

A 3D-printed orange lattice vase with a white rose. The vase is made of a fine, porous lattice structure and has a wide, flared top. A single white rose is placed next to the base of the vase. The background is a dark, textured surface.

Multiscale Topology optimization for Convergent Manufacturing

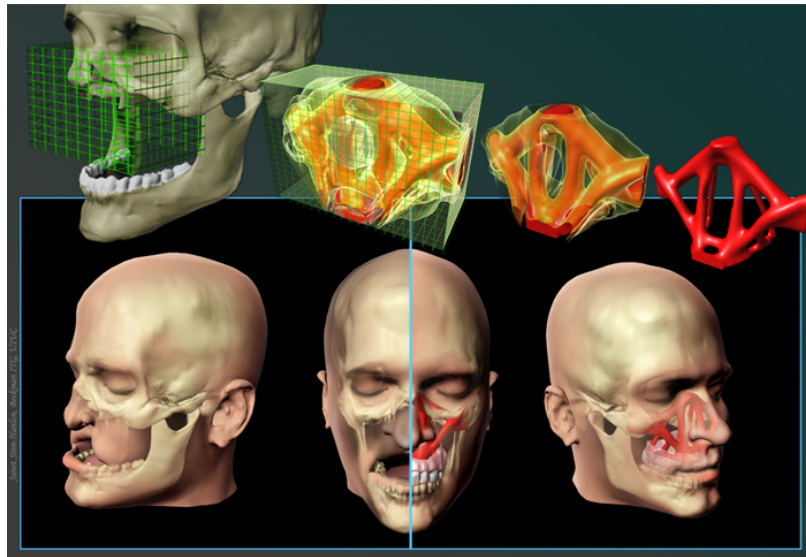
G. H. Paulino

Margareta E. Augustine Prof. of Engineering, Princeton University

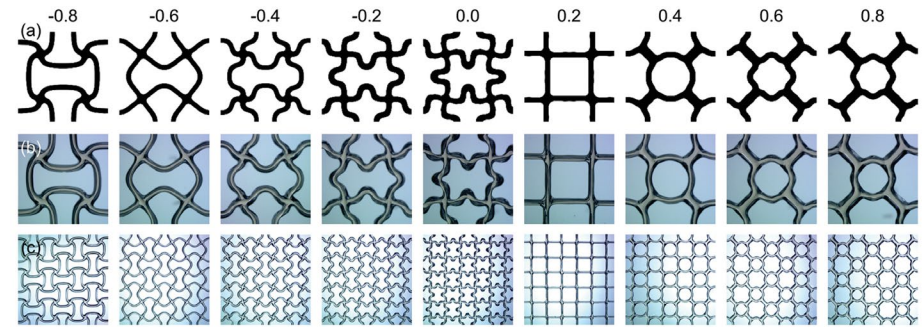




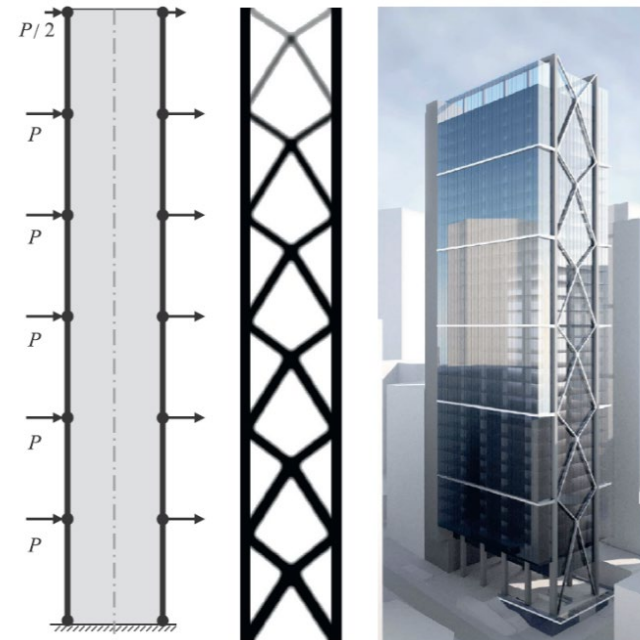
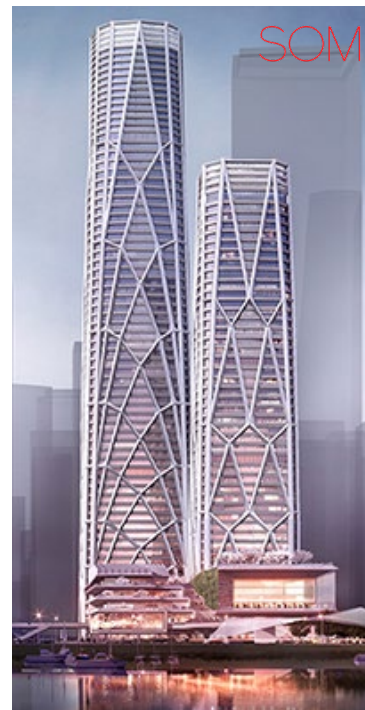
Applications of Topology Optimization



Sutradhar, Paulino, Miller, Nguyen.
Proc Natl Acad Sci. 54:1123-1135. 2010.



