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CRITERIA AND METHODS OF PRODUCTION OF AMORPHOUS MATERIALS

Bartłomiej JEŻ[1], Marcin NABIAŁEK[1], Konrad GRUSZKA[1], Pawel PIETRUSIEWICZ[1], Kinga JEŻ, Jakub RZĄCKI[1], Michal SZOTA[2], Katarzyna BŁOCH[1], Joanna GONDRO[1]

[1] Institute of Physics, Faculty of Production Engineering and Materials Technology, Czestochowa University of Technology, 19 Armii Krajowej Str., Czestochowa, Poland
[2] Institute of Engineering Materials, Faculty of Production Engineering and Materials Technology, Czestochowa University of Technology, 19 Armii Krajowej Str., Czestochowa, Poland

Abstract

The article contains a brief history of amorphous materials. Information on the properties of these materials is provided and the criteria for amorphous materials produced by A. Inoue are discussed. Two selected methods of producing fast-cooled alloys have been characterized. The melt spinning method and the centrifugal casting method have been described by providing appropriate apparatus diagrams. In addition, the article describes processes of initial preparation of feed materials for the production of fast-cooled alloys and describes the process of forming a polycrystalline ingot. Selected methods of investigating structure of amorphous materials are described: X-ray diffraction and mossbauer spectroscopy.

Keywords: *amorphous; melt-spining; centrifugal method.*

Introduction

Metals and their alloys are present in the everyday life of man for centuries. Initially, the development of new materials consisted in discovering new elements and then creating their alloys. In the modern era, many materials have been developed with a very precise chemical composition in order to achieve the desired properties. Applying new chemicals is not the only way to find new materials. One of the relatively recently discovered roads is the fast-cooled alloys. At the end of the 1960s a new group of materials called amorphous materials was born [1,2]. Researchers have created a material that incorporates crystalline phases, but the casting method has allowed the material to be free of crystalline phases. The structure of the new material was described as amorphous. Studies have shown that these alloys exhibit completely different properties than crystalline alloys of the same chemical composition [3-5]. The development of this branch of material was slow. Over the years, new methods have been developed for the production of amorphous materials to produce higher amounts of alloys [6-13]. A breakthrough in the production of amorphous materials was the study of A. Inoue and his team. Based on experiments, he has developed three criteria for the production of amorphous materials: multi-component alloys (at least 3 components), large differences in atomic radius of main alloy components (at least 12%) and negative mixing heat [14, 15]. The interest in these materials has increased considerably. Currently amorphous materials are produced on a massive scale. New alloys are still in development and their methods of manufacture have been

Corresponding author: bartek199.91@o2.pl

improved. Below you will find the selected methods of their production and the initial preparation of the batch material.

Preparation of the batch for the production of fast-cooled alloys

The production of amorphous materials is a difficult process. In addition to ensuring adequate cooling rates, it is important to ensure that they are suitable for their manufacture. The important factors are: to provide a suitable atmosphere during the melt casting process and the high purity of the elements used to make the ingot and to accurately weigh them. The first step after the development of the chemical formula of the alloy is the preparation of the weights. As a rule, elements with a purity of over 99.99% are used. Accuracy of weighing components is important in view of obtaining the desired chemical composition of the material. Already a small addition of some elements has a great influence on the possibility of obtaining an amorphous structure as well as on the final properties of the material. The material thus prepared should be melted to obtain the same chemical composition throughout the bulk of the ingot. The apparatus and the process of preparation of the ingot are shown in Figure 1.

