Metallic Glasses

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Metallic liquids crystallize rather readily, and glasses were first made from them by ultra-rapid cooling. With well chosen alloy compositions, however, the critical cooling rates for glass formation need not be high; they can approach the low values associated with conventional silicate glasses. Without the need for rapid cooling, such compositions can be made in thick sections (1cm or more). The advent of these *bulk metallic glasses* (BMGs) has stimulated the intense interest. Bulk samples facilitate measurements, notably of elastic and mechanical properties, and these have been the focus of recent attention. This presentation aims to explain why BMGs (and metallic glasses more generally) are remarkable and useful materials, and to make links with the key themes of the workshop.

The glass-forming ability of metallic melts is related to their composition, to the structure of the liquid and glass, to the fragility of the liquid. Compared to conventional engineering alloys, metallic glasses show unusually high yield stress and elastic strain limit, while being formable via viscous flow. Some metallic glasses are tough and some brittle, and some show embrittlement on annealing. These features can be correlated with the elastic properties of the glasses, in particular the ratio of the shear and bulk moduli. Interestingly, the elastic properties of the glass may also be correlated with liquid fragility. The unfortunate implication is that better glass-forming compositions will also tend to be more brittle. Ways around this problem will be considered.

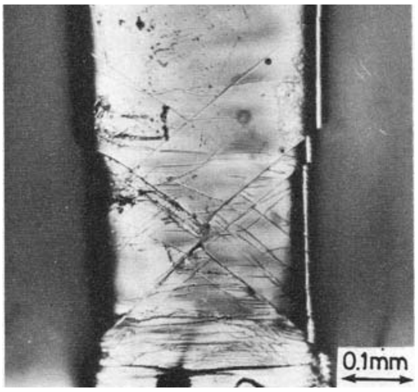
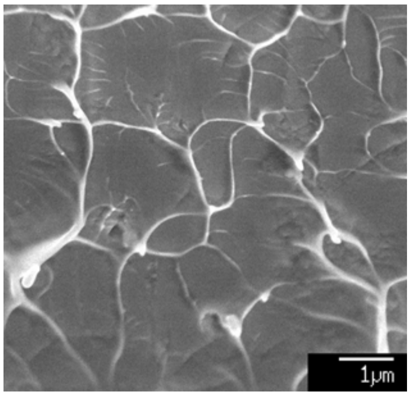


Figure 1: (left)
Shear bands in a Pd-based BMG deformed at room temperature.

Figure 2: (right)
Fracture surface of a Ce-based BMG showing the characteristic 'vein' pattern associated with local softening.



From an engineering point of view, the key drawback of metallic glasses is that their plastic deformation under ambient conditions is inhomogeneous, sharply localized into *shear bands* 10-20 nm thick (Figure 1). This localization implies work-softening, and indeed, liquid-like structures are commonly found on fracture surfaces (Figure 2). We will focus on the mechanisms of shear-banding, the controversial question of local heating, and how the banding phenomenon is related to liquid fragility. Ways to make the deformation of metallic glasses more homogeneous, and thereby to improve their elongation in tension (*ductility*) will be considered. Links between deformation and structure will also be explored; metallic glasses can exhibit remarkably high levels of anisotropy in properties and structure as a result of deformation.