Effect of PEO-coatings in hybrid Zn-Mg alloys processed through high-pressure torsion

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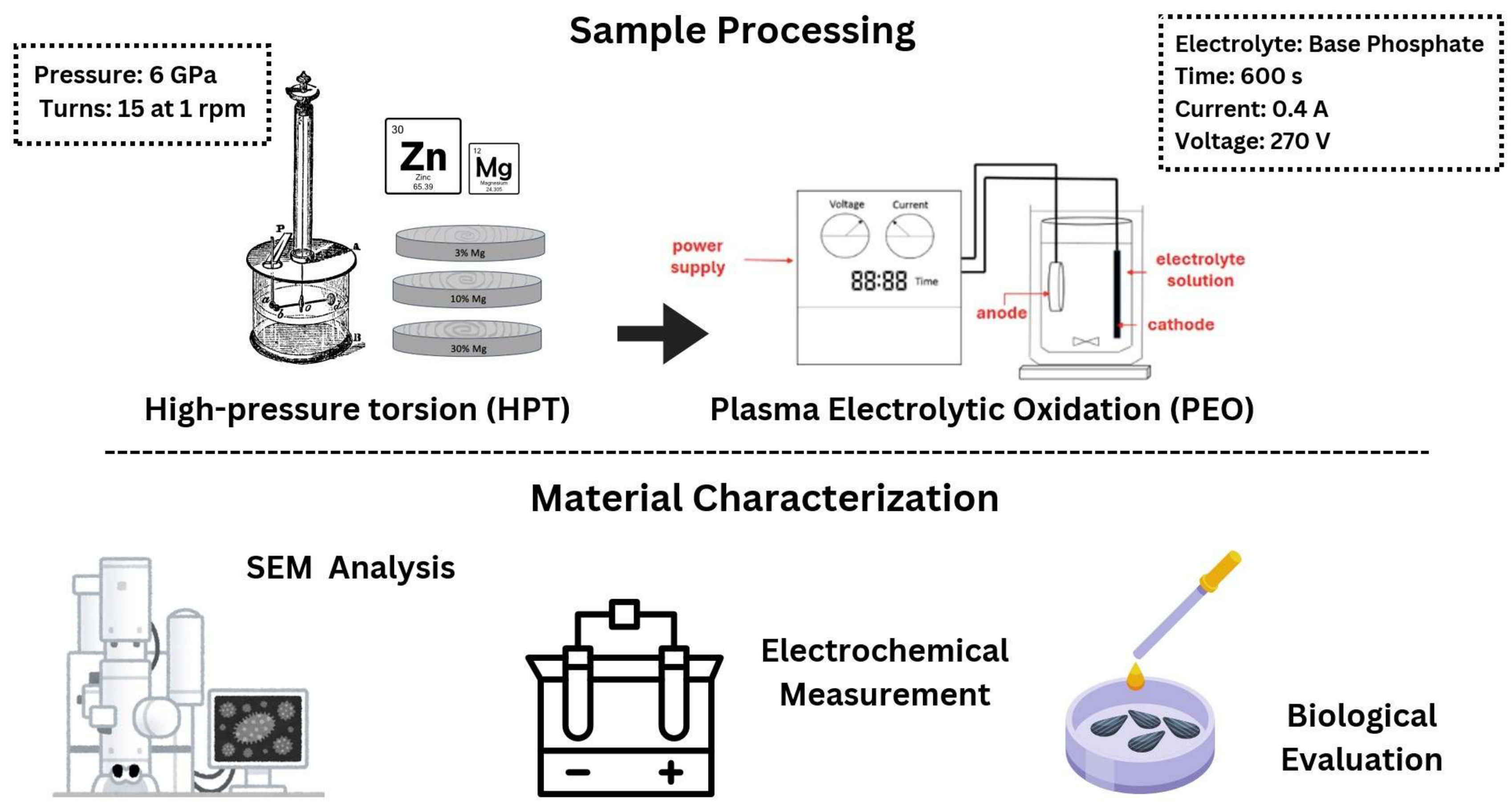
Introduction