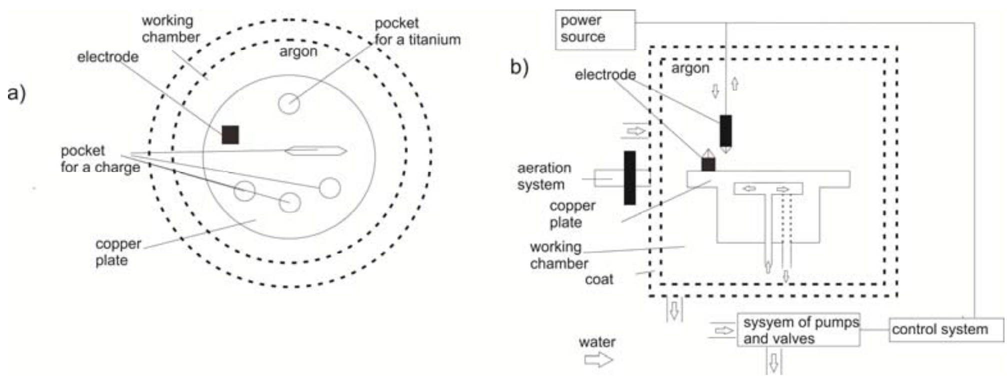

Fig. 1. Scheme of apparatus for making ingots using the arch method: a) top view, b) side view

The preparation process of the ingot is decisive in terms of the possibility of producing an amorphous material. The prepared material is melted into one sample called an ingot. Polycrystalline ingots are manufactured under oxygene-less conditions. The work chamber, after being filled with the feed material, is pumped out of the air. When the vacuum level is reached, argon is applied to the chamber. In such a prepared atmosphere, the correct ingot production process is performed. In the presented method, this is done b y means of a plasma arc on a water-cooled copper plate. The titanium melting is done before ingestion to absorb the residual oxygen present in the working chamber. Digging the ingot several times ensures a good mixing of its components. In order to obtain the best possible decomposition of the elements, the ingot is rotated by manipulator after each melting.

Selected methods of amorphous materials production, investigation and application

The amorphous materials that have been used for several decades are unidirectional cooling of the molten alloy by casting onto a rotating copper wheel. A method called melt spinning enables the production of high quality amorphous materials. Alloy is obtained in the form of tape. Owing to its capabilities, the melt-spining method was implemented in industry [16, 17]. The scheme of the apparatus and the process of producing amorphous materials is shown in Figure 2.

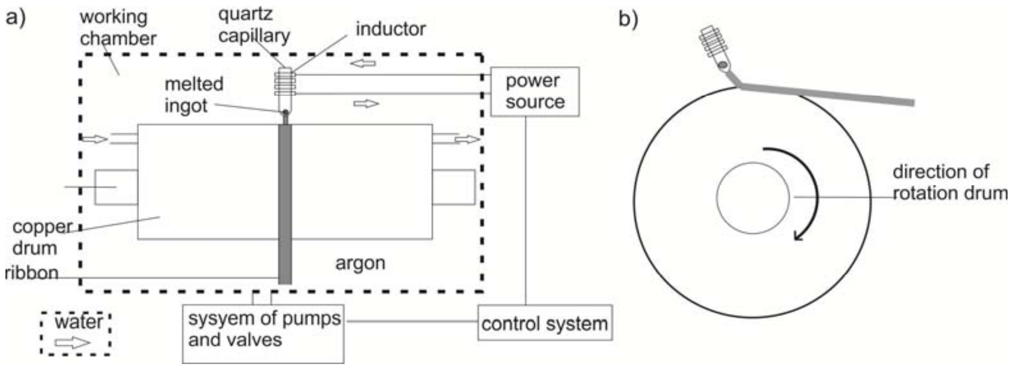

Fig. 2. Schematic production of amorphous materials by melt - spinning: a) Front view, b) Side view

The polycrystalline ingot is placed in a quartz capillary. When the chamber is closed, the chamber is pumped out. The high level of vacuum creates a reduction in the amount of oxygen present in the chamber. Due to its high reactivity, Oxygen is undesirable when producing amorphous materials. When empty, the inert gas is flushed into the chamber, most often because of the price of argon. Once the appropriate conditions have been established in the working chamber, the proper casting process is carried out. The ingot in the quartz capillary is melted by means of vortex currents. The molten feed is fed through the hole in the capillary on the rotating wheel. The material may fall gravity or be pushed out by pressure. Copper wheel is water cooled. When the liquid melt falls on the surface of the drum, it is rapidly cooled down. Having a speed of 10^6 K / s The tapes thus obtained have a width of about a few millimeters, mass production is much larger. The thickness of the produced tapes remains the same, reaching about a dozen micrometers. The thickness of the tapes often limits the possibility of their use so intensively searched for new methods of producing amorphous materials. One of these methods is to cast the liquid alloy to the copper mold using centrifugal force. The essence of the method is shown in Figure 3.

