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Amorphous materials in the production of new implants

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Abstract
Amorphous materials based on magnesium are new materials for potential biomedical application, especially for new implants, as they bear resemblance to titanium implants. $Mg_{66}Zn_{30}Ca_4$ alloy has specific properties, especially mechanical and corrosive, therefore, it has biomedical application as its properties are better than that of other materials. The following paper describes amorphous alloy based on magnesium, properties and shows how to produce amorphous samples of $Mg_{66}Zn_{30}Ca_4$.

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1. Introduction

In recent times magnesium based bulk metallic glasses are examined as a new group of engineering materials, which can be a potential biodegradable material with applications in medicine and especially in orthopedics. From a two-component alloy $Mg_{70}Zn_{30}$ it is possible to obtain only a bulk metallic glass in a form of bands, which limits an application of this amorphous structure alloy in medicine (SURYANARAYANA, C. 2011, NOWOSIELSKI, R. 2015).

The research area of bulk metallic glasses is very wide. Scientists undertake numerous attempts to examine bulk metallic glasses, including mechanical, thermo-physical, structural and magnetic ones. Bulk metallic glasses are called metals and their alloys, which, due to fast cooling, reach amorphous structure. Bulk metallic glasses are characterized by higher density than materials of crystalline structure and also with high durability and ductility for bending and compression (NOWOSIELSKI, R. 2015, BABILAS, R. 2013).

A group of Mg-Ca alloys is characterized by a possibility to regulate mechanical properties and biocompatibility by means of increasing or decreasing of Calcium share in an alloy. Their main disadvantage is low corrosion resistance and unfavourable mechanical qualities. The second alloy group Mg-Zn was thoroughly examined, especially by research groups from China (LEBUDA, A. 2013).

In ideal biodegradable material for an implant applied from bone fracture stabilization should assure proper fixing, complete degradation and complete replacement of a bone tissue in a fracture area. Research works for biodegradable materials are a basis for medicinal development, including materials engineering (NOWOSIELSKI, R. 2015, ZHANG, B. 2011).

Recently, magnesium based bulk metallic glasses have been examined as a new group of engineering materials, which can be a potential biodegradable material for applications in medicine, especially in orthopedics (ZHANG, B. 2011).

For the production of bulk metallic glasses, there are various methods which use rapid cooling of crystalline alloys. For the production of bulk metallic glasses there are the following methods: High Pressure Die Casting, Copper Mold Casting, Cap-Cast Technique, Suction-Casting Method. High-Pressure Die casting is the most popular and common method to produce bulk metallic glasses. The advantage of this method is rapid molding, which can achieve a high cooling rate and good contact with a 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 was designed and used by Inoue to produce Mg-based bulk metallic glasses. This method is used for the production of complex shapes, where changes in the shape of the mold allow the casting material to form of in the shape of plates (BABILAS, R. 2013, LEBUDA, A. 2013, BABILAS, R. 2013).

For this research, the alloys of the Mg-Zn-Ca system were chosen, as their quality composition meets the requirements of a biocompatible chemical composition. This allows for the complete solubility of an alloy in the tissue's environment and bodily fluids without harmful side effects on the recipient. It is also responsible for the bioactive properties of an alloy exhibited by growth of bone tissue on an implantation area (ZHAO, Y. 2008, NOWOSIELSKI, R. 2008).

2. Experimental

2.1. Materials

Three samples with composition $Mg_{66}Zn_{30}Ca_4$ were prepared using elemental cuts of magnesium (99.99% purity), zinc (99.99% purity) and calcium (99.99% purity).

2.2. Research methodology

The first step included the preparation of the pure elements Mg, Zn and Ca was to create a binary alloy in an Al_2O_3 crucible. To prepare this alloy, the induction melting method was utilized under an argon atmosphere. The two samples that were studied were produced by means of the pressure die casting method to form plates (Fig. 1).

a)

b)

Fig. 1. Samples of $Mg_{66}Zn_{30}Ca_4$ in the form of plate with 2 mm (a) and plate with 1 mm (b)

X-ray diffractometer X'Pert Pro Panalytical was used to study the structure of fabricated plates. The data of diffraction lines were recorded by the "step-scanning" method in 2θ range from 20° to 100° and with 0.013° step.

