chips containing antibodies or receptor-binding domains, because simple binding is only one of the many functions proteins can have, hence these chips have very limited potential to study the full extent of enzymatic functional activities.

The key to the success of Hamachi's approach lies in the combination of different building blocks to make these materials, in a similar way to biological systems — assembling them bit by bit from the bottom up. A good example is a seashell or a tooth, where very small amounts of proteins are used to construct the scaffold that allows inorganic mineral to self-organize into a well-ordered structure. The structure confers special properties tailored for a particular function. The same is true for Hamachi's hydrogel scaffold, where sugar and peptide moieties are combined to build a useful medium to array proteins. An axiom that works for fabricating materials at the nanoscale level is: two is always better than one.

A number of peptide- and protein-based hydrogels have been discovered and developed over the last decade[2–10]. These hydrogels form well-ordered nanofibre scaffolds with extremely high water content ranging between 0.1–1%, similar to that reported by Hamachi and co-workers[1]. These nanofibre scaffolds have been used for three-dimensional cell cultures, for controlled release of drugs, and other uses — but until now not for protein chips. Their range of applications will certainly expand in the coming years as more people become aware of their potential.

The thing that all these different hydrogels have in common is an extraordinary capability to trap water. Where does this property come from? The answer may lie in their nanofibre structure. Although they have little in common in terms of their basic chemical components, primary sequences, and origin of materials, they are all amphiphilic — that is they have both hydrophilic and hydrophobic parts — and self-assemble into well-defined nanofibres with high aspect ratio and surface area. These nanofibres form networks containing nanosized hydrophilic cavities that accommodate small clusters of water molecules in a space where convection and flow are reduced — much like the small Greek islands that break the waves of the Aegean sea —thus allowing the protein activities to be unhindered. This is in sharp contrast with many synthetic and biological polymeric gels that often form microfibres and microcavities, and hence have significantly reduced surface area and can entrap less water compared with those formed from nanofibres.

The next big challenge will be inexpensive large-scale production of hydrogels. For any materials to be widely adopted, cost is often the determinant factor. A few milligrams of material may be enough to prove a concept in the laboratory, but hundreds of kilograms to tons may be needed to manufacture the material at industrial scale to spur a new industry. Without solving this problem, the best research will remain just the best research.

References

1. Kiyonaka, S. *et al. Nature Mater.* **3,** 58–64 (2004).
2. Zhang, S., Holmes, T., Lockshin, C. & Rich, A. *Proc. Natl Acad. Sci. USA* **90,** 3334–3338 (1993).
3. Aggeli, A. *et al. Nature* **386,** 259–262 (1997).
4. Petka, W. A., Harden, J. L., McGrath, K. P., Wirtz, D., & Tirrell, D. A. *Science* **281,** 389–392 (1998).
5. Lee, J., Macosko, C. W. & Urry, D. W. *Biomacromolecules* **2,** 170–179 (2001).
6. Hartgerink, J. D., Beniash, E., & Stupp, S. I. *Science* **294,** 1684–1688 (2001).
7. Nowak, A. P. *et al. Nature* **417,** 424–428 (2002).
8. Schneider, J. P. *et al. J. Am. Chem. Soc.* **124,** 15030–15037 (2002).
9. Jin, H. J. & Kaplan, D. L. *Nature* **424,** 1057–1061 (2003).
10. Zhang, S. *Nature Biotech.* **21,** 1171–1178 (2003).

MATERIAL WITNESS

A matter of taste

Do materials have a personality? Mike Ashby and Kara Johnson ask this question in the December issue of *Materials Today*, and their answer is: of course they do. Metals are 'cold, clean, precise': strong and reliable, but impersonal. Wood is warm, soft and associated with good craftsmanship. Plastics are cheap, fun, gauche, synthetic, chameleon-like.

Well, this much seems obvious. Designers have long used their choice of materials to say something about their products, from the filigree of Celtic goldsmiths to the wooden furniture of the Arts and Crafts movement and the insouciant plastics of the Pop Art style. What is curious is that these associations transcend instances of contradictory materials usage: wood appears in most uncraftsman-like contexts such as cheap packaging, whereas plastics house expensive, high-tech electronic products and feature in cutting-edge biomedicine.

Ashby has been a pioneer in the business of materials selection: how to choose materials in engineering so that they represent the best compromise between potentially conflicting criteria such as strength, lightness and cost. For an engineer, that is often where the story starts and ends: aesthetics rarely enter the equation. Or if they do, the aesthetic of the engineer often expresses itself in the intrinsic quality of the design: a well-built bridge is automatically beautiful, as Brunel believed.

However, because not everyone shares that belief, products that are designed to be sold – that is to say, to capture a consumer market – have to acknowledge a wider vision of aesthetic appeal. Part of that appeal is purely functional: how well does the product work, and for how long? Much of it, however, is bound up with the 'personality' of the material components and their manner of processing and assembly. What is their shape, colour, texture, their cultural associations? Then it becomes harder to unravel cause and effect. Did the flat, economical contours of Bauhaus design precede a material in which they could be economically realised, or did the use of moulded plywood help to determine that aesthetic?

I'm not sure we recognize how deeply ingrained materials' personalities are in our cultural preferences. Plastics can mimic the appearance of other materials so closely as to be sometimes all but indistinguishable, and yet (as Ashby and Johnson point out), many people would baulk at being buried in an imitation-wood plastic coffin, even if it were biodegradable. It would feel like being thrown away in disposable plastic packaging. These non-material connotations of materials are reminiscent of how painters once insisted on using precious ultramarine for religious iconography.

What this means is that anyone who is going to use materials science in industrial design, from computers to construction machinery (for even that has to be sold in a competitive market), could surely benefit from instruction in the role and history of materials in art and culture. That is why initiatives like the one developed by Mark Miodownik at King's College London to bring engineers into contact with the arts (see www.eee.kcl.ac.uk/ mecheng/mam/engart.html) are well worth encouraging.

Philip Ball