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Influence of TPMS Topology on the Kinetics of Hydrolytic Degradation of Polymeric Scaffolds

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ABSTRACT

Polymeric scaffolds based on aliphatic polyesters are widely used in tissue engineering due to their ability to undergo gradual resorption while maintaining temporary mechanical support. The degradation process is governed by a combination of polymer chain scission mechanisms, oligomer diffusion, and autocatalytic effects, which are strongly dependent on the geometry of the porous structure.

This study presents a numerical investigation of the influence of triply periodic minimal surface (TPMS) topologies, including Gyroid, Diamond, and IWP, as well as their gradient-based variations [1], on the kinetics of hydrolytic degradation. The simulations were performed using the finite element method in the COMSOL Multiphysics environment, employing a reaction–diffusion model based on the framework proposed by Pan et al. [2], which describes molecular weight reduction and transport of degradation products under identical material parameters and boundary conditions.

In addition, the mechanical stability of the structures was analyzed by accounting for the evolution of the elastic modulus as a function of the degradation state. It is demonstrated that topology significantly affects both the degradation rate and the resulting mechanical performance. Gyroid-based structures exhibit a more uniform stress distribution and a more gradual reduction in stiffness, whereas Diamond and IWP structures show localized stress concentrations and earlier mechanical failure. [3]

Furthermore, the use of gradient structures enables coordinated control of degradation kinetics and spatial distribution of mechanical properties. The obtained results highlight the critical role of TPMS topology in the design of biodegradable scaffolds with tailored resorption kinetics and mechanical reliability.

KEYWORDS

Hydrolytic degradation; polymeric scaffolds; bone tissue engineering; triply periodic minimal surfaces (TPMS); finite element method

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