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CHARACTERIZATION OF SELECTED MG-BASED AMORPHOUS ALLOY

Abstract: This paper describes results of chosen investigations of Mg-based amorphous alloy. The amorphous structure has been verified by X-ray diffraction method, SEM observations and thermal analysis. The investigations have been done on the glassy alloy $Mg_{65}Cu_{25}Y_{10}$ in the form of plate which was obtained by copper mould pressure casting.

1. Introduction

Bulk metallic glass is an alloy of metals or metals with metalloid, which has an amorphous structure, resulting from the high rate of cooling during the casting process (transition from the liquid to the solid state without the step of crystallization).
Metallic glasses can be divided into conventional and bulk forms. Characteristic structure of crystal materials (Fig. 1a) is a repeatable arrangement of atoms in three main directions, while amorphous materials (Fig. 1b) are characterized with random distribution [1].

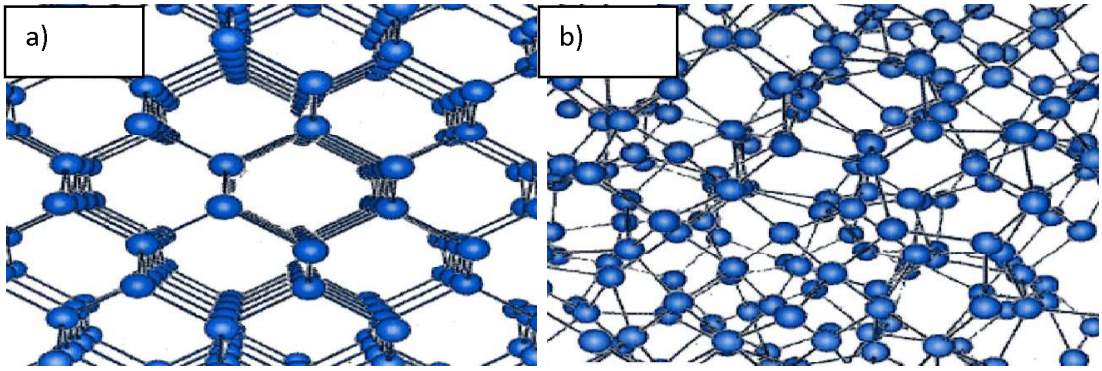

Fig. 1 Crystalline structure (a) and amorphous structure (b) [1]

The Mg-based amorphous alloys are the new group of materials, which are characterized by a high glass-forming ability, low crystallization temperature and low density.
Most of the researches were conducted using Mg-Cu-Y alloys with different alloying elements like Zn, Ni or Ag [2].

The main problem is to obtain the amorphous structure. In order to prove that the obtained structure is amorphous - XRD, microscope and calorimetric examinations are carried out.

2. Useful experimental methods

Constant knowledge development in range of materials has caused the widening and improving investigation methods. At the moment the scientists are able to examine phenomenons concerning phases occurring in alloys, atomic lattice structure, structure, revealing defects and to determine mechanical, corrosive, physical and technological properties. Used methods can be divided with regard to type of obtained results, chemical analysis, physical research, mechanical properties examination, non-destructive testing, corrosion testing, metallographic examination, X-ray crystallography. Those methods are used for structure analysis and engineering materials properties with crystalline structure.
Those research can be used also for testing the structure and amorphous material properties.
Amorphous structure research includes [3,4,5]:

X-ray examination

X-ray diffraction (XRD) concerns crystalline, polycrystalline and amorphous substances and to determine phase structure composition which occur in tested samples. This is the basic method of structure and defect material analysis. Diffraction data are obtained in form of diffractograms which depict relationship between diffraction reflection intensity and spacing between the planes d or Bragg's reflective angle 2θ. Diffractogram composes specific and unique diffraction picture of specific substance. This picture always looks the same for specific substance. Diffraction testing is carried out by the diffractometer or goniometer [6].