Clausen, Wang, Jensen, Sigmund, Lewis. *Adv. Mater.* 27:5523-5527. 2015

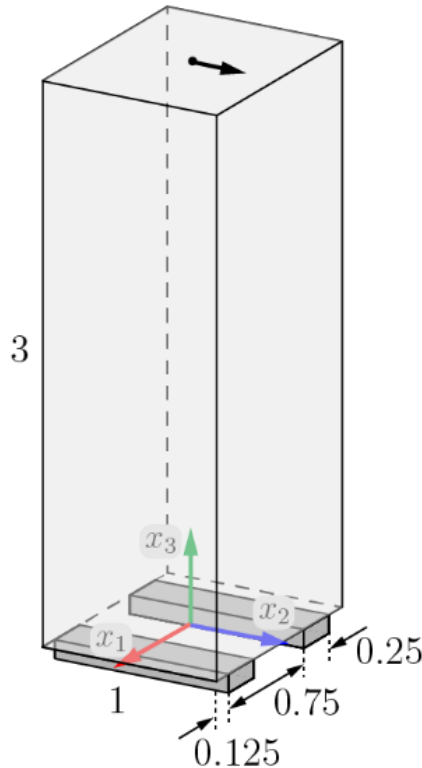


Beghini, Beghini, Katz, Baker, Paulino.
Eng Struct. 59:716-726. 2014.

Effect of porous, anisotropic materials

Design domain

$192 \times 40 \times 64$ hex mesh
(half domain, symmetry)



