Self-assembling alkyl-silane anticorrosion coatings for resorbable Mg devices

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INTRODUCTION: Magnesium (Mg) and its alloys represent promising candidates for transient orthopedic devices[1]. Mg is highly biocompatible, since Mg^{2+} is one of the essential ions and is present naturally in the body. It is also low weight and has mechanical properties compatible to bone. One of the obstacles for use of Mg in clinical application is its initial massive corrosion reaction leading to the formation of gas pockets around the implantable devices. To regulate the rate of corrosion we propose to use self-assembled alkylsilane (AS) coatings. Such coatings decrease the rate of corrosion by isolating a metallic devise from the liquid environment. Importantly, the surface chemistry and biological activity of AS coatings can be modified via covalent attachment of molecules of interest to the coating.

METHODS: Mg disks (99.9% purity) were polished and etched with HNO_3 and some of them were passivated with NaOH prior to the coating procedure. Amphyphilic AS decyltriethoxysilane (DTES) and tetramethoxysilane (TMOS) were co-polymerized for 90 min and the Mg disks were dip-coated in the solution and dried at 37°C. Some of the coatings were aminated with 3-Aminopropyl-triethoxysilane (APS). Corrosion dynamics was assessed using H_2 evolution method and potentiodynamic polarization as described elsewhere[2]. Scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS) characterization of the coatings was conducted to assess their structural integrity. MC3T3 cells were cultured on the AS coated Mg disks for 15 days under routine tissue culture conditions.

RESULTS: The SEM revealed a homogeneous smooth 1 µm thick AS film covering entire area of the disk (Fig. 1A). Analysis of the scratch made with a razor blade has revealed a laminar structure of the layer. H_2 evolution analysis showed that AS coating has dramatically decreased the rate of corrosion (Fig. 1B). Similarly the potentiodynamic polarization experiments demonstrate almost 2 orders of magnitude reduction in Icorr from 995 $\mu A/cm^2$ for bare Mg to 12.5 $\mu A/cm^2$ for AS coated and aminated samples. Contact angle measurements show that AS coating is hydrophobic (120° for the coated sample vs. 60° for bare Mg). However, when AS coatings were functionalized with APS the contact angle decreased to 70°. The results of the tissue culture studies demonstrate that cells survive for 2 weeks on the surface of AS coated Mg disks (Fig. 1C). The analysis of the coating surface after 2 weeks in the cell culture conditions revealed that the surface of the coating has cracked leading to a cobblestone appearance, however by and large the coating remained on the surface of the metal (Fig 1.C,D).

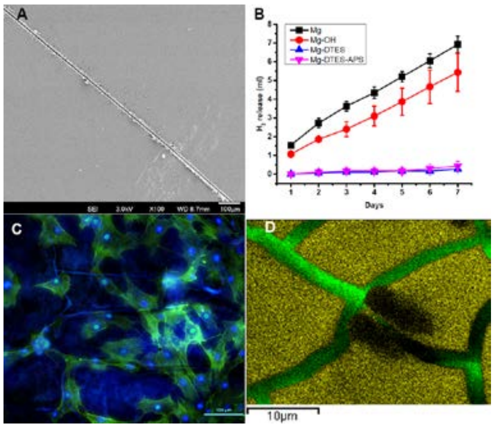

Figure 1. Figure1.A SEM micrograph of an AS coated Mg disk, scratched with a razor blade. B H_2 evolution profiles of bare (black); NaOH passivated (orange), DTES coated (blue) and DTES/APS coated (magenta) Mg disks. C. Epifluorescence micrograph of MC3T3 cells cultured for 14 days on the DTES/APS coated Mg disks. Blue lines in the background correspond DAPI stain absorbed in the cracks. Green- F-actin IF; Blue DAPI staining. D. EDS map of an AS caoated Mg disk after 2 weeks in the tissue culture. Green- Mg K edge, Gold- Si K edge.

DISCUSSION & CONCLUSIONS: The resuts of our study demonstrate that self-assembled AS coatings can provide a viable solution for the regulation of the corrosion rates of the implantable Mg devices. Furthermore, these coatings can support cell attachment and proliferation.

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