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Castings of bulk metallic glasses of controlled degree of crystallinity and improved ductility.
Description for the general public

The casting of metallic components is an important part of manufacturing industry, with relevance ranging from works of art to the highest-technology aerospace parts. The foundry industry, whose business is casting, is an essential part of any industrialized economy. This is certainly true in Poland, where the foundry industry is developing and extending its reach into products of higher added value. While there are continual refinements of the conventional metallic alloys used in cast components, the basic sectors of the industry (cast irons and light alloys (aluminium and magnesium) for example, and the basic alloy compositions are well-established and see only incremental change. Only rarely do really new, potentially revolutionary opportunities arise — this project aims to exploit the opportunity offered by the novel category of material known as “bulk metallic glasses”.
Conventional metallic alloys are crystalline: the atoms are arranged in a regular, repeated array, and in particular align in flat sheets that can (through the motion of particular configurations) slide over each other, allowing the metal to bend or be stretched. While this “plasticity” is useful in avoiding brittle cracking, it can make the metal rather soft. In metallic glasses, in contrast, the atoms are not in a regular array. The term “glass” refers to this atomic disorder, not to any appearance (for example transparency) like conventional window glass. The metallic glasses have a fully metallic appearance, but their properties do differ significantly from conventional metals.
Their disordered structure means that plastic flow is difficult; the stresses necessary to bend them out of shape are some ten times higher than for conventional alloys. They are therefore also scratch-resistant, and attractive for use in springs. Unlike window glass, they can be very tough, and indeed it is a metallic glass that has the highest “damage tolerance” (combination of strength and toughness) of any engineering material.
In normal casting, crystallization occurs as the solid forms in the mould. This crystallization must be avoided to make a glass, and it is known in the laboratory that this can be achieved, even at the relatively low cooling rates achievable in foundry practice. Although, there have been some niche and short-lived applications (for example, golf-club heads), the great potential of metallic glasses to provide improved products largely remains to be translated from the laboratory into foundry industry. This project aims to tackle the broad range of challenges in doing so. The properties of glass-forming liquids are very different from those of conventional alloys (for example they are more viscous) requiring new processing conditions to be adopted. Much work must be done to optimize the compositions to avoid crystallization and permit glass formation, and to determine the input parameters needed for the computer simulation that is an essential part of modern foundry practice.
The avoidance of crystallization means that the cast component does not shrink so much in the mould; the benefits are greater dimensional accuracy and surface quality, so that fewer finishing operations are required to obtain the final product. In this way, the use of metallic glasses can be cost-effective and energy saving. There are yet further opportunities by tuning the alloy structure to be part-glass, part-crystalline. This project aims to provide a basis for exploiting such opportunities in foundry practice.