Bulk Metallic Glasses (BMG or Bulk Amorphous Alloys)

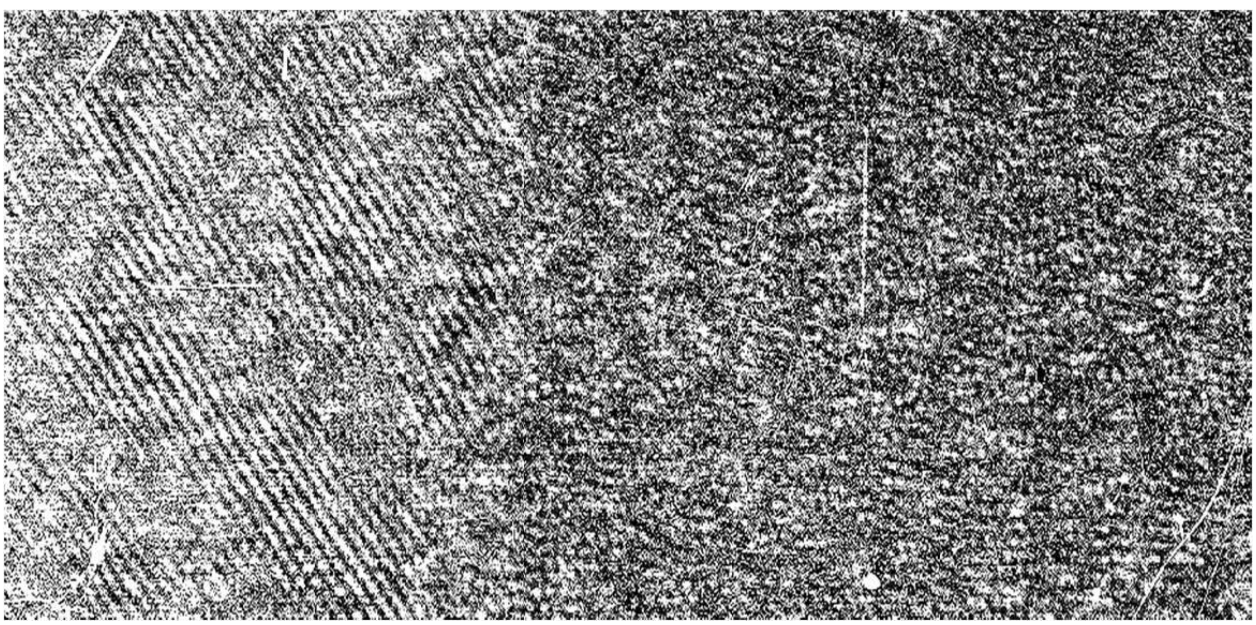
Bulk Metallic Glasses (BMG or Bulk Amorphous Alloys) are a new class of metallic alloys with a unique amorphous atomic structure. The amorphous atomic structure provides very high yield strength and very high Hugoniot elastic limit (HEL) under shock impact conditions. The very high strength of BMG's is available in as-cast form, which provides a cost-effective net-shape casting process. This also provides an opportunity to make various composites with tailored properties for specific applications. For example, the deformation mode of composites can be designed for self-sharpening by utilizing the adiabatic shear band formation in BMG's. As such a new class of tungsten composites with self-sharpening effect are developed for Kinetic Energy Penetrators.

Atomic Structure of BMG's

The atomic structure is the foremost striking characteristic of the BMG' as it fundamentally differentiates from ordinary metals. The figure below shows a TEM micrograph, where the atomic structure of BMG versus the atomic structure of a conventional metal (Zirconium) is shown. The atomic structure of conventional metals is a periodic structure in which the layout of atomic species shows repeating patterns over an extended range. This atomic structure is called "crystalline" and is said to have long-range order. By contrast, no discernable patterns exist in the atomic structure of BMG's, which is called amorphous and said to have no long-range order. For the first time, amorphous atomic structure became possible for the solid bulk forms of metals with the discovery of BMG's. This unique atomic structure places BMG's in a new domain of properties unattainable by ordinary metals.

Properties of BMG's

One of the direct consequences of the amorphous atomic structure of BMG's is very high yield strength, which approaches to the theoretical limit and far exceeds the strength values available in crystalline metals and alloys. For example, yield strength of over 1,800 MPa (250 ksi) has been achieved in Ti-base BMG's, which is more than twice the strength of conventional titanium alloys. Meanwhile Fe-base BMG's can have yield strength values over 3.3 GPa exceeding any other metallic alloy. Furthermore, this very high strength of BMG alloy is available in "as-cast" form and does not require any thermo-mechanical operations as common to the ordinary high-strength alloys. The figure below shows the yield-strength of various crystalline and BMG alloys.



TEM micrograph showing the amorphous atomic structure of BMG (on the right) versus crystalline atomic structure of a typical metal (on the left). (Magnification ~X 5 Millions. The amorphous microstructure provides properties beyond the envelope of conventional alloys. For example, yield strengths of over 2 GPa and Hugoniot elastic limit of over 7 GPa are readily achievable in BMG's. (Atakan Peker, Caltech 1994)

Another unique property of BMG's is the superior elastic strain limit: i.e., the ability to retain its original shape (memory) after undergoing very high loads and stress. For example, a typical Ti-base BMG has an elastic strain limit of 2% exceeding any other metallic alloy. Under shock conditions, the elastic strain limit can reach up to 4%. These and other properties show some variation with chemical composition of a specific BMG alloy. As such, optimization of some properties can be achieved to a certain degree by varying chemical composition.

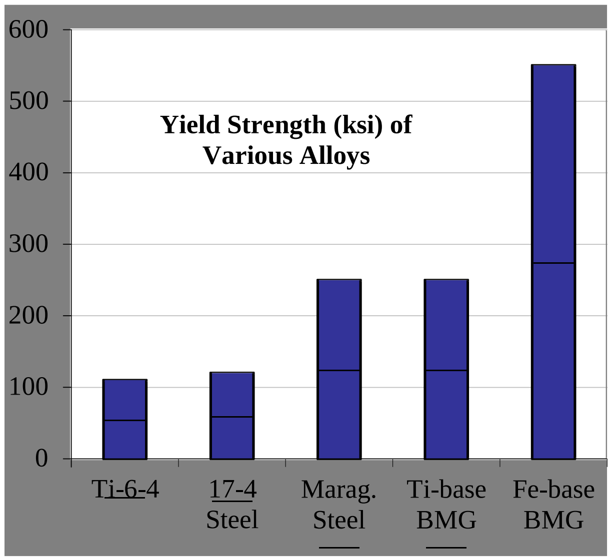


Fig. 2: Yield strength of various alloys. The very high yield strength of BMG's is available in the "as cast" form, which provides greater design flexibility and performance advantages in various applications. Generally, conventional high strength alloys are available only in wrought form limiting their use.