Zn is a biodegradable metal with intermediate corrosion rates between Fe and Mg. Still, it is the least studied to date, and the *in vivo* effects in the medium/long term still need to be fully understood. Studies so far have shown that Zn has good corrosion resistance and acceptable biocompatibility. Still, significant concerns have been raised due to its poor mechanical strength, aging at room temperature, creep effects, and high sensitivity to strain rate[1]. Some preliminary studies supported that incorporation of Mg for Zn-alloys can improve the performance of the material in terms of corrosion resistance[2].

Additionally, the processing of the material can have a strong effect on the microstructural composition and the mechanical properties. High-pressure torsion (HPT) is widely used as a severe plastic deformation technique to create ultrafine-grained structures[3]. Alternatively, using coatings is another strategy to enhance the performance of degradable materials. Plasma electrolytic oxidation (PEO) is a technique in which the material is oxidizing in a controlled way[4]. The synergic combination of these two techniques is expected to obtain a strong candidate for biomedical implants.

This study aimed to evaluate how the amount of Mg in hybrid samples processed through high-pressure torsion alters the PEO process

Experimental Design



Results

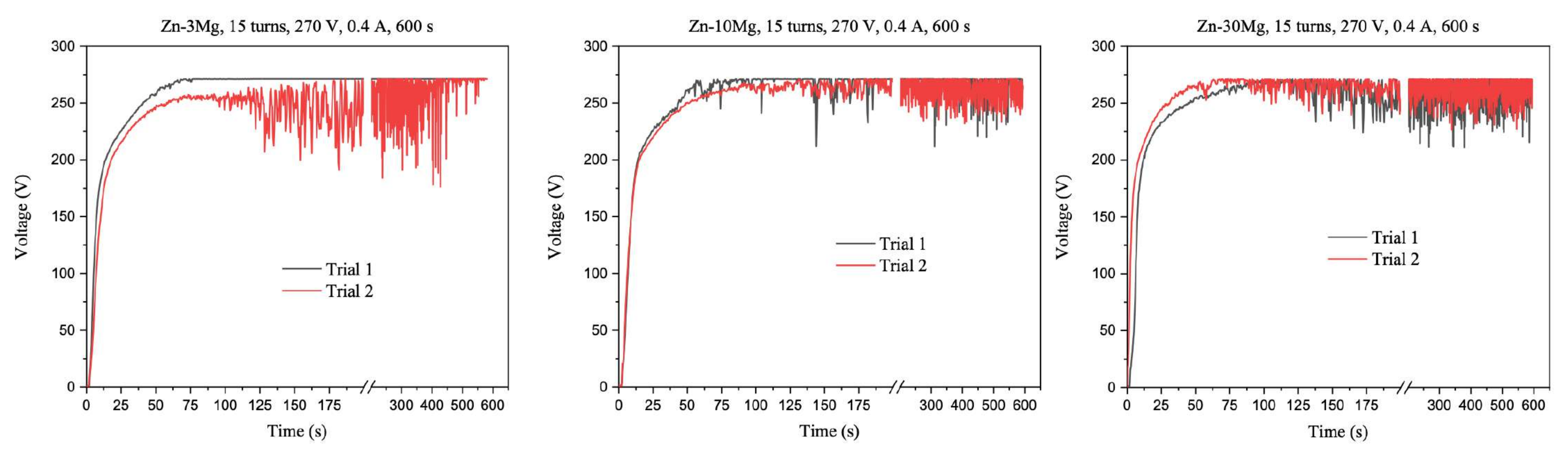


Fig.1: Voltage-time curves for the PEO process

The working parameters of the PEO were optimized until reproducible coatings were obtained (Fig.1). The Zn-3Mg sample showed the best results in terms of homogeneity. Due to the large portions of Mg in the Zn-30Mg samples, a difference in thickness was observed in Fig.2.

