Enhancing Corrosion Resistance of Mg Implant via Surface Anodization for Biomedical Applications

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Statement of purpose:

Magnesium has a great potential as a bioimplant material, because Mg ion is an essential mineral for human body and its mechanical properties such as elastic modulus and specific gravity are similar to those of human bones. Moreover, the degradability of magnesium is a big advantage for bioresorbable implants. The degradation property of magnesium, however, could be a drawback to its chemical and mechanical stability. In a physiological condition containing Cl^-, pure magnesium corrodes too rapidly, leading the local pH increase and hydrogen gas accumulation which ends up with alkaline poisoning near the implant surface [1]. To control the degrading rate, various surface modifications are suggested and anodization is found to be one the most effective methods [2]. In this study we conducted anodization under new conditions and subsequently heat treated them to enhance their corrosion resistance.

Methods:

Pure magnesium specimens with dimensions 30 x 20 x 3 mm were cut from extruded plates and polished with SiC papers. The anodization process was performed in an electrolyte containing 300 mL of 4M KOH + 0.4M KF + 0.21M Na_3PO_4 for 20 min at 25℃. Anodization started with constant current density of 15mA/cm^2 and when the voltage reached 70 V constant voltage was maintained. The anodized sample was heat treated for 2 h at 200, 300 and 400℃. The surface morphology and composition were examined by scanning electron microscopy (SEM) and x-ray photoelectron spectroscopy (XPS), respectively. *In vitro* cell tests were carried out using pre-osteoblast cell lines (MC3T3-E1) to evaluate their biocompatibility.

Results:

The images of the anodized surface and its cross-section are shown in Fig. 1. The pore size was approximately 0.3 μm and the average thickness of the layer was 0.6 μm. Anodized layer was thinner and less porous than previous reports [3-4]. An XPS spectrum shown in Fig. 2 indicates the main component of anodized layer. The calibrated peak binding energy is 49.4 eV, implying that there is a O-H bonding (49.5 eV, pure Mg : 49.8 eV). The result of *in vitro* MC3T3 cell adhesion tests to compare anodized layer with pure magnesium surfaces is shown in Fig. 3. After culturing for 5 h, pre-osteoblast cells spread better on the anodized oxide layer, compared to those on the pure magnesium, indicating that anodized layer is effective in reducing degradation rate and also it is biocompatible than pure surface.

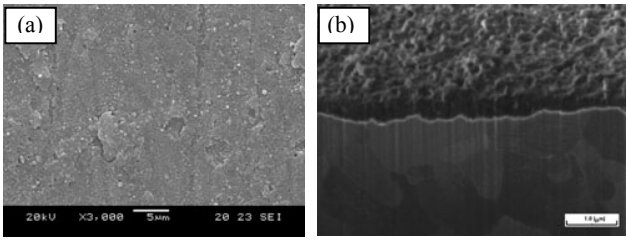

Fig 1. (a) Surface morphology and (b) cross-section image of anodized magnesium, investigated by SEM and FIB, respectively. The average oxide film thickness is 0.6 μm.

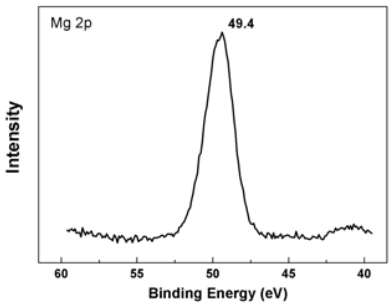

Fig 2. XPS spectrum of anodized magnesium surface.

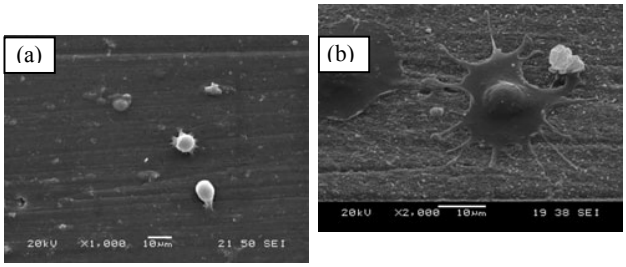

Fig 3. Initial MC3T3 cell adhesion image of (a) pure magnesium and (b) anodized magnesium after culturing for 5 h.

Conclusions:

In order to control the biodegradation rate of pure magnesium, new electrolyte composition and anodizing condition were introduced. After anodization, uniform and thin $Mg(OH)_2$ layer was formed. According to the cell adhesion test, this anodized layer is effective in reducing the degradation rate. Subsequent heat treatment was also effective in enhancing the corrosion resistance of magnesium surface.

References:

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[2] Song GL. Corros Sci. 2007; 49:1696-1701
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