Particle size and shape of $Mg_{66}Zn_{30}Ca_4$ sample fractures were characterized by means of the scanning electron microscopy (SEM), SUPRA 25 ZEISS, with magnification up to 2000x.

3. Results and discussion

3.1. XRD

X-ray diffraction tests were carried out with the X-ray diffractometer X'Pert Pro with cobalt anode. Figure 2 a and b showed that the test sample of Mg66Zn30Ca4 alloys has an amorphous structure. XRD pattern shows a broad halo between 30-50°, which is typical for amorphous structures of magnesium alloys.

a)

b)

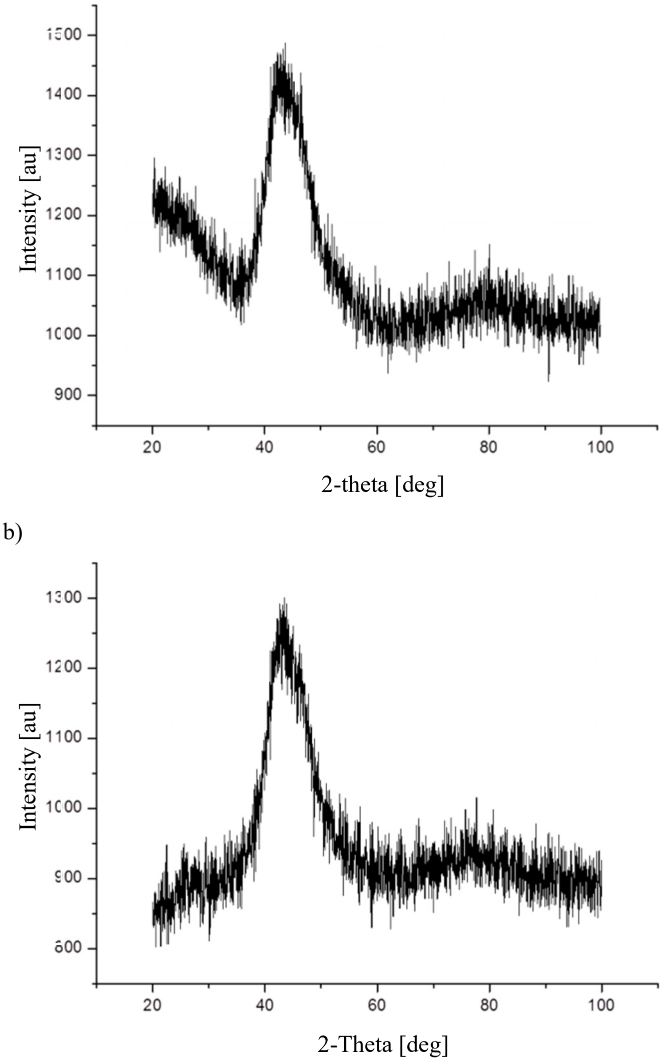

Fig. 2. Plate 2mm (a) and plate 1mm (b)

3.2. SEM

Fractographic investigations of the sample fracture surfaces (Fig. 3) reveal that they are characterized by the mixed mode morphology. Both areas characteristic of fracture morphology called "smooth" and "flake-like" fractures are visible. The areas of "flake-like" morphology are characteristic for hard and brittle alloys. These properties are typical for bulk metallic glasses based on magnesium. Photographic analysis establishes that investigated fracture surfaces have an appearance characteristic of an amorphous material.