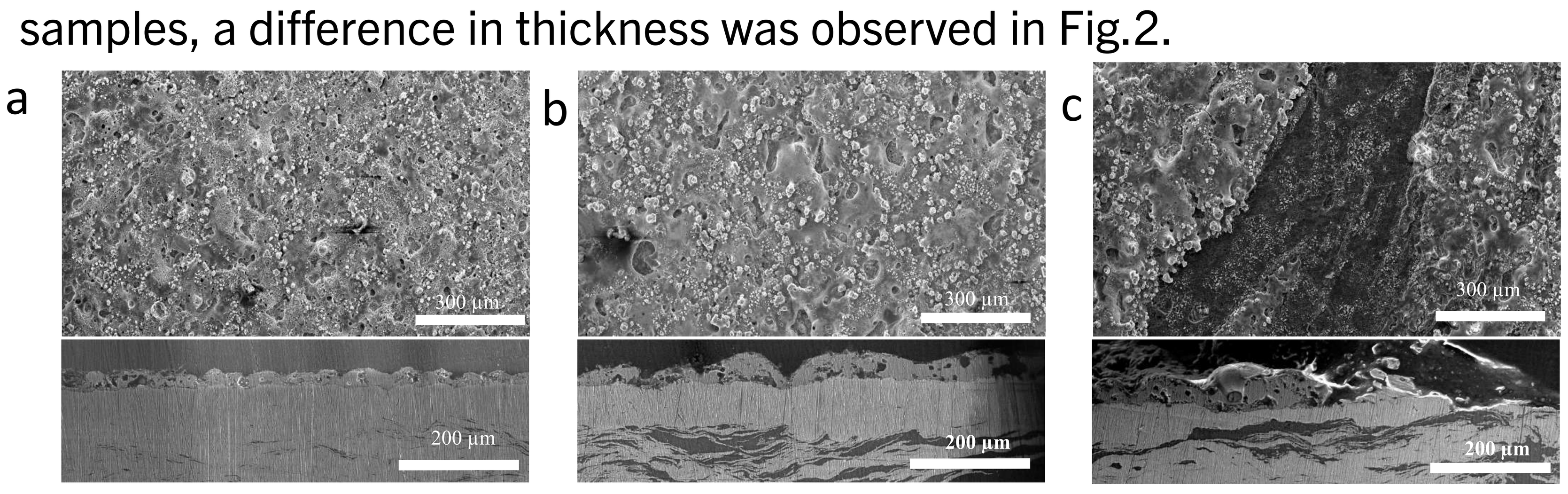


Fig.2: SEM images of coatings surface and cross-section **a)** Zn-3Mg, **b)** Zn-10Mg, **c)** Zn-30Mg

Fig.3 shows the difference in corrosion rates between uncoated and coated samples. With a PEO coating, the yearly corrosion rate significantly decreased compared to the uncoated samples (Table.1). However, it was also found that an increase in Mg also increased the corrosion rate.

