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TECHNOLOGY DEVELOPMENT OF MAGNESIUM-BASED BULK AMORPHOUS ALLOYS

Abstract: The paper presents some methods for producing bulk metallic glasses. The study was performed on ternary Mg-based alloys. The $Mg_{65}Cu_{25}Y_{10}$ glassy alloy was prepared in the form of rods by pressure die casting method of molten alloy into water cooled copper mold. The X-ray diffraction investigations revealed that the examined samples obtained in the bulk form were amorphous.

1. Introduction

The Mg-based amorphous alloys are the new and attractive group of nanostructured materials, which are characterized by a high glass-forming ability, low crystallization temperature and low density. As compared to their crystalline equivalents, they have greater strength and corrosion resistance due to the specific structure and atomic configurations.

The main problem associated with the preparation of amorphous materials based on light metals is to apply the appropriate cooling rate of the liquid alloy to avoid the crystallization process. An additional difficulty is the rapid oxidation of alloying elements. These difficulties could be minimized by choosing the appropriate method of preparation and using of appropriate equipment and taking into account of all the casting parameters.

The special technology to obtain amorphous alloys based on magnesium has been developed by using pressure casting of molten alloy into the copper mold.

2. Origins of Mg-based bulk metallic glasses

Magnesium-based bulk metallic glasses have been first time prepared by Inoue et al. by pressure casting of liquid metal into the copper mold. Many investigations of structure analysis of the ternary Mg-Cu-Y amorphous alloys were done to demonstrate the relationship between the stability of the amorphous structure and the topology of atoms arrangement in a short range order. Many alloying additions have been used to improve the glass-forming ability of Mg-based bulk metallic glasses. The most common alloying elements include: Ni, Zn, Ag, Pd, Gd, Tb and Nd. The fact is that the density of amorphous alloys with the participation of these metals is about 3 g/cm^3, and is about 50% greater than conventional crystalline alloys on the magnesium [1-3].

3. Chosen casting methods

Many various methods using rapid cooling of molten alloys were used for the achieving of bulk metallic glasses. The critical cooling rate of the alloy, which is appropriately depended of the chemical composition influenced on forming glassy materials. The copper mold is often used to achieve a sufficiently high cooling rate of liquid alloys in the preparation of bulk metallic glasses. A copper has good thermal conductivity. Moreover, that material is cheaper in comparison with, for example, silver.

Depending on various casting methods of preparation of metallic amorphous alloys and their chemical compositions, metallic glasses could be divided into [4,5]:

a) conventional metallic glasses (CMGs), cast in the form of ribbons and wires,

b) bulk metallic glasses (BMGs), cast in the form of rods, rings or plates.

Currently, many researchers have continued to develop of many conventional casting techniques for producing amorphous materials with higher dimensions. Conventional metallic glasses could be prepared by: spraying liquid metal method, splat-cooling method, double-roll casting method, melt-spinning method, laser-spin melting method. In addition, there are developed some methods to prepared bulk metallic glasses as: high pressure die casting, copper mold casting, cap-cast technique and suction-casting.

Pressure die casting (Fig. 1) is a most popular and common method to fabricate bulk metallic glasses. Advantages of this method are: rapidly molding, that will achieve high cooling rate and good contact with the copper alloy form under the influence of high pressure applications. However, a disadvantage of this method are the pores formed as a result of shrinkage during solidification of the liquid metal. This equipment designed and used by Inoue to produce Mg-based bulk metallic glasses. This method is used for the production of complex shapes, and the change in shape of the mold allows the casting material in the form of rods and plates. This method is used by Inoue to produce BMGs in the Mg-Cu-Y alloys system [4,6].

Copper mold casting is the most common method to produce BMGs in different alloy systems. Raw materials for alloy preparation could include either pure metals or master alloys of some of combinations of them and also some of the elements. The alloys are melted by induction melting techniques [4].

Cap-cast technique is a simple technique used to increase the maximum diameter of the cast glassy samples. This is followed by solidification of molten contact form. At the same time low pressure of about 1 kN, is used to push the lid down into the liquid metal. The biggest advantage of this technique is that the high level of cooling is achieved not only at the sides and bottom of the casting, since they are in contact with the mold, but also in the upper part of the sample, as it is in contact with the metal [4].

Suction-casting method is another popular method of achieving of BMGs. In this method, the melt is introduced into the mold by means of the pressure difference between the melting and casting chamber [4].

4. The pressure die casting method

Fabrication of Mg-based amorphous alloys required the special casting technology due to maintaining rigorous conditions. In this paper a modified the pressure casting of molten alloy into the copper mold was used to produce Mg-based glassy materials with including the stage of preparation of master alloys and casting of bulk amorphous samples. The preliminary studies were performed on $Mg_{65}Cu_{25}Y_{10}$ (at.%) master alloys and bulk metallic glasses in the form of rods. The studied alloy was achieved by two steps. The first stage included the preparing of binary alloy with pure elements of Cu (99.9%) and Y (99.9%) by induction melting under an argon atmosphere. Then binary alloy was melted with Mg (99.9%) pieces in an electric furnace to obtain a master alloy with the nominal composition. Figure 1 presents the pressure casting method which has been used to fabricate the samples of bulk metallic glasses in the form of rods [2,7,8]. The master alloy was re-melted in a protective atmosphere using induction melting, then injected into the copper mold by the pressure casting method to obtain glassy samples in the form of rods and plates. The casting process was done in a special prepared chamber with inert gas (argon).

