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Effect of Powder Metallurgy Processing on the Mechanical and Corrosion Behaviour of Biodegradable Zinc Alloys

Zinc-based alloys are renowned for their excellent biocompatibility and controlled degradation behaviour, making them highly suitable for applications such as stents and bone fixation devices. Among various fabrication methods, powder metallurgy, particularly mechanical alloying (MA) and spark plasma sintering (SPS) has emerged as a transformative approach. These techniques enable the production of ultrafine-grained microstructures with exceptional mechanical properties. Alloys within the Zn-Mg system have demonstrated tensile strengths exceeding 350 MPa and elongations over 12%, meeting the rigorous mechanical requirements of medical devices. Furthermore, materials produced by powder metallurgy techniques are characterized by decreased texture strength compared to the conventionally produced zinc-based alloys, decreasing the tendency to anisotropy and asymmetry of mechanical properties. In summary, facilitating grain and phase refinement as well as phase redistribution, powder metallurgy offers a compelling pathway for the development of advanced biodegradable zinc-based materials with improved mechanical performance.

However, the corrosion behaviour of zinc-based alloys is a critical factor for their successful application in biodegradable implants. Corrosion mechanisms in these materials are significantly influenced by their microstructure and surface characteristics. Research on Zn-Mg-based alloys has identified localized corrosion mechanisms driven by micro-galvanic cells between the Zn matrix and intermetallic phases, such as Mg_2Zn_{11}. In this respect, grain size refinement achieved through advanced powder metallurgy techniques enhances corrosion uniformity, reducing the risk of premature material failure. Initial surface layers, including ZnO and MgO, play a vital role in forming more complex protective corrosion products, such as hydrozincite and simonkolleite, which regulate the overall degradation rate. Moreover, the use of complex corrosion media, such as MEM, DMEM, or FBS, adds further complexity to the corrosion reactions and significantly alters the corrosion rate making the estimated values of corrosion rate close to the in-vivo degradation rates.