Scanning electron microscopy

Scanning electron microscope (SEM) is used to examine microstructure and sample analysis. This microscope has unusual resolution ability in range from 2,5 up to 5,0 nm during examination of cast samples. Additional advantage is the depth of focus which is used to examine strongly developed surfaces. Materials tests done with help of the electron microscope can be divided into three basic areas with regards to degree of sample's surface topography development. The first group are the investigations related to material decohesion and analysis of strongly developed material surfaces. Those are fractographic tests allowing to link the fracture structure with damage mechanism and material properties. Second area contains analysis of medium developed surfaces. Those are surfaces subjected to corrosion process. Third group uses high resolution ability of scanning microscope. In this case the flat surfaces are the subject of examination which correspond to surfaces of optical microscope metalographic specimens [7,8].

Thermal analysis

Thermal analysis describes changes which occur in material during temperature impact. Material under the test can undergo physical changes, like: glass-transition (vitrification), devitrification, crystallization, melting, sublimation, vaporization or boiling as well as chemical changes like: decay reaction, reduction, oxidation. These thermo-analytic investigation consist of [9,10,11]:

- TGA – Thermogravimetric Analysis, which records material mass changes,
- DTA – Differential Thermal Analysis, which bases on gradual and precisely determined heating and cooling of the sample, recording different temperatures

between test sample and a reference material where both are in the same conditions. The result of this test is the curve showing relationship between thermocouple voltage difference and temperature.

- DSC – Differential Scanning Calorimetry, which determines changes of heat stream difference of reference material during enforced temperature changes. The result of this test is the curve showing relationship between delivered heat energy into the sample and temperature.

3. Results and discussion

The investigations have been carried out on the received $Mg_{65}Cu_{25}Y_{10}$ alloy of in the form of plate (Fig. 2a) with thickness of 1 mm and width of 5 mm. This sample has been obtained by the pressure casting method of molten alloy into copper mould cooled by water. The casting process was done in the argon atmosphere.

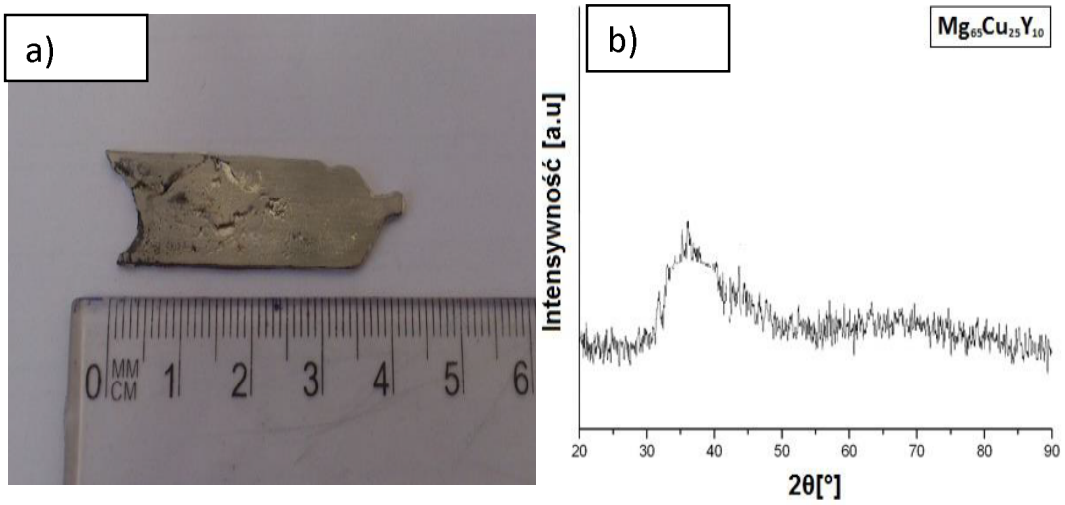

Fig. 2 External morphology (a) and XRD pattern (b) of $Mg_{65}Cu_{25}Y_{10}$ metallic glass in the form of plate

X-ray diffraction tests have been carried out by the X-ray diffractometer X'Pert Pro with cobalt anode. and showed that the test sample of $Mg_{65}Cu_{25}Y_{10}$ alloy has the amorphous structure. XRD pattern shows broad halo between 30-50° which is typical for amorphous structure of magnesium alloys (Fig 2b). What is more, single diffraction peak could be observed on the amorphous halo which may probably suggest a beginning of oxidation of prepared sample.

