DEVELOPMENT OF NOVEL BINARY AND MULTI-COMPONENT BULK METALLIC GLASSES

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Abstract

Bulk Metallic Glasses (BMGs) have been drawing increasing attention in recent years due to their scientific and engineering significance. A great deal of effort in this area has been devoted to developing BMGs in different alloy systems. BMGs based on certain late transition metals (e.g., Fe, Co, Ni, Cu) have many potential advantages over those based on early transition metals. These advantages include even higher strength and elastic modulii, and lower materials cost, to name but a few that are highly preferable for a broad application of BMGs as engineering materials. Nevertheless, these ordinary-late-transition-metal-based BMGs generally have quite limited glass-forming ability (GFA). In particular, for the Ni-based and Cu-based alloys reported prior to this research, the maximum casting thickness allowed to retain their amorphous structures is only ~2 mm (or lower) and ~5 mm (or lower), respectively.

The first important finding during this research was that certain quinary Ni-based alloys in the Ni-Cu-Ti-Zr-Al system can be cast into 5 mm diameter amorphous rods. This critical casting thickness is the highest for any reported Ni-based BMG's, indicating that these alloys are the easiest metallic glass formers based on Ni discovered to date. Secondly but more interestingly, certain binary alloys in the Cu-Zr and Cu-Hf systems were found to form bulk amorphous samples with casting thicknesses as high as 2 mm. The discovery of these binary BMGs was very surprising since it had been widely considered that only multi-component (having at least three elements) alloys could form bulk metallic glasses. These new binary BMGs have not only challenged the traditional concept about bulk metallic glass formation, but also provided interesting subjects for

future theoretical studies such as molecular dynamics simulations since they possess both the simplicity of binary alloys and the good GFA of multi-component BMGs. As a matter of fact, these binary BMGs have also led to a third and perhaps most significant discovery during this research: the family of Cu-based BMGs in the Cu-Zr-Al-Y system that possesses a critical casting thickness up to 1 cm. These quaternary Cu-based alloys, together with some complicated Fe-based alloys reported by two other groups during the course of this research, are the first centimeter-level BMGs based on the ordinary late transition metals.

This thesis first reviews the fundamentals related to BMG development, then reports in detail the formation and properties of the above-mentioned binary and multi-component BMGs based on Ni and Cu. A generalized geometric model for the critical-value problem of nucleation developed in this research is also presented.

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