Fractal architected pyrolytic carbon scaffolds: Hierarchical design strategies for geometry-governed mechanics in musculoskeletal regeneration

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3D printed scaffold for bone tissue engineering

The ideal bone tissue scaffold
- **Biocompatible**
- **Osteogenic biofunctionality**
- **Interconnected porosity**
- **Efficient mass transport**
- **Mechanically stable**

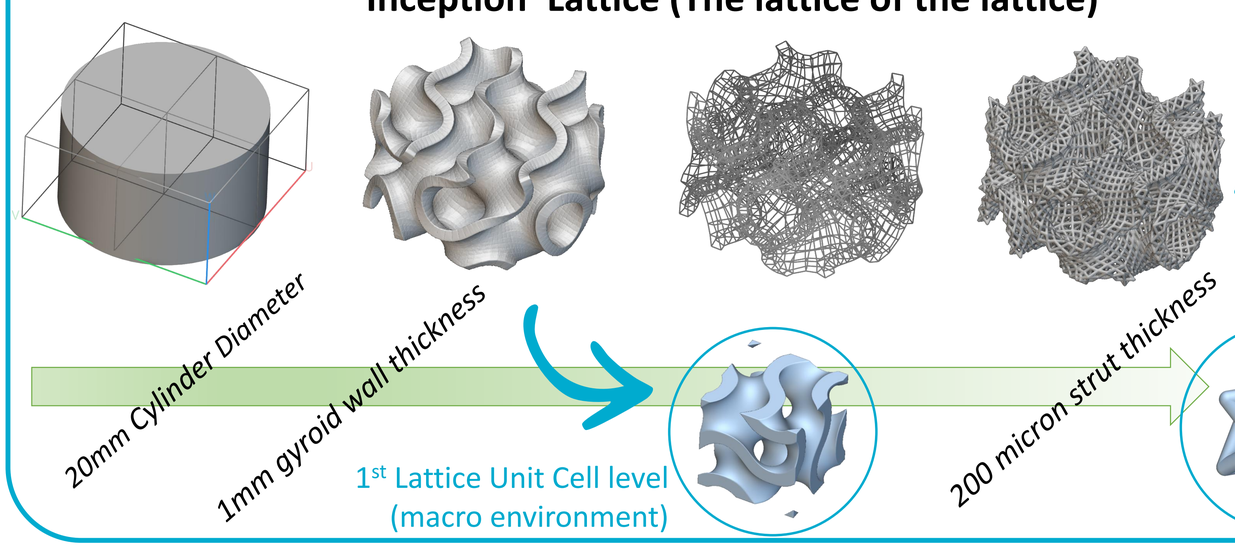
Current challenges:
- **Architecture–mechanics trade-off:** increasing porosity to promote ingrowth typically reduces stiffness.
- **Fabrication limitations:** limited feature resolution and inherent process variability can distort the designed microarchitecture, leading to mechanical anisotropy

Current materials:
- Polymers
- Metals
- Ceramics
- Composites
- Biogels

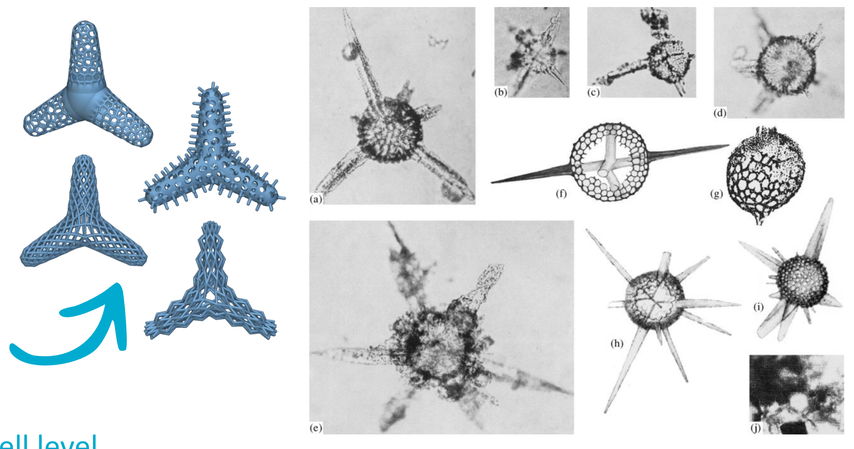
Pyrolytic carbon (PyC): A novel solution
- Facile micro/nano-scale patterning
- Good biocompatibility
- Mechanical compatibility
- MRI compatible