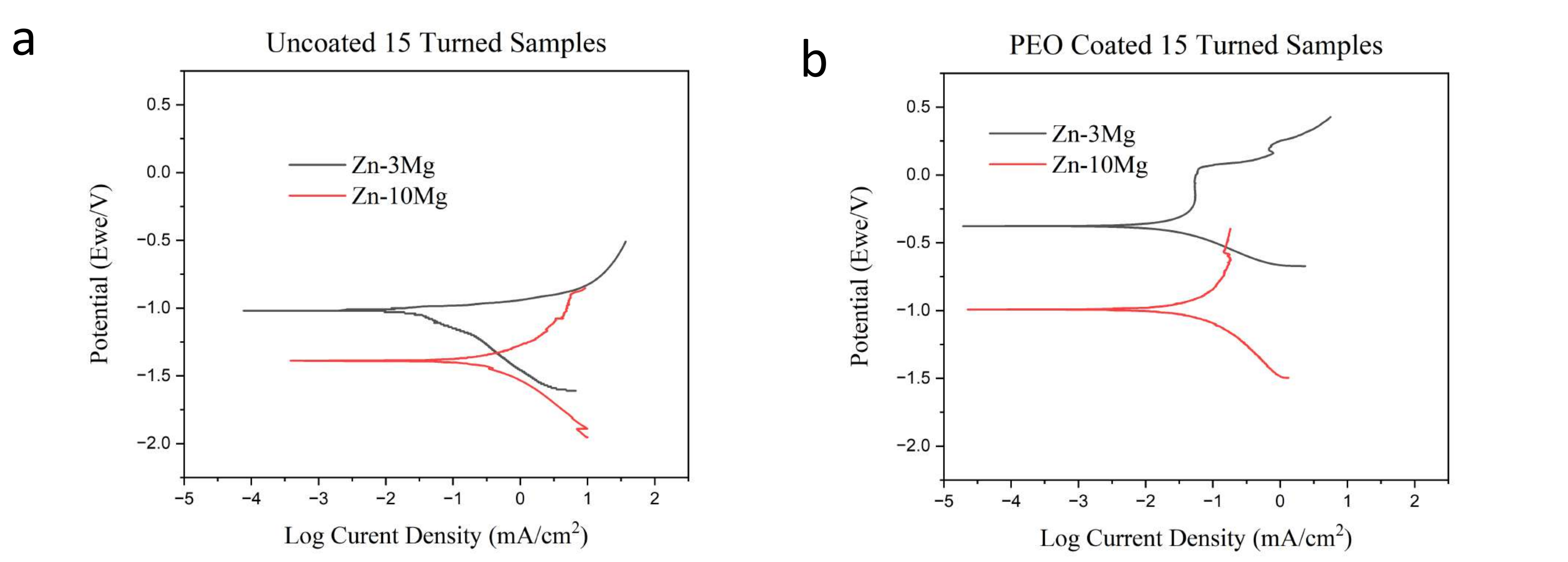


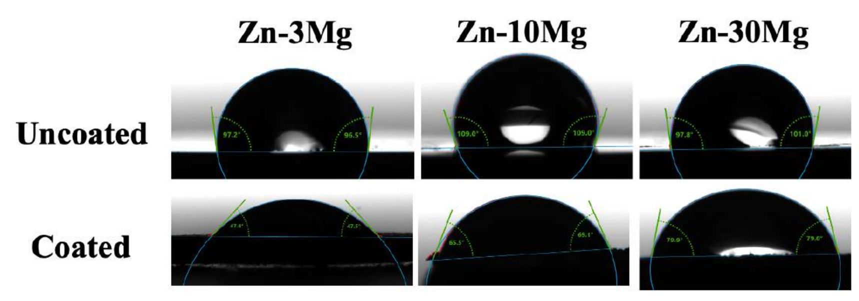
Fig.3: Results from the electrochemical corrosion test **a)** uncoated and **b)** coated samples

Table.1. Electrochemical corrosion study*

	Ecorr (V vs SEC)		Icorr (µA/cm²)		Cathodic Slope (V)		Anodic Slope (V)		Corrosion Rate (mm/year)	
Sample	Uncoated	Coated	Uncoated	Coated	Uncoated	Coated	Uncoated	Coated	Uncoated	Coated
Zn-3Mg	-1.02	-0.38	28.91	11.32	0.40	0.20	0.07	0.14	0.87	0.340
Zn-10Mg	-1.39	-0.99	145.21	18.28	0.34	0.47	0.26	0.13	3.81	0.480

*Information on Zn-30 Mg data was not reproducible, data not show

Wettability of the samples showed an important improvement after PEO treatment in samples Zn-3 Mg and Zn-10Mg but not in Zn-30Mg. Fig.4



	Zn-3Mg	Zn-10Mg	Zn-30Mg
Uncoated	95.9.±1.7	106.7.±2.4	87.7.9.±7.9
Coated	46.7.±0.6	65.26.± 2.9	81.7.± 8.3

Fig.4: Contact angle measurement of untreated and coated samples

The biological validation was carried out using different techniques, which included the measurement of mitochondrial activity (indirect test) and the observation of the cell-material interaction (direct test) in osteoblasts (Saos-2) after 24 H. In general, cells were more susceptible to higher concentrations of Mg and uncoated materials. In Fig.5, an improvement in the sample with lower Mg content and with coating can be observed.

