Development of biodegradable zinc-magnesium-silicon alloys by powder metallurgy processes

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Biodegradable metals are considered for temporary replacement and fixation of damaged human tissue. Zinc achieves excellent biocompatibility and corrosion properties making him a promising candidate for biodegradable devices such as stents, screws etc. However, pure zinc and some zinc-based alloys suffer from poor mechanical properties (yield, ultimate strength, elongation, and endurance against creep at 37 °C). Improvements can be achieved by alloying or preparation techniques.

We focused on the preparation of ternary Zn-Mg-Si alloy from pure powders by mechanical alloying (MA) and compaction by spark plasma sintering (SPS). Magnesium was selected as the alloying element due to the positive effect on the mechanical properties of zinc by strengthening related to formed secondary phases and solid solution strengthening. Silicon is more commonly used in magnesium alloys to increase creep resistance. With zinc, it works as a reinforcement in the form of fine particles or solid solutions due to the absence of any intermetallic phases in the Zn-Si phase diagram. MA was selected as the technology enabling the formation of fine-grained, homogeneous microstructures consisting of solid solutions and metastable intermetallics. The selected powders were compacted by the SPS, fast compaction technique, preventing grain coarsening.

The microstructure and mechanical properties of the prepared materials were studied and compared to binary alloys (Zn-Mg, Zn-Si). The results showed that the MA parameters (MA time, milling ball size, etc.) affect the process powders phase composition and particle size distribution. The desired microstructure condition was observed for the longest times (8 hours) and intermediate milling balls (1 cm). Compaction by SPS produced a fine, homogeneous microstructure consisting of zinc matrix, intermetallic phase Mg_2Zn_{11} and partially dissolved magnesium in the form of a solid solution. The fine microstructure with intermetallics enhanced the hardness and tribological properties.

This work was supported by the grant of Specific university research A2_FCHT_2022_109.