

Biological scaffolds for improved viability and mechanical performance of biomineralized engineered living materials

Dissertation Defense

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The development of sustainable construction materials is becoming increasingly important as conventional building materials, particularly concrete, contribute substantially to global carbon emissions and environmental degradation. Materials containing living cells, often called engineered living materials (ELMs), have emerged as a promising alternative because they can be manufactured with lower energy costs and can imbue materials with living functionalities such as self-healing, photosynthesis, and environmental responsiveness. While most existing ELMs are limited to non-structural applications, biomineralized ELMs offer the potential to function as more sustainable structural materials with living functionalities. However, current biomineralized ELMs are often limited in their use cases because of their low microbial viability and poor mechanical performance. Natural biomineralized materials do not experience these limitations because of their use of a biological scaffold. Biological scaffolds can help maintain microbial viability by providing protection and sometimes nutrition to cells. They can also improve material properties by precisely templating mineral formation within complex geometries. Using a biological scaffold to manufacture biomineralized ELMs may also improve the viability and material properties in a similar manner. Three aims were pursued to test this approach. The first demonstrated that mycelium scaffolds can produce biomineralized ELMs with greater microbial viability and structural complexity. The second investigated how biomineralization affects the mechanical properties of 3D printed cellulose-chitosan filaments and identified which microstructural characteristics govern strength. The third evaluated how mycelium scaffolds affect the mechanical performance, strengthening mechanisms, and microbial viability of biomineralized ELMs. Together, these findings extend microbial viability and clarify the strengthening mechanisms that govern biomineralized ELMs. Findings in this dissertation provide design principles to guide the development of more sustainable and more functional construction materials.

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