Hierarchical fractal design strategies

'Inception' Lattice (The lattice of the lattice)



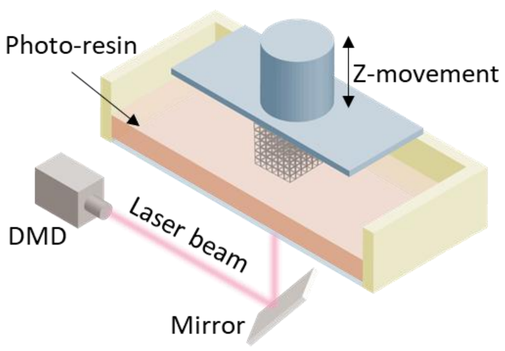
Interlocking self-assembled structures for TE bone scaffolds

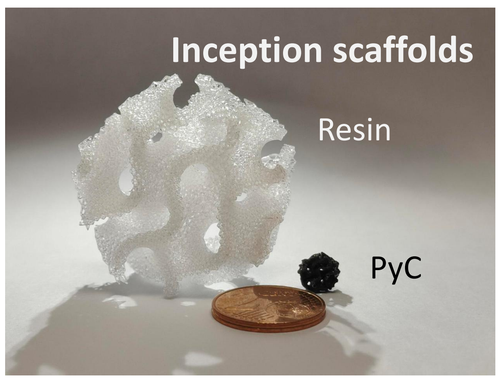


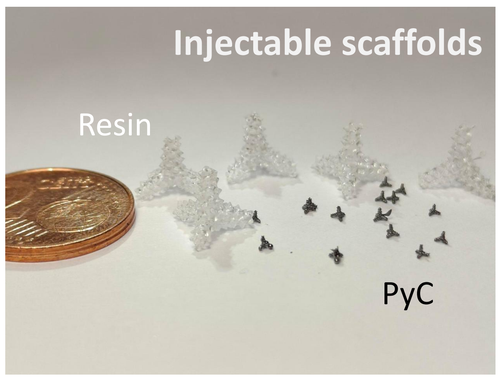
A biomimetic design strategy inspired by radiolarians

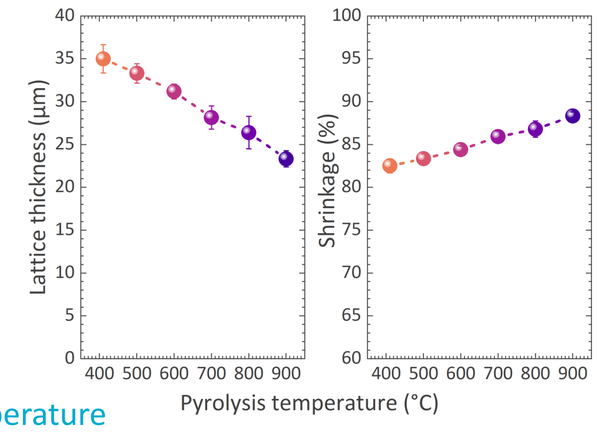
3D printed PyC fractal scaffolds manufacturing

