomic-scale story behind a series of related bio-resorbable phosphate glasses that can promote a strong interface with bone, and have potential use as bactericidal coatings for dental implants and joint replacements. When silver, copper or gallium ions are incorporated in the coating, they prevent the formation of pathogenic microbial films which otherwise could cause serious systemic infection in the patient. The materials are effective even against multi-resistant bacteria, and have the potential to avoid issues of drug-resistance altogether.

Neutron diffraction methods, including those based on the substitution of silver isotopes, have proven central to these studies by revealing the atomic-scale detail of the all-important metal ions within the multi-component glass. These isotopic substitution techniques are not easy, however, because the scattering differences between many isotopes may be very small and require an intense neutron source to see them.

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References

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