Toward a mechanistic understanding of trace-element influence on corrosion at the magnesium-biology interface

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Biodegradable magnesium (Mg) implants are a promising alternative to permanent metallic implants in biomedical applications. Yet, their effectiveness is hampered by unpredictable corrosion in the physiological environment, resulting in premature implant failure and potential toxicity [1]. A key parameter influencing this phenomenon is the behavior of trace elements (Fe, Zn, Cu) present in the peri-implant microenvironment and as impurities in Mg. These elements are known to impact Mg dissolution by creating active cathodic sites, though their behavior in physiological conditions is still unknown.

Conventional chemical analysis methods, such as SEM/EDS or XPS, lack the necessary elemental sensitivity and spatial resolution to understand the chemical nature of the interfacial layer forming on corroding implants. In this study, laser ablation coupled with inductively coupled plasma mass spectrometry (LA-ICP-MS) was employed for trace-element analysis of corrosion products [2].

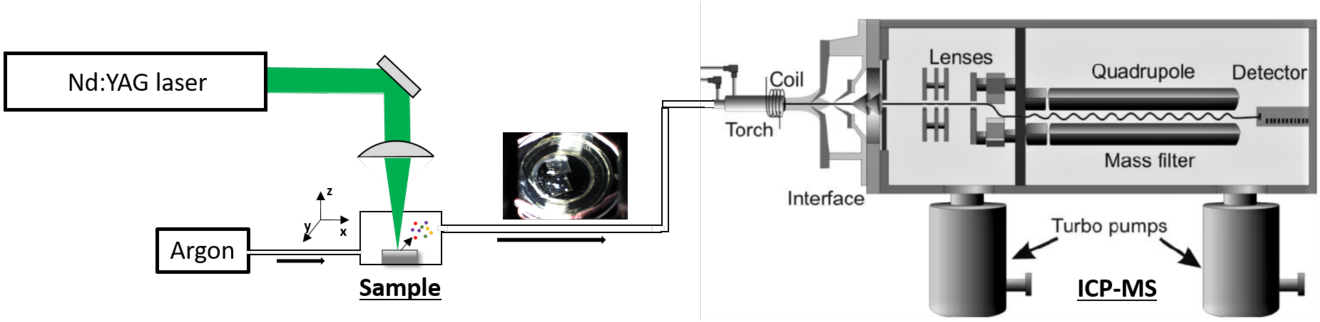

Figure 1: Laser Ablation – Inductively Coupled Plasma – Mass Spectrometry device used to characterize Mg corrosion layer [3].

Through the optimization of lateral probing and trace-element analysis on Mg model systems of varying trace element purity exposed to Simulated Body Fluids (SBF), the study achieved sufficient sensitivity (3.6 ppm) to distinguish purity levels based on the Fe content in the Mg Matrix. This data correlates with the dissolved Fe content quantified by ICP-MS liquid-phase analysis (SBF composition) following contact of SBF with Mg. The interplay of Fe with complex electrolytes is further studied by electrochemical quartz crystal microbalance (eQCM) at potentials establishing on Mg surfaces, which revealed insights into Fe-redeposition kinetics and trace-element quantification, particularly in the electrochemical potential range where strong hydrogen reduction dominates the current signal. This comprehensive approach sheds light on the intricacies of Mg implant corrosion, offering valuable insights for the development of more robust and reliable biodegradable implants in biomedical applications.

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