Constraint definition

$\mathcal{G}_1$ varies

$\mathcal{E}_1 = \{1, \dots, N\}$

$\bar{v}_1 = 0.022$

Algorithmic parameters

Filter radius, $R = 0.0625$

Filter power, $q = 3$

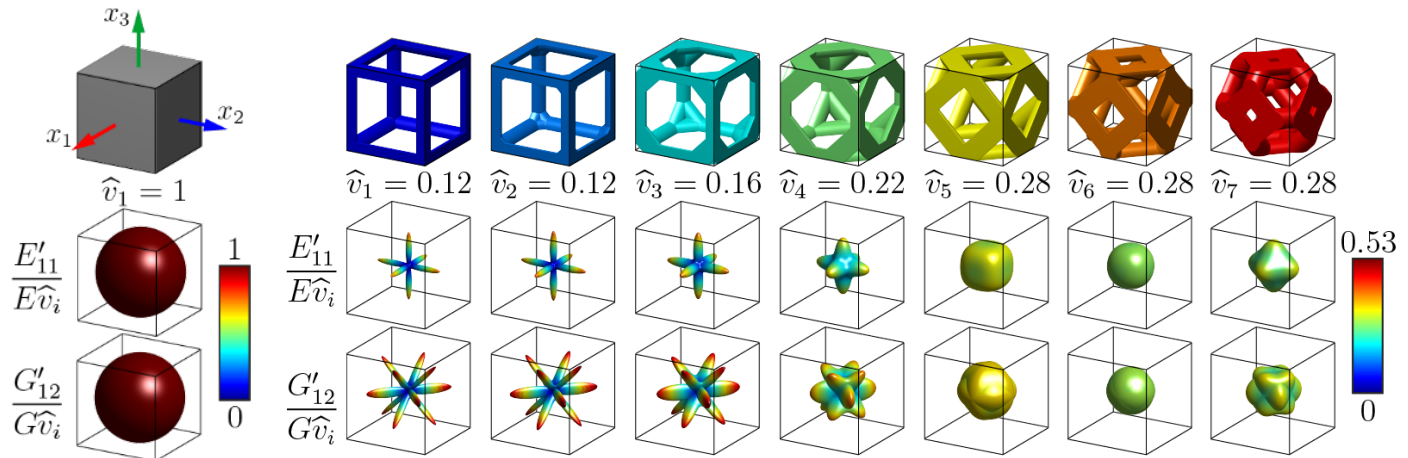
$p = [1, 1.5, 2, 2.5, 3]$

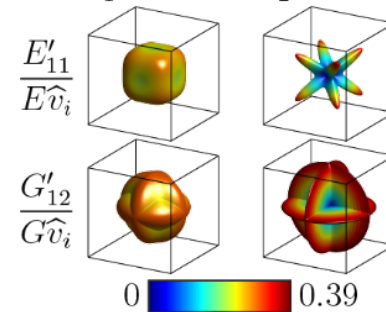
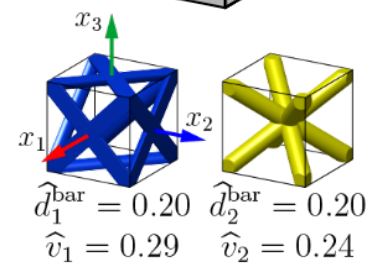
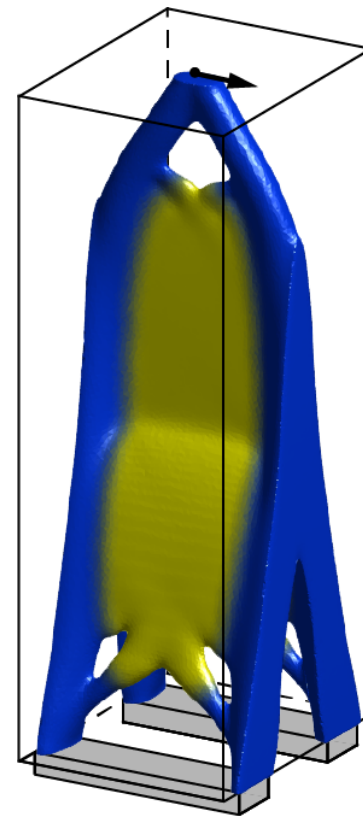
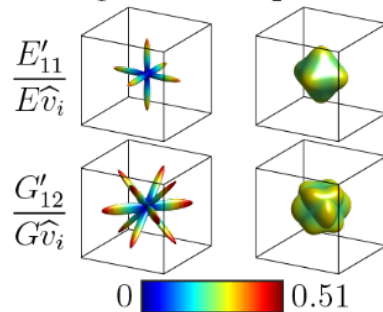
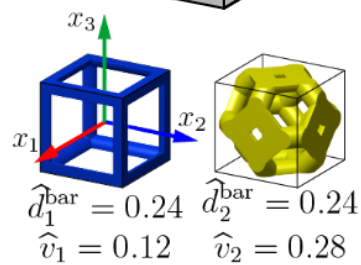
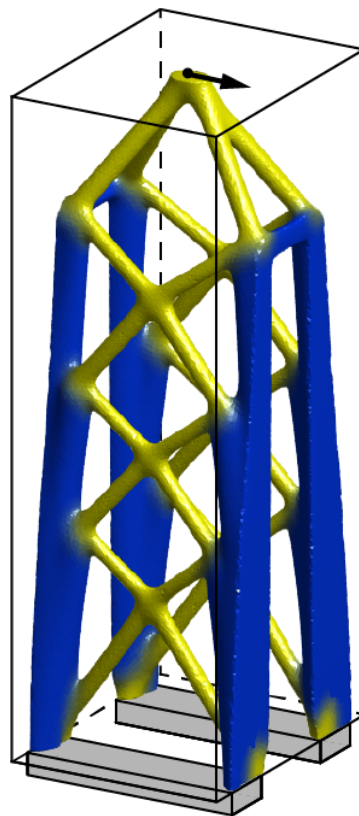
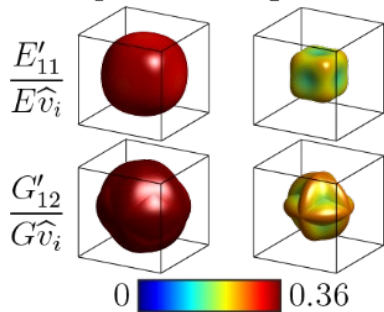
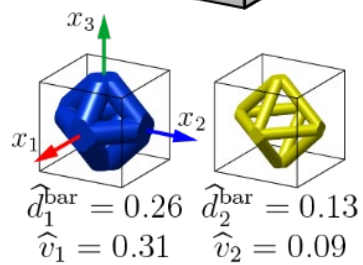
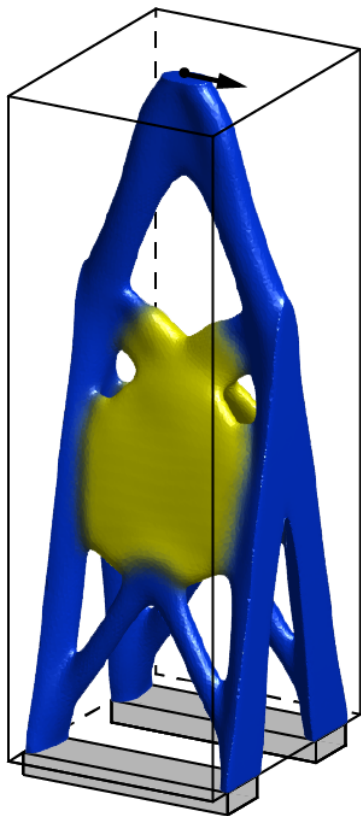
$\gamma = [0, 0.2, 0.5, 0.8, 1]$

