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Abstract

Development of an oxygen-sensitive hydrogel for monitoring oxygen diffusion in tissue engineering

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Additive manufacturing has revolutionized the development of biomaterials by enabling precise control over structural properties at the microscale. In tissue engineering, oxygen transport remains a major challenge, particularly in the development of vascularized artificial tissues [1]. To address this, we present an oxygen-sensitive hydrogel fabricated using one-photon polymerization and two-photon polymerization (2PP), designed for real-time observation of oxygen diffusion characteristics. One-photon polymerization was employed to produce larger hydrogel samples for bulk diffusion experiments, while 2PP enabled the fabrication of membrane-like structures with micrometer precision for integration into microfluidic environments.

The hydrogel, based on polyethylene glycol diacrylate (PEGDA), incorporates methylene blue as an oxygen-sensitive dye. The reversible reduction of methylene blue to its colorless form (leuco methylene blue) allows for a colorimetric response upon changes in oxygen concentration [2]. This color change was stable and reproducible, enabling both visual and spectroscopic analysis. Diffusion experiments at 37 °C showed that diffusion distances within the samples reached up to 350 µm, with oxygen diffusion rates between 3.2 and 7.4 µm/min during the initial 30–35 minutes. The permeability was tuned by adjusting PEGDA concentration, photoinitiator content, and UV exposure duration.

Results demonstrate that hydrogel supports controlled oxygen diffusion, provides a quantifiable response to oxygen gradients, and exhibits tunable permeability through additive manufacturing techniques. This approach offers a valuable tool for studying oxygen supply in engineered tissues and could enhance the design of microfluidic organ-on-a-chip systems.

Our findings indicate that oxygen-sensitive hydrogels hold great potential for improving in vitro tissue models by enabling precise monitoring of oxygen distribution, which is essential for cell viability and function. Future research will focus on integrating oxygen-sensitive hydrogel into microfluidic systems, enabling dynamic flow studies and co-culture applications to simulate vascularized environments more accurately.

AUTHOR'S STATEMENT

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