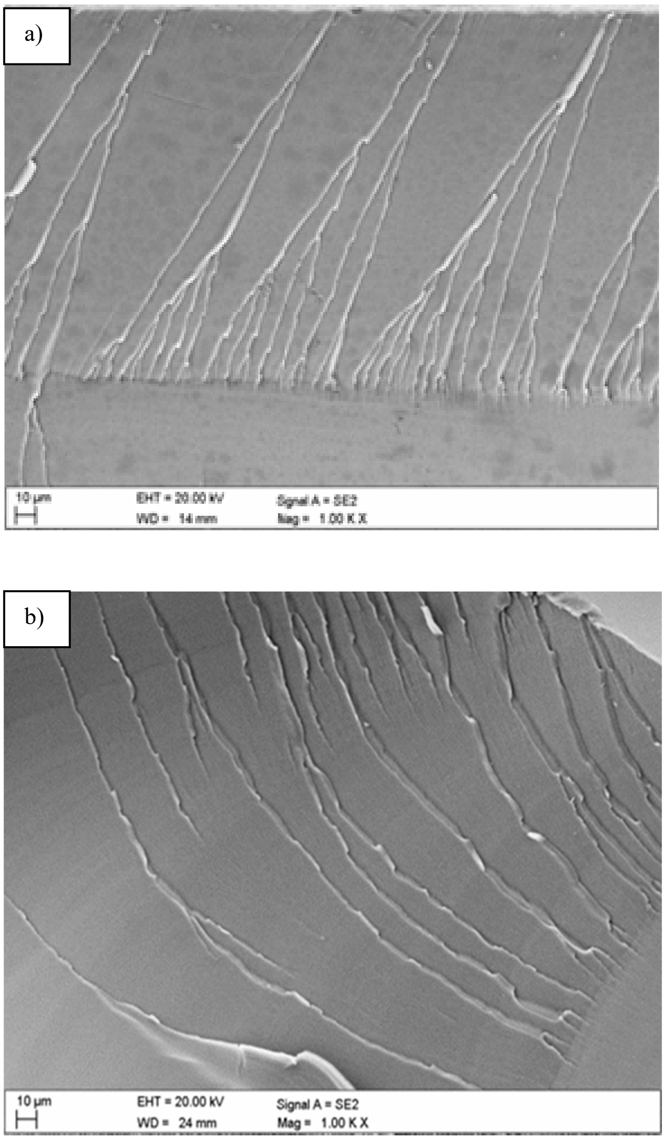

Fig. 3. Fracture morphology sample in the form of plates – SEM images of magnification a) 1000x (plate 1); b) 1000x (plate 2)

3.3 Corrosion

Corrosion test samples of the amorphous alloy $Mg_{66}Zn_{30}Ca_4$ were held at a constant temperature of 37°C for 24 hours (Fig. 4). The burette was filled with Ringer's solution and shut-off valve. The samples were placed in a sealed vessel. The vent valve was fixed in a closed traffic silicone tap to assure no air bubbles would enter the vessel with the samples, which could have caused uncontrollable changes to the liquid level.

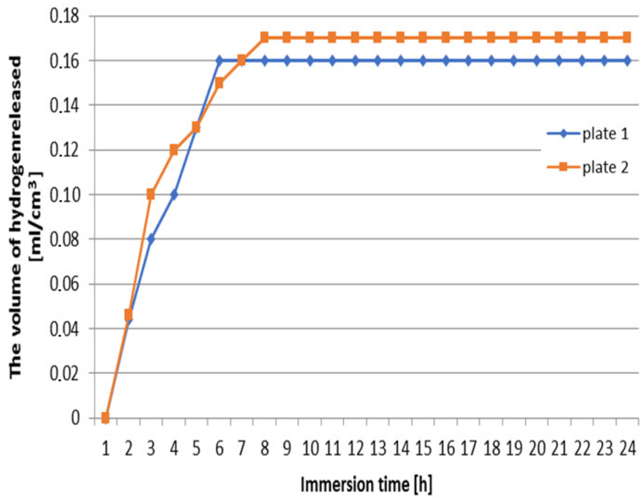

Fig. 4. Corrosion tests samples of the amorphous alloy $Mg_{66}Zn_{30}Ca_4$

4. Summary and conclusion

1. Samples of bulk metallic glass in the form of plates were generated.
2. X- ray investigations confirmed that the samples have an amorphous structure.
3. Fractographic investigations of fracture surfaces indicated the presence of "flake-like" fractural morphology, which is characteristic of brittle materials, and a property characteristic for Mg-based bulk metallic glasses.
4. The research submersible cast magnesium alloy plates Mg66Zn30Ca4 with amorphous structure showed that the samples have a uniform amorphous release of hydrogen.
5. Based on tests we can use amorphous materials for biomedical application.

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新型植入物生产中的无定形材料

關鍵詞
非晶材料
镁
散装金属玻璃
植入物
腐蚀测试

摘要
基于镁的无定形材料是潜在的生物医学应用的新材料，特别是对于新的植入物，因为它们与钛植入物具有相似性。Mg66Zn30Ca4合金具有特殊的性能，特别是机械和腐蚀性，因此它具有生物医学应用性能，因为它的性能优于其他材料。以下论文描述了基于镁的非晶合金的性能，并展示了如何生产Mg66Zn30Ca4的无定形样品。