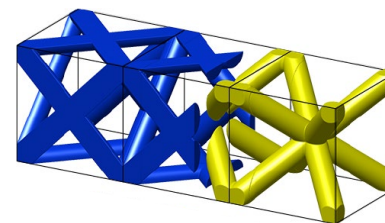
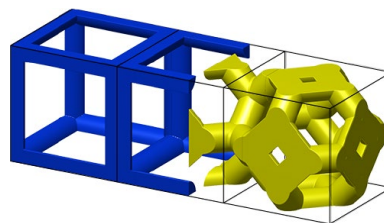
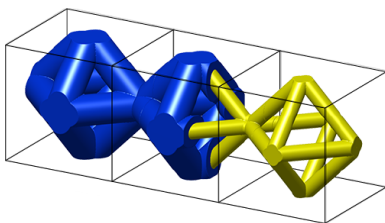
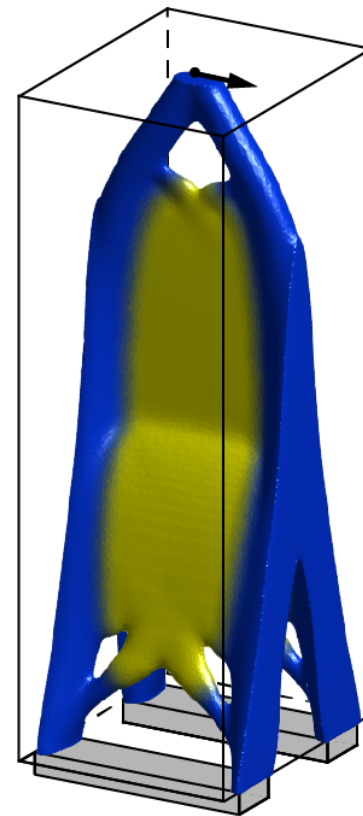
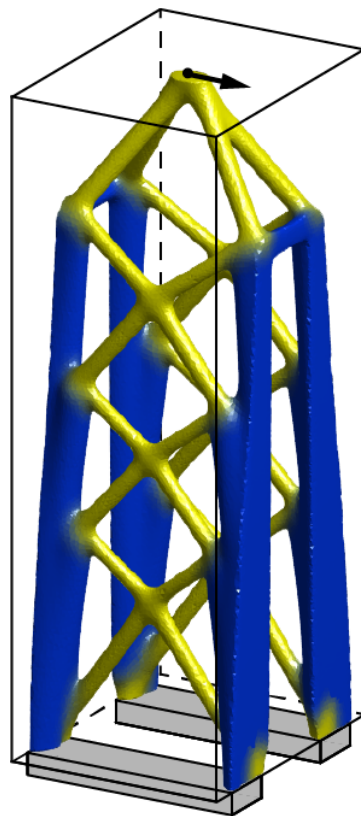
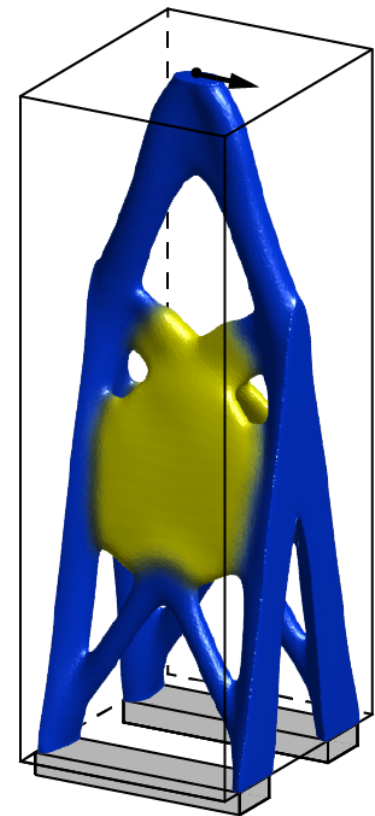
MaxIter = [100, 100, 100, 100, 200]

