Biodegradable metallic zinc alloys for biomedical applications

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ABSTRACT

Biodegradable metals, such as zinc (Zn) appear to overcome some of the drawbacks of permanent metallic implants. However, the uncontrolled biodegradation of Zn-alloyed materials is still a concern for biomedical applications compromising biocompatibility and mechanical properties. In this work, two strategies based on severe plastic deformation or polymeric coatings are evaluated to overcome degradation drawbacks.

Cold-rolled Zn-0.5Mg and Zn-2Ag bars (Goodfellow, UK) were modified as follows: (1) ECAP was performed to the bars, supplying an equivalent strain of 0.76 each pass; (2) PCL was dissolved in chloroform and spin-coated onto the surfaces. The microstructure was observed by SEM/EDS and EBSD. Tensile and nanoindentation tests were performed. The corrosion was studied by PDP and EIS.

Fig. 1 shows the microstructure of the as-received alloys. Ultra-fine grain structure was achieved after ECAP (Fig. 2), providing superplastic behavior to the Zn-2Ag alloy (elongation over 200 %). Nanoindentation maps showed similar hardness distribution after ECAP. PCL-coated samples presented a noteworthy decrease in current density (from 15 μA/cm^2 down to 0.5 μA/cm^2), and EIS confirmed the effect of the PCL layer with a higher impedance modulus.

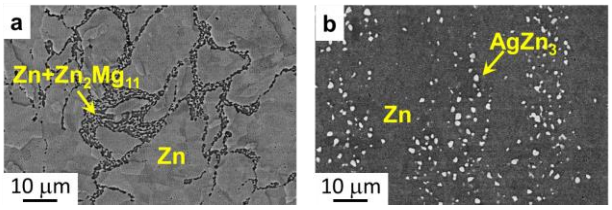

Fig 1. SEM micrographs of (a) Zn-0.5 and (b) Zn-2Ag.

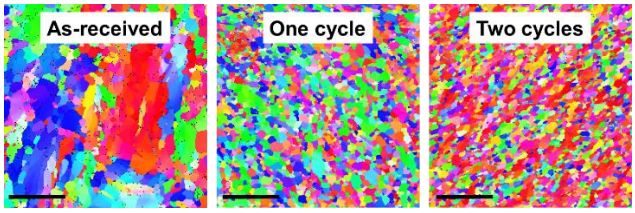

Fig 2. EBSD images of Zn-2Ag after ECAP. Scale bar 10 μm.

The influence of the secondary phases on the mechanical reinforcement of Zn was previously studied [1]. However, their presence also forms galvanic pairs and favors localized corrosion, which could provoke the future cracking of the implant. Regarding this, our study showed that PCL coating delays early degradation, while the refined microstructure obtained after ECAP homogenizes further corrosion. Both approaches can be used to control corrosion at different degradation timepoints, fundamental for the proper biointegration of the Zn-based implants.

[1] C. García-Mintegui, L. C. Córdoba, J. Buxadera-Palomero, et al. Bioactive Materials, 6 (2021).