INVESTIGATING THE EFFECT OF CONDUCTING POLYMER GRAPHENE OXIDE COMPOSITE ON MAGNESIUM CORROSION

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INTRODUCTION

Conventional medical devices require the use of materials which have been experimentally proven to be corrosion resistant when placed within certain fluids. However, biodegradable materials are being considered for applications where temporary medical device placement is desired(1). Magnesium (Mg) is a very promising material for an array of biomedical applications including vascular, musculoskeletal, and general surgery due to its excellent physical and chemical properties(2). However, the issue with biodegradable Mg is its rapid degradation, non-uniform corrosion, and the associated by-products inside human body(2). Mg corrodes in aqueous environment via an electrochemical reaction as follows:

\[ \text{Mg} + \text{H}_2\text{O} \rightarrow \text{Mg(OH)}_2 + \text{H}_2 \]

Based on the products of corrosion reaction, it is known that a higher Mg ion concentration as well as a higher hydroxide ion concentration in the corrosion solution suggest a higher corrosion rate for the Mg. There are currently several ways to minimize the corrosion of Mg implants such as magnesium-based alloys(2), anodization(3), and organic coatings(4). Despite promising results, each of these techniques has disadvantages for biomedical applications(2)(3)(4).

Fortunately, there has recently been promising work with conducting polymers for controlling corrosion on non-Mg metals(4)(5). There has however been little study of conducting polymers for Mg corrosion protection. Studies have suggested that conducting polymer acts as a physical barrier and it also displays the property of anodic protection during the corrosion prevention(6). More importantly, conducting polymer can reduce the generation of hydrogen gas, which is the main reason for poor implant integration(6).

OBJECTIVE

A conducting polymer coating consisting of poly 3,4-ethylenedioxythiophene (PEDOT) doped with negatively-charged graphene oxide (GO) was electropolymerized on the surface of Mg. The objective of the study was to test how PEDOT-GO coatings would affect the Mg corrosion using pH test and Mg ion assay.

HYPOTHESIS

Based on the promising results from previous studies on conducting polymer for corrosion control, the hypothesis was that Mg coated with PEDOT-GO would have a lower corrosion rate than the uncoated Mg.

METHODS

Mg ribbon (20mm*3mm*2mm) was cut and cleaned with ethanol. Polymerization solution consisting of 20mg GO mixed and 2mL ethanol was sonicated for 30 minutes. 40 ul EDOT and 70 ul deionized water were then added to the sonicated polymerization solution. Mg specimens were coated with PEDOT-GO film on a Garmy potentiostat/femtostat with a constant potential of 0.7 volts over 400 seconds using a two electrode setup. Coated Mg specimens were then dried in the freezer for 2 days.

pH test and Mg ion assay were carried out in phosphate buffer saline solution (PBS) with standard surface area to volume ratio 1:50 (cm²:ml). The immersion solution was replaced with the fresh PBS every day. The uncoated part of Mg specimens was mounted in epoxy to ensure that only the coated area was exposed to the PBS solution for both tests. pH of each PBS solution was measured with pH sensor every day. For Mg ion assay, 10 ul extract was added to 200 ul Magnesium Liquicolor assay (Xyldyl blue) reagent and was allowed to react for 10 minutes. The absorbance value was read from spectrophotometer and the corresponding concentration was calculated according to the calibration curve.

RESULTS

The results of the pH test are shown in Fig 1. The error bars represent standard deviation for each group (n=3). In the Fig.1, we can see a decreasing trend in the pH for both the coated and uncoated Mg during 4 day immersion with the coated Mg showing a lower pH than the uncoated Mg. Since a lower pH indicates a lower hydroxide ion concentration, the
result from pH test suggests that PEDOT-GO coating decreased the corrosion rate of Mg.

Fig.1 The pH of immersion solution during 4 day immersion (n=3)

The results of Mg ion assay are shown in Fig 2. From this figure it can be seen that there is decreasing trend of Mg ion concentration for both coated and uncoated Mg as the immersion time increased. For all readings except Day 1, the coated samples showed a decreased total amount of Mg ion in the corrosion solution compared to the uncoated Mg. The decreased Mg ion concentration from Day 2 through Day 4 for the coated samples indicates that the coating decreased underlying Mg corrosion.

Fig.2 The Mg ion concentration of immersion solution during 4 day immersion (n=3).

DISCUSSION

The result from both the pH test and the Mg ion assay converge to the same conclusion that Mg coated with PEDOT-GO has a lower corrosion rate than the uncoated Mg supporting the original hypothesis. However, during the experiment it was observed that some coatings had a high delamination level while others remained relatively intact which suggests that there were still variations between the coatings. Therefore in next step, more consistent coatings should be obtained using charge controlled electropolymerization instead of voltage control. This will ensure there is the same amount of charge used to deposit the polymer on the surface of the Mg and therefore each coating will have the same thickness. Also in vivo tests can be conducted to investigate the performance of Mg coated with PEDOT-GO in the actual physiological system. The proposed tests will help further verify the effectiveness of PEDOT-GO coatings which show great promise for controlling Mg corrosion in the biomedical applications.

REFERENCES


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