Candidate materials

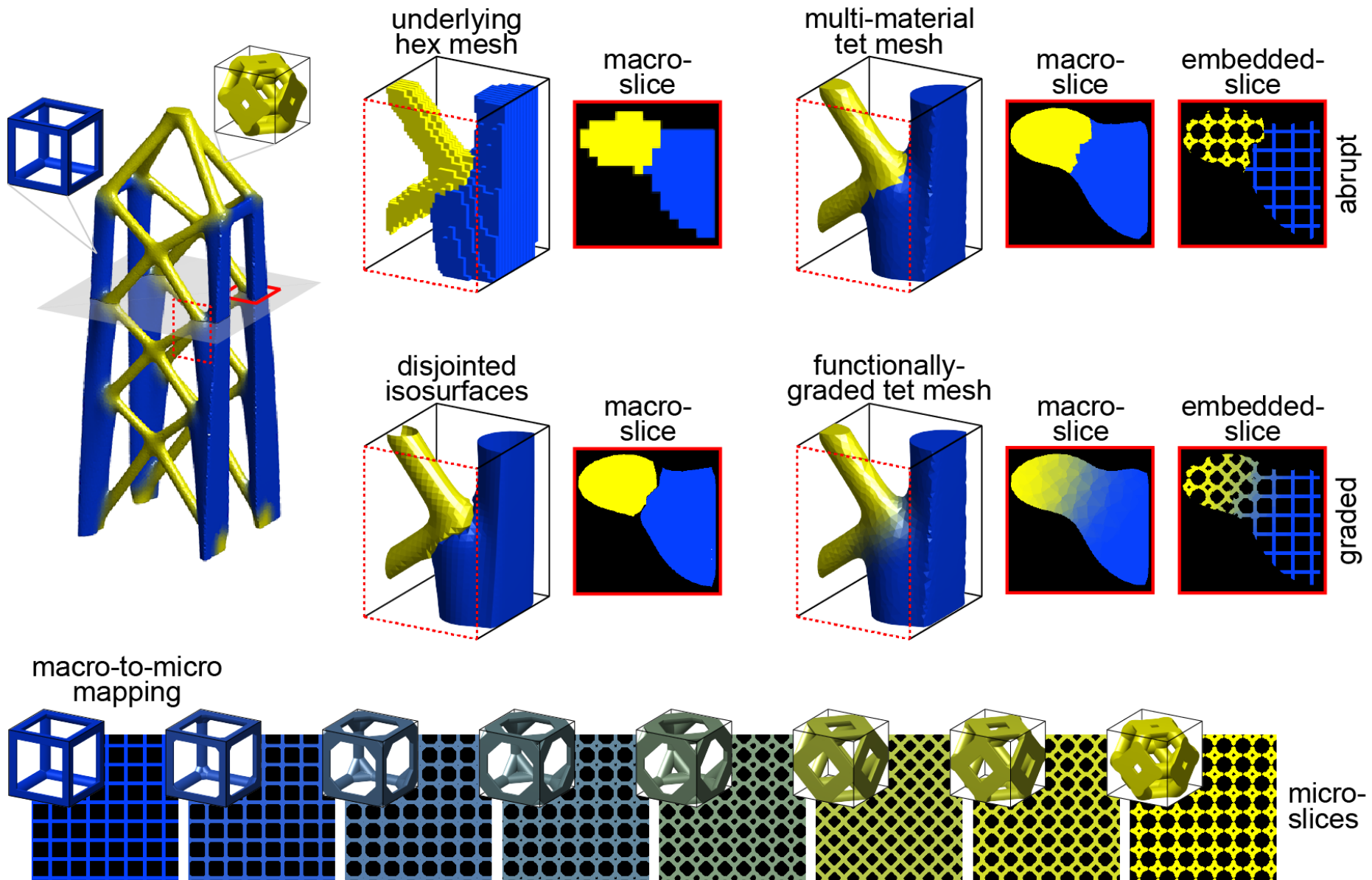
$E = 1$
 $\nu = 0.3$
 $\hat{d}_i^{\text{bar}} = 0.24$