DLP 3D printing





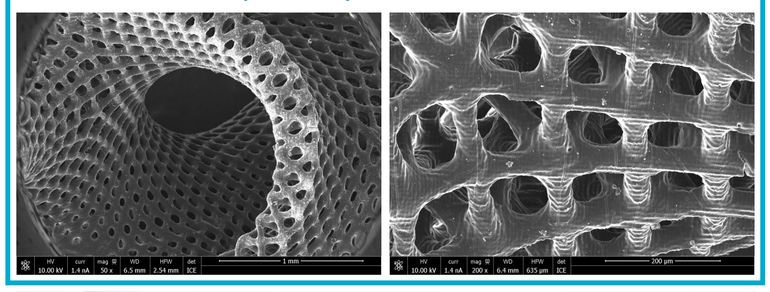


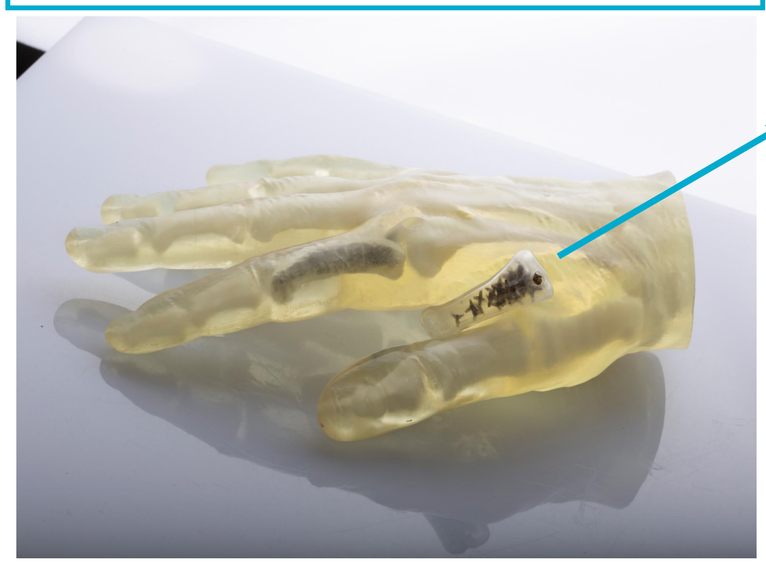


Volumetric shrinkage dependent on geometric characteristics and temperature

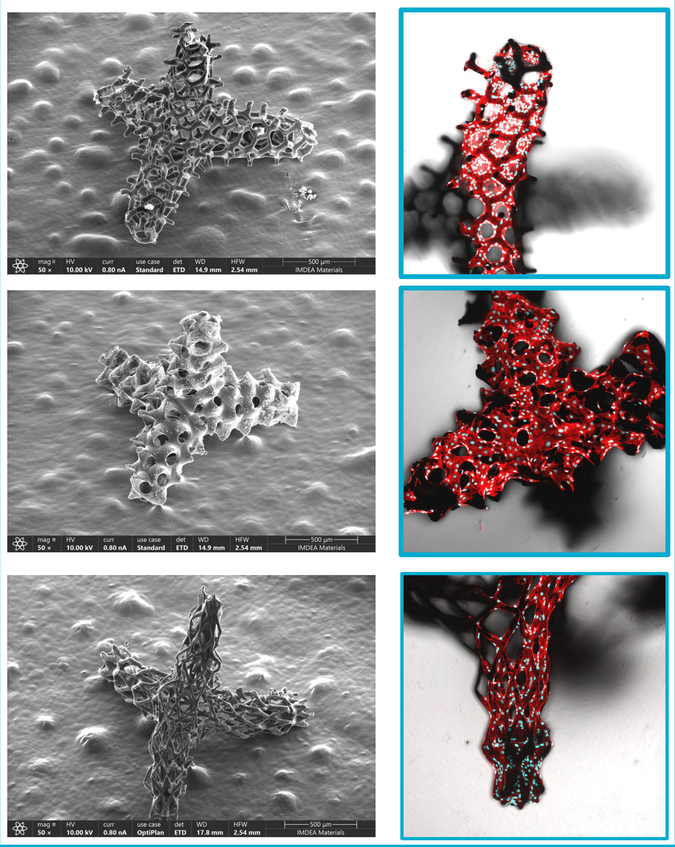
Results

Multiscale inception PyC scaffolds





MC3T3-E1 cells on injectable PyC tetrapods



Conclusion

- **Successful fabrication of multiscale fractal PyC scaffold for bone tissue engineering.**
- **Porosity and interconnectivity resulting from the incorporation of the second lattice structure reduce the risk of breakage and deformation during pyrolysis.**
- **More than 95% of volumetric shrinkage achieved for injectable PyC scaffolds.**
- **Preferable cell growth was observed on PyC injectable tetrapods.**
- **On going work: fractal scaffold at cellular scale using 2 photon polymerization system**

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