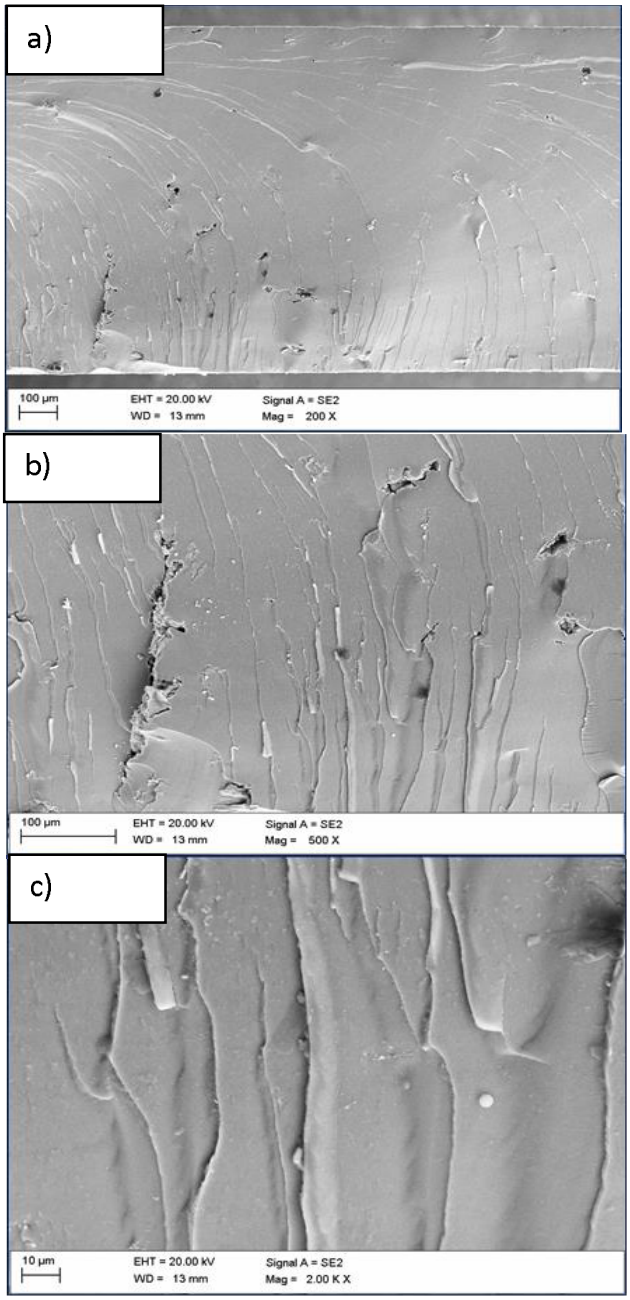

Fig. 3 Fracture morphology of $Mg_{65}Cu_{25}Y_{10}$ glassy alloy – SEM images with magnification of: a) 200x, b) 500x, c) 2000x

Figure 3 shows fracture morphology of the amorphous plates obtained by SEM observations with magnification of 200x, 500x i 2000x. On the chosen areas one can see mixed fractures as well as scaly. The scaly fractures are typical for brittle bulk metallic glasses.

DTA method was used to determine the onset (T_m) and end (T_L) of melting temperature of $Mg_{65}Cu_{25}Y_{10}$ master alloy (Fig. 4). Tests have been carried out with using Netzsch DSC 404C calorimeter in temperature range of 200 - 800 ^oC with heating rate of 10 K/min and an

argon protective atmosphere. The T_m temperature was 441°C and the T_L temperature was 583°C.

