SCIENCE AS A VOCATION AND CAREER

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3D PRINTING OF PIEZO-POLYMER PLLA DOPED WITH MAGNETITE NANOPARTICLES AND USING TRIPLY PERIODIC MINIMAL SURFACE GYROID STRUCTURE FOR CRITICAL BONE DEFECTS

Bone defects caused by trauma, disease or congenital disorders are a significant challenge for orthopedic surgeons. The development of bone tissue engineering has brought new hope for the regeneration of critical bone defects. One of the most promising techniques in bone tissue engineering is 3D printing of bone scaffolds [1]. In this technique, the scaffold acts as a temporary support for cell growth and tissue formation. In this article, we propose a novel approach for the fabrication of bone scaffolds using triply periodic minimal surface (TPMS) gyroid structure with a piezo-polymer poly-l-lactic acid (PLLA) doped with nanomaterials of magnetite [2, 3]. The use of magnetite nanoparticles allows for the magnetic alignment of the scaffold, which can facilitate the bone regeneration process. The TPMS gyroid structure has excellent mechanical properties and a large surface area, which promotes cell adhesion and proliferation. This paper will discuss the development and characterization of the bone scaffold, as well as its potential applications in bone tissue engineering.

In recent years, bone tissue engineering has emerged as a promising approach for the repair and regeneration of critical bone defects [4]. The use of 3D-printed scaffolds is a critical component of this approach, as it provides a temporary matrix for cell attachment, proliferation, and differentiation, ultimately leading to the formation of new bone tissue [5]. The mechanical properties of the scaffold, such as its porosity, pore size, and mechanical strength, are crucial factors in determining the success of bone tissue engineering [6].

Various materials have been used to fabricate bone scaffolds, including natural polymers, synthetic polymers, and ceramic materials. Natural polymers, such as collagen and chitosan, have excellent biocompatibility but are limited by their mechanical strength and stability [7]. Synthetic polymers, such as poly(lactic-co-glycolic acid) (PLGA) and poly(caprolactone) (PCL), have good mechanical properties but can cause an inflammatory response [8]. Ceramic materials, such as hydroxyapatite and tricalcium phosphate, have excellent biocompatibility but can be brittle and difficult to process [9].

To address these limitations, researchers have explored the use of composite materials for bone tissue engineering. One example is the use of piezoelectric materials, such as poly(l-lactic acid) (PLLA) doped with barium titanate nanoparticles, which can generate electrical signals in response to mechanical stress and promote bone regeneration [10]. Another example is the use of magnetic nanoparticles, which can facilitate the alignment and differentiation of osteoblasts [11].

In our study, we propose a novel approach for the fabrication of bone scaffolds using triply periodic minimal surface (TPMS) gyroid structure with a piezo-polymer PLLA doped with nanomaterials of magnetite [2, 3, 12].

A solvent-based method was used to prepare Poly(l-lactic acid) (PLLA) doped with magnetite nanoparticles. PLA pellets were dissolved in dichloromethane at 60°C with magnetic stirring. Magnetite nanoparticles were made using the co-precipitation method and dispersed in dichloromethane using sonication for 30 minutes. The mixture was poured into a flat tray, covered, and left to dry for 2 days at room temperature.

Table 1

Tensile testing results

Porosity (%)	Average ultimate tensile strength (MPa)
0	27.30
70	21.19
50	19.47
30	16.33

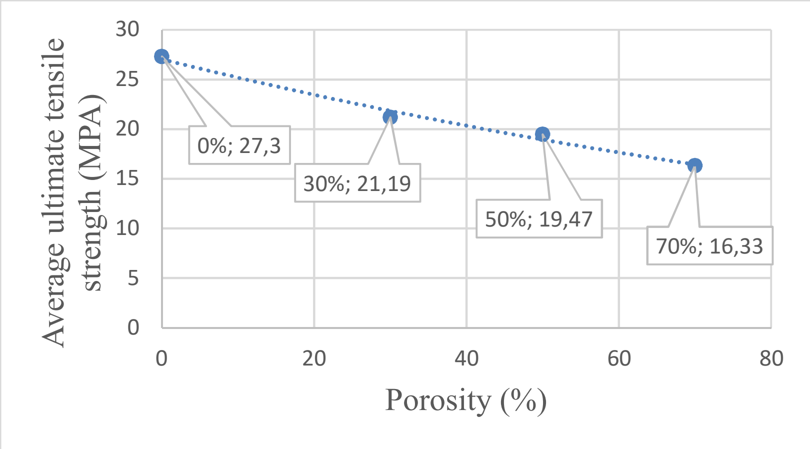

Fig. 1. Average ultimate tensile strength vs porosity percentag

The PLLA/magnetite composite material was extruded into filaments using a custom-built extruder and heated to 200°C. The filaments were used in a 3D printer "Ultimaker 3" to print testing samples with a TPMS gyroid structure. The CAD (computer-aided design) model was converted to STL (stereolithography) format and sliced using Slic3r software. Specimens were designed using ASTM (American Society for Testing and Materials) standard. Gyroid structure was used as infill pattern. Four different infill percentages (30%, 50%, 70%, and 100%) were used to prepare 3 specimens for each type. The resulting specimens were characterized for their mechanical properties and suitability for use as bone implants.

The specimens were tested for their tensile strength according to the ASTM D638 standard. They were stretched at a constant rate of 0.5mm/min until they broke using a testing machine. The data on load and displacement were collected using a data acquisition system.

The average tensile strength and modulus of elasticity for each infill percentage are summarized in the table below:

Our study investigated the effect of gyroid structure and porosity on the tensile strength of 3D-printed PLLA/magnetite composites. We observed a significant decrease in ultimate tensile strength as the porosity of the specimen increased. This could be attributed to the reduction in material density and the presence of voids, which act as stress concentrators and lead to early failure of the composite. To our knowledge, this is the first report on the tensile properties of PLLA/magnetite composites with gyroid structure and porosity. Our results suggest that the mechanical behavior of these composites can be tuned by controlling the porosity and structure of the printed parts, and further optimization is required to achieve the desired properties for specific applications.

The study of PLLA doped with magnetite and 3D printed using a gyroid structure showed that the material's porosity significantly affects its ultimate tensile strength (UTS). As the porosity increased from 0% to 70%, the UTS decreased from 27.30 MPa to 21.19 MPa due to the formation of voids within the material. Adding magnetite nanoparticles to the PLLA matrix did not significantly affect the material. This means that the material's magnetic properties can be adjusted without affecting its mechanical strength.

The results of this study highlight the importance of optimizing the porosity of 3D printed materials to achieve the desired mechanical properties. The scaffolds can be further studied under the exposure of magnetic field to find out piezoelectric response. Specimens can be observed under Scanning electron microscopy (SEM) to understand the surface morphology.

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FIELD PROGRAMMABLE GATE ARRAY BASED I & C SYSTEMS FOR NPPS: ENHANCING SAFETY AND EFFICIENCY

Introduction to NPPs

NPPs, or Nuclear Power Plants, are large facilities that use nuclear reactions to generate electricity. These reactions typically involve nuclear fission, which releases energy that is then used to heat water and produce steam. The steam powers a turbine, which drives a generator to create electricity. One of