Low Magnetic Susceptibility Zr-Nb Alloys to Prevent Artifacts in MRI

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Statement of Purpose: Magnetic resonance imaging (MRI) is used as an important diagnostic tool for whole-body, especially for brain. This method has advantages in non-invasion and no exposure to radiation for the human body. However, images of organs and tissue are disturbed around metallic implants and artifacts occur in intense magnetic field of MRI instruments [1]. On the other hand, over 70% of implant devices consist of metals because of their high strength, high toughness and good durability, while magnetic susceptibility of metals is still relatively large. Therefore, metals show a low magnetic susceptibility or antimagnetic materials are required for medical devices and instruments for operations and treatments used under open MRI. Among various pure metals, Zr possesses low magnetic susceptibility compared to Ti, Co and Fe alloys. In addition, it is reported that Zr-Nb alloys show good mechanical properties, corrosion resistance [2] and constituent elements show low toxicity [3]. Thus, Zr-Nb alloys are one of the promising alloy systems for preventing artifacts under MRI. The purpose of this study is to investigate the relation between magnetic susceptibility and composition of Zr-Nb alloys. Effects of the microstructure on magnetic susceptibility of the Zr-Nb alloys were also investigated. These researches will enhance the development of Zr alloys that prevent artifact under MRI.

Methods: Zr-Nb alloys were prepared with arc melting furnace as button ingots under high purity argon atmosphere. The ingots were cast using casting machine to rods with 3.2 mm in diameter and 30 mm in length. This dimension was the inner size of a test tube for magnetic susceptibility balance. The amount of Nb in the alloy was changed from 0 to 100 mass%. The magnetic susceptibility was measured with the magnetic susceptibility balance. Microstructure of Zr-Nb alloys were characterized by fluorescent X-ray analysis(XRF), optical microscope(OM), scanning electron microscope(SEM), energy dispersive X-ray spectroscopy(EDS), X-ray diffraction(XRD) and transmission electron microscope(TEM). The TEM specimens were prepared by twin-jet electropolisher in a solution of H_2SO_4 and C_2H_5OH after a mechanical thinning to about 100μm.

Results: Fig.1 shows the relation between magnetic susceptibility and Nb content. Magenetic susceptibilities of Zr once decreased with the increase of Nb content and showed minimum value from 3 mass% to 9 mass% Nb, followed by the increase of the value with the increase of Nb content. From the XRD profiles and TEM observation, the□ phase (bcc) was confirmed in Zr-6Nb, Zr-9Nb and Zr-20Nb alloys. In addition, the α phase and ω phase were identified from XRD result of Zr-6Nb and Zr-9Nb. In particular, the orientation relationship between the α and βphase was confirmed to be the Burgers' relationship in Zr-6Nb alloy. Furthermore, three constituent phases of α phase, βphase and ω phase were detected in Zr-9Nb. The total magnetic susceptibility of a system of two components depends on the magnetic susceptibility of additional elements and its additive amount [4]. However, the amount of Nb changed from 3 mass% to 9 mass%; this result did not follow the above though the amount of Nb increased. These results indicate that the concentration of Nb and/or its constituent phase affect the magnetic susceptibility of Zr-Nb alloys.

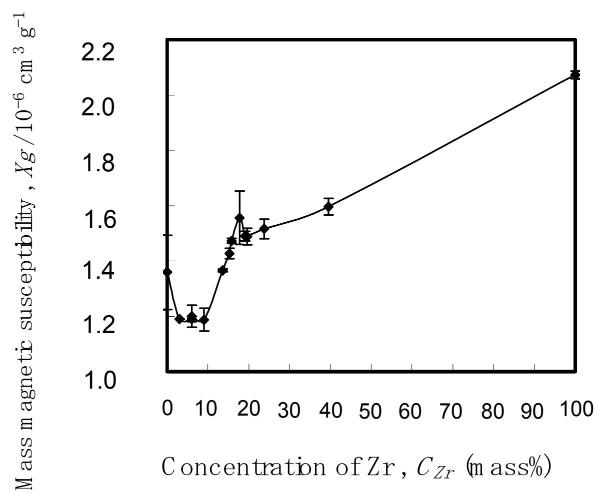

Figure 1. Composition dependence of mass magnetic susceptibility of Zr-Nb alloys.

Conclusions: Mass magnetic susceptibility of Zr-Nb alloy showed minimum value from 3 mass% to 9 mass% Nb. The phase constitutions of Zr-Nb alloys were complex from 3 mass% to 9 mass%, while in 20 mass% Nb, the phase constitution was not complex. The phase constitution may affect the magnetic susceptibility.

References:

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