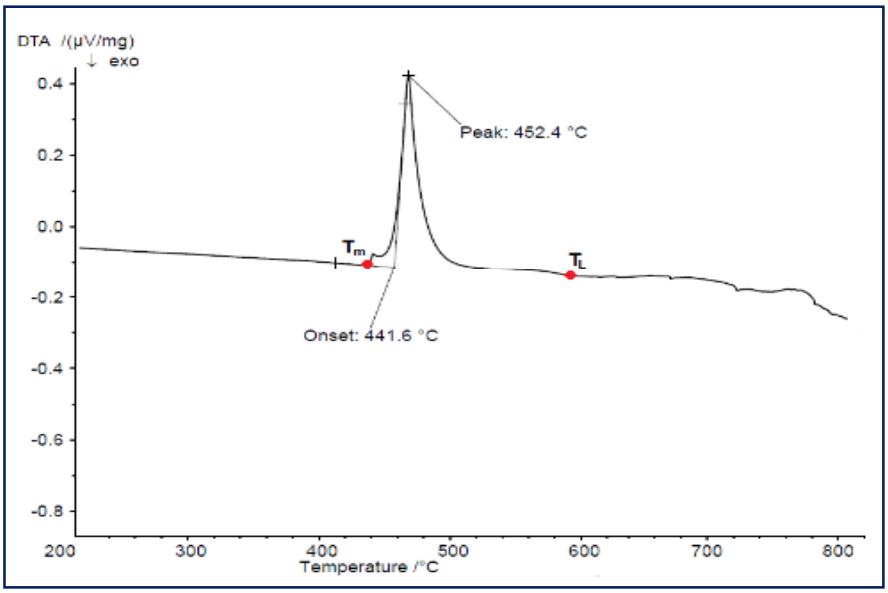

Fig. 4 DTA curve of Mg65Cu25Y10 master alloy

Similarly, DSC method (Fig. 5) method was used to determine the glass-transition (T_g), onset crystallization (T_x)and peak crystallization temperature (T_p). The investigations werecarried out using the Netzsch DSC 404C calorimeter in temperature range of 100-400°C. Measurements have been carried out in argon protective atmosphere and heating rate of 10 K/min. The T_g was 122°C, the T_x temperature was 180°C. The crystallization peak temperature equals to 188°C. Value of ΔT_x is 58°C and is similar to values showed in the literature for this alloy. ΔT_x is the difference between temperature T_x and T_g.

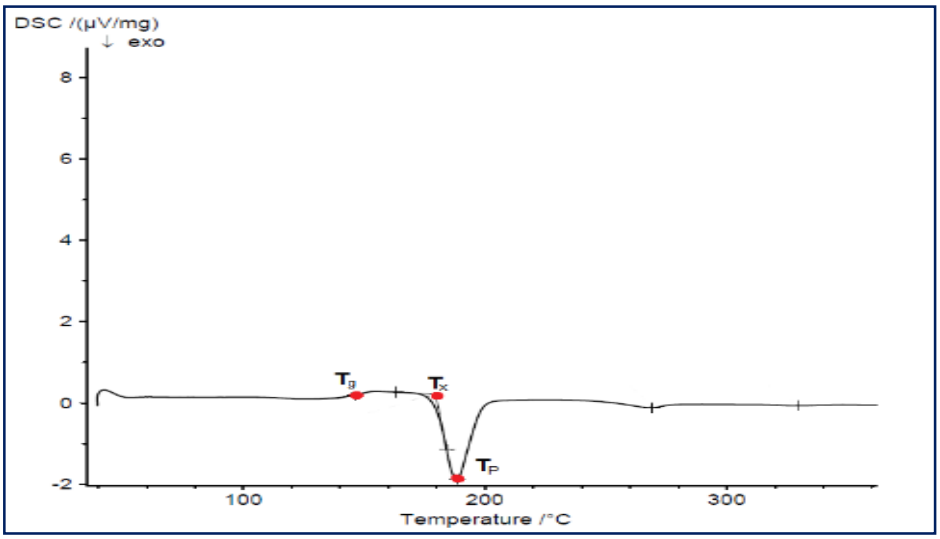

Fig. 5 DSC curve of Mg65Cu25Y10 glassy alloy

4. Conclusions

In this paper experimental methods used for verification of an amorphous structure and selected properties of $Mg_{65}Cu_{25}Y_{10}$ alloy have been described. X-ray analysis confirmed that the obtained alloy has amorphous structure. Analysis of fracture surfaces has showed the presence of scaly fractures which are typical for brittle metallic glasses. Calorimetric analysis allowed to determine the onset crystallization temperature (T_x= 184°C), crystallization temperature peak (T_p=190°C) and the glass-transition temperature (T_g=134°C).

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