This is a rather rare method of producing amorphous materials. It can produce castings of unusual shapes. In contrast to the melt-spining method, the centrifugal method is characterized by a much lower cooling rate. Depending on the construction of the device and the mold, it is possible to achieve a cooling rate of 10^3 K/s. As with the melt-spining method, the polycrystalline ingot is placed in a quartz capillary. Also, in this case, a vacuum is produced before the amorphous melt is cast into the working chamber and then charged with argon. The charge is melted by means of vortex currents. The liquid melt exits the quartz capillary under the action of centrifugal force. Its source is the rotation of the handle with quartz capillaries [18, 19]. Confirmation of obtaining an amorphous structure can be achieved inter alia by X-ray diffraction or microscopy.

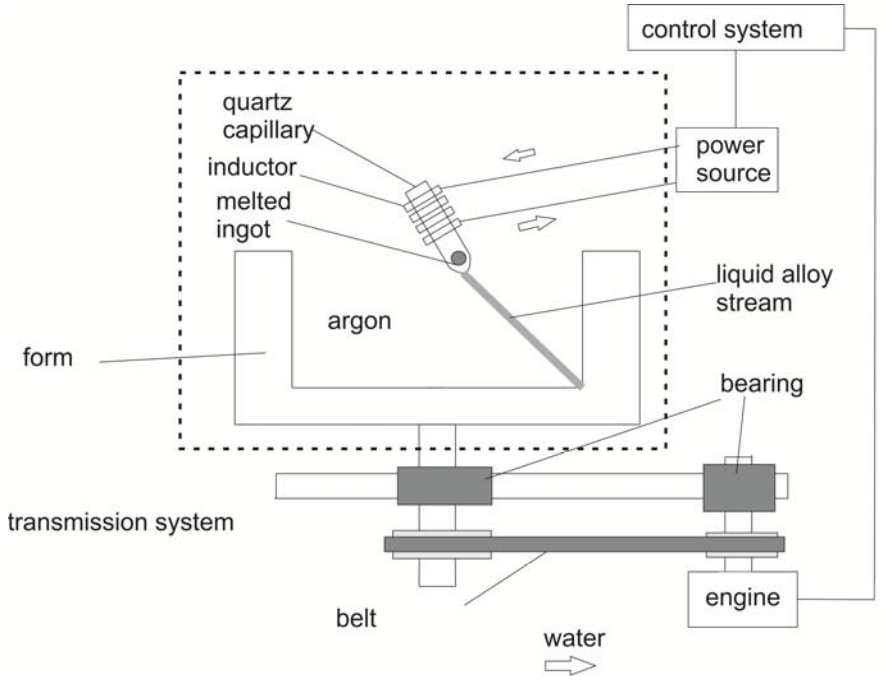

Fig. 3. Scheme production of amorphous materials by centrifugal method, side view

In the case of X-ray diffraction, the amorphous structure is characterized by a wide maximum observed on the diffraction pattern, commonly referred to as the amorphous halo. However, X-ray diffraction does not detect the presence of a crystalline phase when it is present in low concentrations. A good confirmation of the amorphous structure is the observation of the structure obtained under the scanning microscope. In case of production of amorphous materials with high iron content, the material structure can be evaluated by mossbauer spectroscopy. This method allows to indirectly evaluate the distribution of iron in the alloy. The distribution of the superfine fields allows to evaluate the environment of the iron atoms. An amorphous structure is demonstrated by the broad spectrum of asymmetric overlapping lines.

Conclusions

Amorphous materials are widely used because of their unique mechanical and magnetic properties. High saturation magnetization or low coercivity cause amorphous materials to be used in electronics and electrical engineering. An example of their use are transformer cores of high efficiency [20]. In addition, amorphous materials are used inter alia in the production of biomaterials, such as titanium prostheses. Amorphous titanium alloys are characterized by high biocompatibility and corrosion resistance [21]. Another use is the production of tennis racquets or golf clubs [22].

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