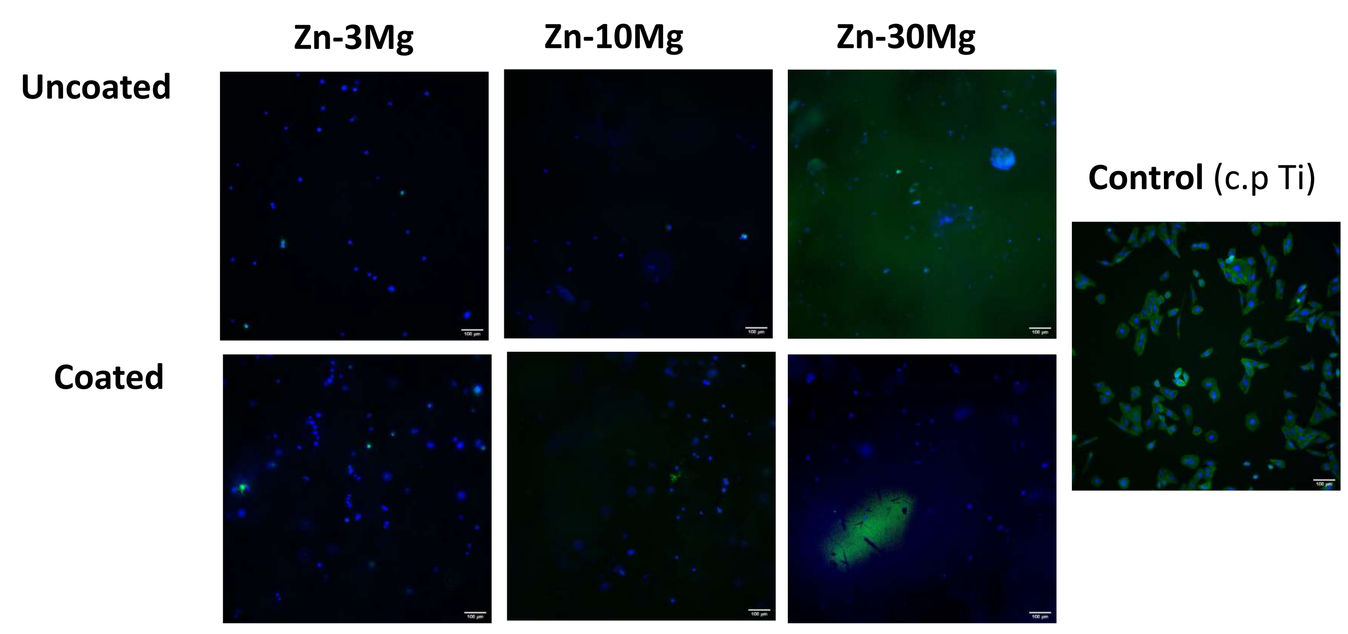


Fig.5: Result of a direct test analyzed by fluorescence imaging, phalloidin (green), and Dapi (blue). An improvement in the viability of cells grown on coated materials was observed

Conclusions

The amount of Mg in Zn-Mg-based alloys showed a significant difference to produce PEO coatings. In HPT-processed samples with lower Mg content, specifically 3% Mg in this study, more uniform coatings are obtained. This reflects a direct improvement in the degradation rate and cell viability.

References [1]Kabir, H, et al. (2021). Bioactive Materials, 6(3), 836-879; [2]Jarzębska, A. et al. (2018). Materials Letters, 211, 58-61; [3]Hernández-Escobar, et al. (2018). Philosophical Magazine, 99(5), 557–584. 4) Fattah-alhosseini; [4]A. et al (2020). Surfaces and Interfaces, 18, 100441

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