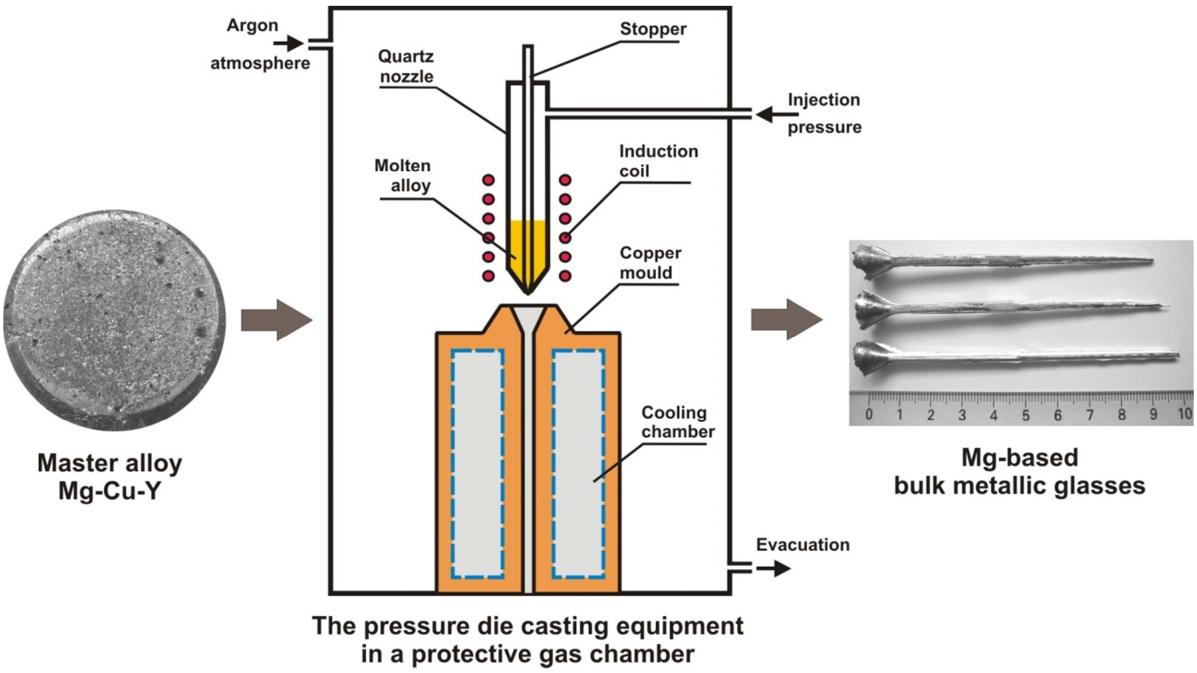

Fig.1. Schematic illustration of casting Mg-based bulk metallic glasses by using the pressure die casting method [8]

Structure verification of the obtained samples in as-cast state was carried out by using of X-ray diffractometer with $Cu_{K\alpha}$ radiation. The data of diffraction lines were recorded by “step-scanning” method in 2θ range from 20° to 80°. The X-ray diffraction investigations revealed that the obtained samples in the form of rods with diameter of 4 mm (Fig.2a) were amorphous. The diffraction patterns of studied Mg-based alloys have shown the broad diffraction halo in the 2θ range of 30-45° characteristic for the amorphous structure (Fig.2b).

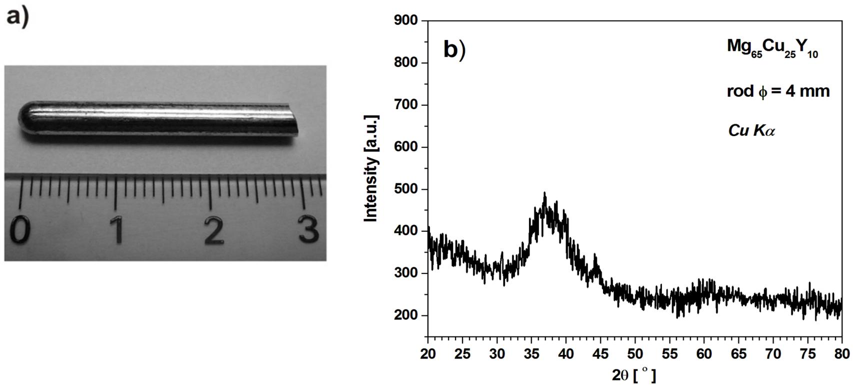

Fig.2. Outer morphology (a) and X-ray diffraction pattern (b) of $Mg_{65}Cu_{25}Y_{10}$ metallic glass in as-cast state in form of rod with diameter of 4 mm

5. Conclusion

The paper describes a method of the pressure die casting used for fabrication of $Mg_{65}Cu_{25}Y_{10}$ bulk amorphous materials in the form of rods with diameter of 4 mm. The studied method is more useful to produced Mg-based metallic glasses than copper mold casting or cap cast methods. The using of high pressure techniques guarantees a good contact of molten alloy with the walls of copper mold and easier achieving of glassy alloys.

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