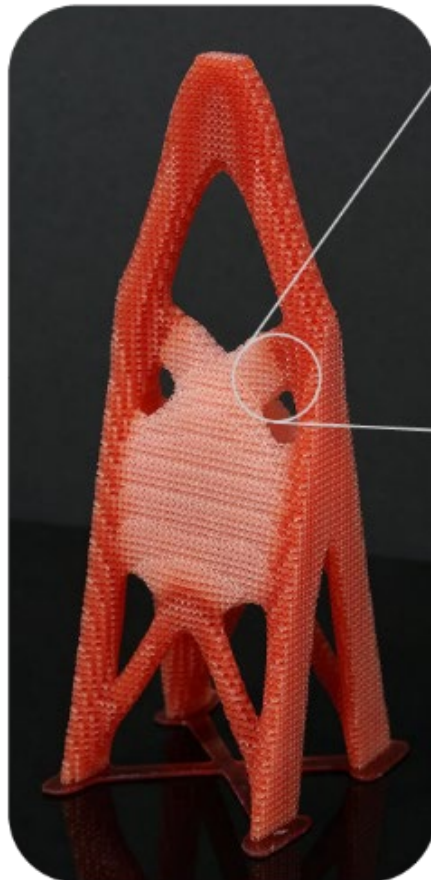
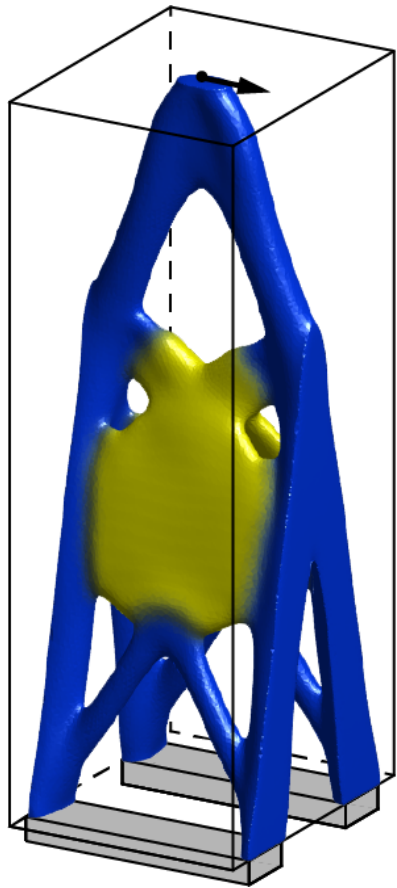




