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Development of Zirconium-based alloys with low elastic modulus for Next-generation Implants bio-materials

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1. Introduction

Today, metallic materials have good biomechanical properties and suitability for general sterilization processes in the biomaterials industry, and they have a great influence on the biomaterial field compared to other materials because they have excellent mechanical properties and corrosion characteristics. Biomaterials are widely used due to the aging population, and metallic materials such as gold, stainless steel, Ti, Co-Cr alloys, and Ni-Ti alloys are used. Ti and Ti-6Al-4V alloys are metallic materials commonly used in dental implants, artificial joints, and plate. However, recent studies have shown that both Al and V ions can cause long-term health problems [1-2]. In addition, currently commercialized metallic biomaterials have a higher magnetic sensitivity and elastic modulus, resulting in artifacts due to image distortion and phase difference in MRI diagnosis of implants. These artifacts are a major obstacle to the diagnosis of patients [1-2]. The difference in elastic modulus between the metallic biomaterial and the natural bone resulting in a stress shielding effect that causes bone resorption. Recently, zirconium alloys with great mechanical properties, low magnetic susceptibility and elastic modulus similar to natural bone have attracted great interest.

2. Experimental details

The zirconium-based alloys were produced by arc-melting process with pure zirconium (99.9 mass%), oxygen free copper, silicon, and tin (99.99 mass%) in an argon gas atmosphere. The homogenization treatment was carried out through about 6 re-melting. The microstructure was observed using optical microscopy (OM) and scanning electron microscopy (SEM). The polishing was carried out up to 4000grit of emery paper, followed by fine polishing with alumina paste (0.05 ㎛). In this study, the test materials were prepared with ternary alloys of Zr-7Si-xSn, Zr-7Cu-xSn alloys (x = 1,5, 10, 15).

3. Results and Discussion

Fig. 1 shows the microstructure of the Zr-7Cu-xSn alloys. The α-Zr phase and Zr_2Cu intermetallic compound were observed. Fig. 2 shows the microstructure of the Zr-7Si-xSn alloys. the α-Zr phase and Zr_2Si intermetallic compound were observed. The diffraction patterns of ternary alloys were analyzed by XRD analysis at 40kV and 30mA with CuKa radiation. The α-Zr phase and intermetallic compounds, such as Zr_2Cu and Zr_2Si were identified in each alloys. Mechanical properties were confirmed by micro Vickers hardness test and compression test. The compressive strength of Zr-7Cu-xSn alloys was 850-1200 MPa. For Zr-7Si-xSn alloys, the compressive strength was 800-1600 MPa. In both ternary zirconium-based alloys, the elastic modulus was 14-25 GPa, which is the same level with the natural bone (15-30 GPa).

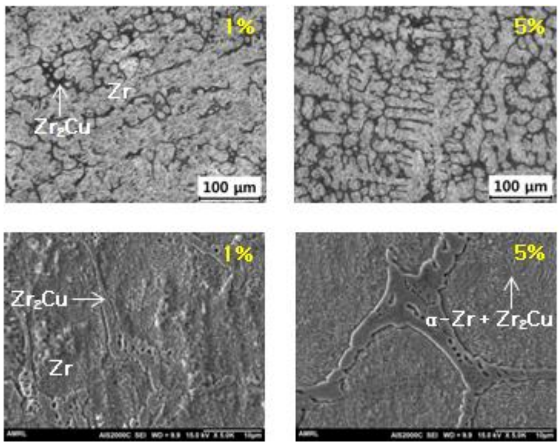

Fig. 1. OM micrographs and SEM micrographs of zirconium-base alloys; Zr-7Cu-xSn (x = 1, 5 wt%)

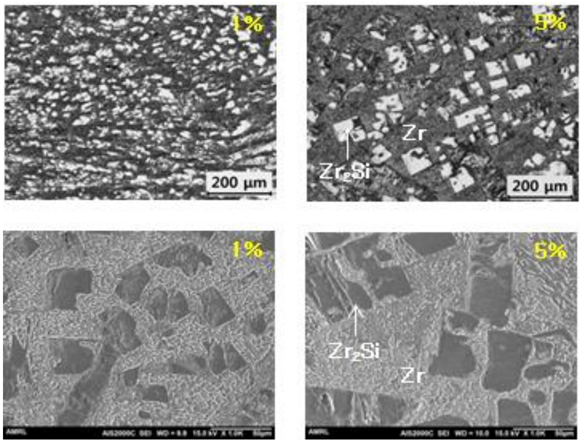

Fig. 2. OM micrographs and SEM micrographs of zirconium-base alloys; Zr-7Si-xSn (x = 1, 5 wt%)

4. Conclusions

The following conclusions were drawn by designing and fabricating a zirconium-based alloys, which is a metallic biomaterial with high utility as a biomaterial.

1. It has investigated that the cast zirconium- based alloys are composed of two phases. The two phases structure of α-Zr and Zr_2Cu in the Zr-7Cu-xSn alloys and α-Zr and Zr_2Si in the Zr-7Si-xSn alloys were evaluated.

2. As the Sn content increased, the Zr_2Cu phase and the Zr_2Si phase became larger and changed into a plate shape. The compressive strength increased with the Sn addition increase at each alloy but the elongation decreased significantly.

3. The zirconium-based ternary alloys have a lower elastic modulus about 14-25 GPa than the commercialized metallic biomaterials. It is the same level with the natural bone (15-30 GPa) So that stress shielding effect can be overcome.

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