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Micro-injection Molding Process Applications: A Study on Microstructure and Mechanical Properties of Biomedical PLA/Mg Composites

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Abstract : Biodegradable implantable medical devices have merged as a widely researched field in recent years. Due to their degradable properties, these materials eliminate the need for secondary surgeries to remove implants, thus offering significant clinical value. Polylactic acid (PLA), as a biodegradable polymer material, has been extensively applied in the medical field due to its excellent biocompatibility as well as the non-toxic and metabolizable nature of its degradation product. Additionally, PLA exhibits high processability, allowing it to be manufactured into various forms through different fabrication techniques to meet diverse medical requirements. However, PLA has shortcomings, including limited mechanical properties, low hydrophilicity, and an acidic environment generated during its degradation process, which need to be overcome by material modifications. This study utilizes magnesium (Mg) powder as an additive phase to improve the properties of PLA-based composite materials. Chemical conversion treatment was employed to form a phosphate coating on the Mg powder surface to improve its interfacial bonding with the PLA matrix. The phosphate-treated Mg powder was mixed with PLA pellets, and test specimens were successfully fabricated using a self-designed micro-injection molding machine. This fabrication process demonstrated excellent stability and efficiency, confirming the feasibility of this approach in PLA-based composite material production. The results indicated that the coated Mg powder could be uniformly dispersed within the PLA matrix and acted as nucleation sites, significantly enhancing the crystallinity of PLA. Further annealing treatment revealed substantial improvements in the thermal stability and mechanical properties of the composite material, enhancing its application potential. Through the immersion test, the degradation mechanism of the composite material was summarized. In the initial stage, degradation was dominated by Mg, and the degradation products neutralized the acidic environment created by PLA degradation, thereby mitigating potential discomfort after implantation. Subsequently, the solution infiltrated the internal structure of the material, promoting hydrolysis of the PLA matrix and accelerating the overall degradation process, thus avoiding an excessively long degradation cycle. The optimized PLA/Mg composite material demonstrated excellent mechanical properties and controlled degradation behavior, showing its potential as a biodegradable implantable medical device. These findings provide a valuable reference for the future development of PLA-based composites and broaden their application prospects in the biomedical field.

Keywords : biodegradable, composites, magnesium powder, metal injection molding, polylactic acid
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