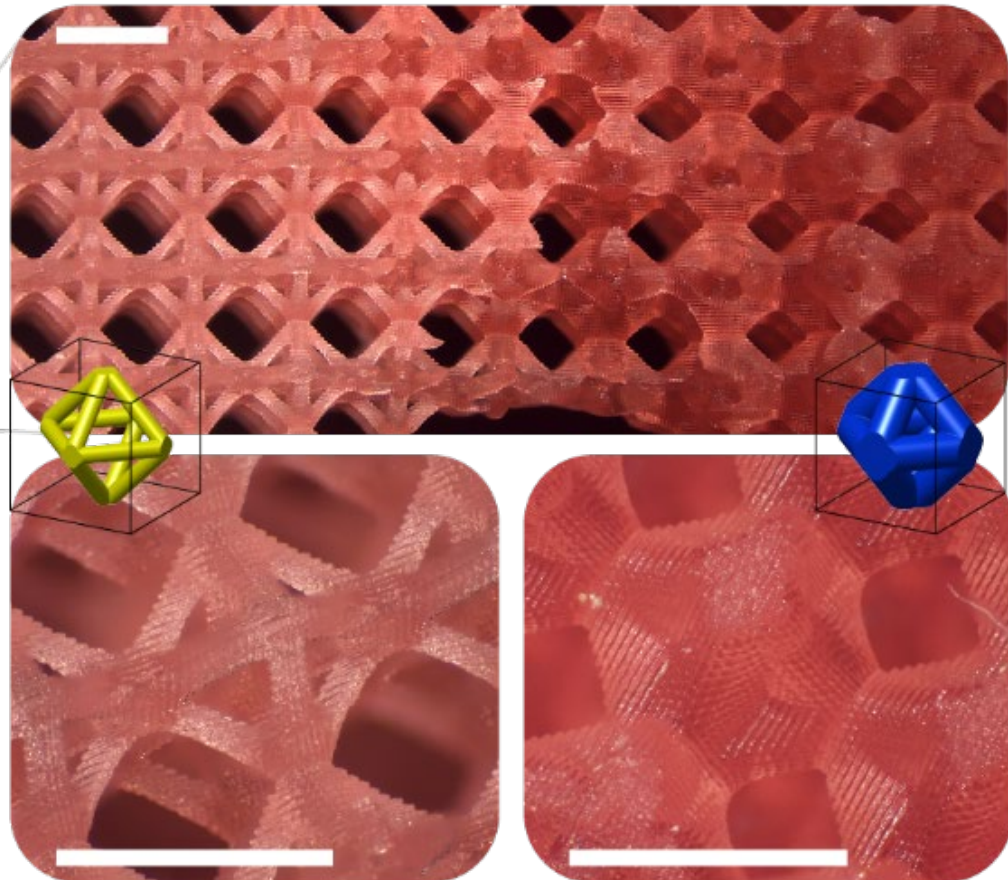


Continuous microstructure embedding



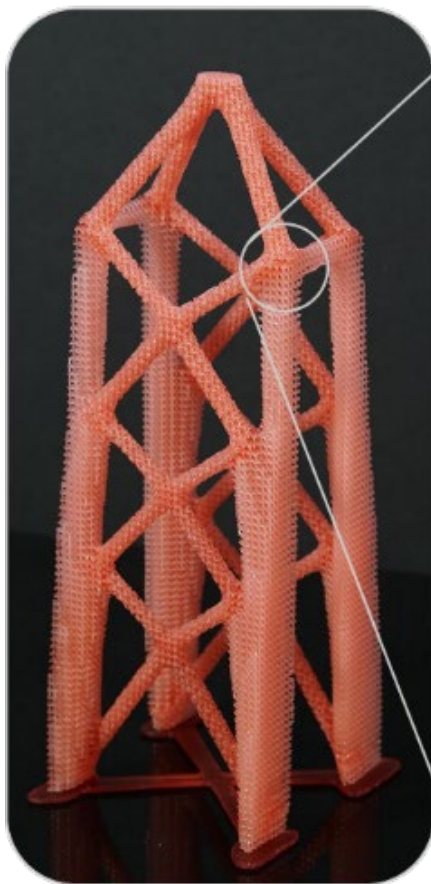
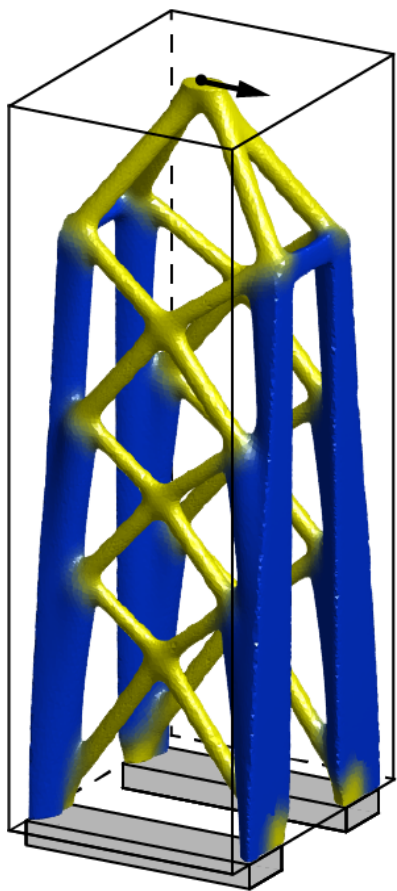


(height = 14.5 cm)
(scale bars = 1.5 mm)

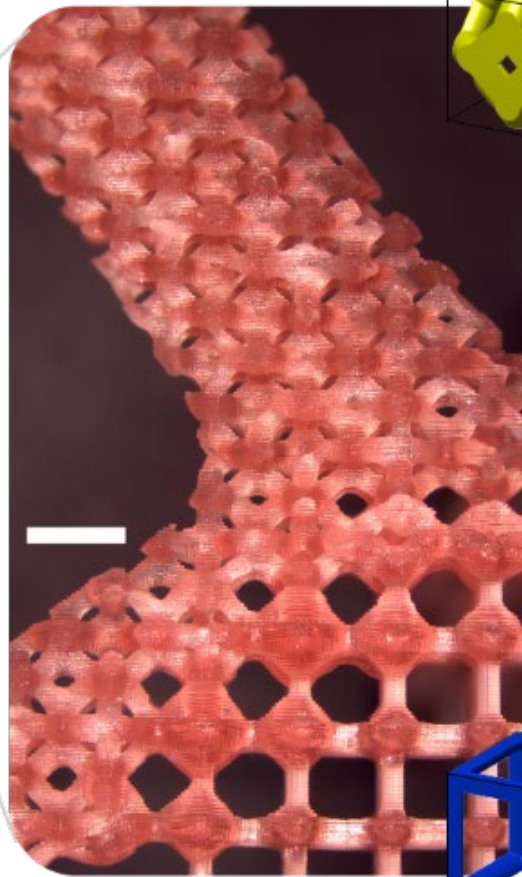


$$d_2^{\text{bar}} = 195 \mu\text{m}$$

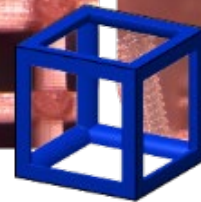
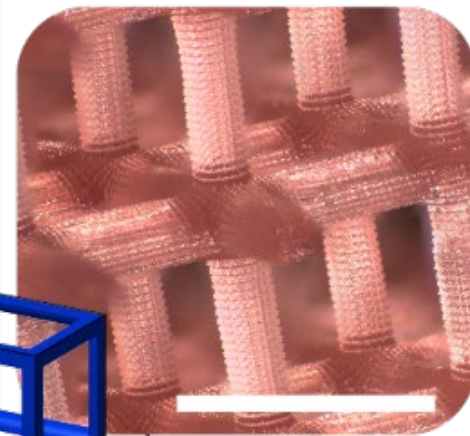
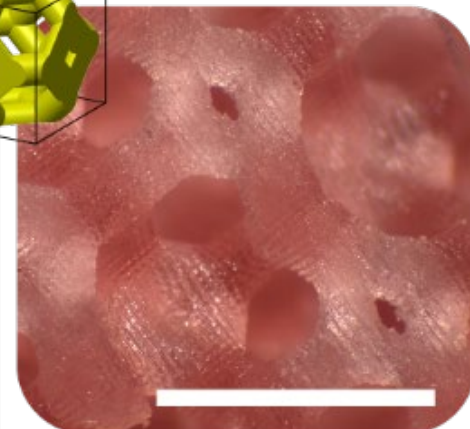
$$d_1^{\text{bar}} = 390 \mu\text{m}$$



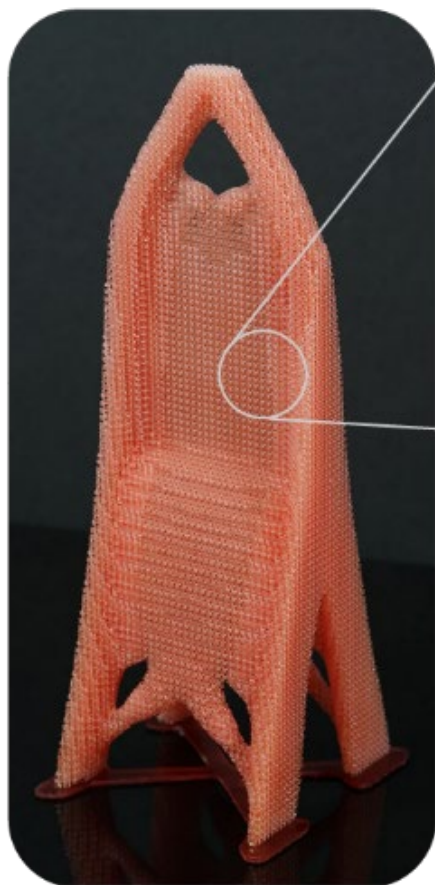
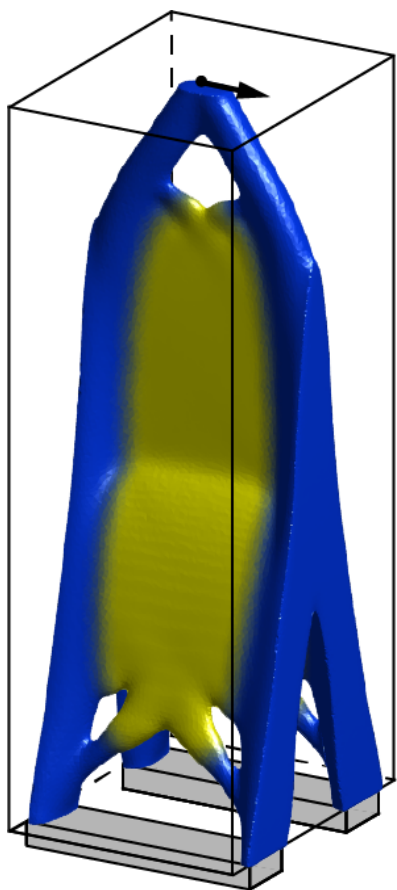
(height = 14.5 cm)
(scale bars = 1.5 mm)



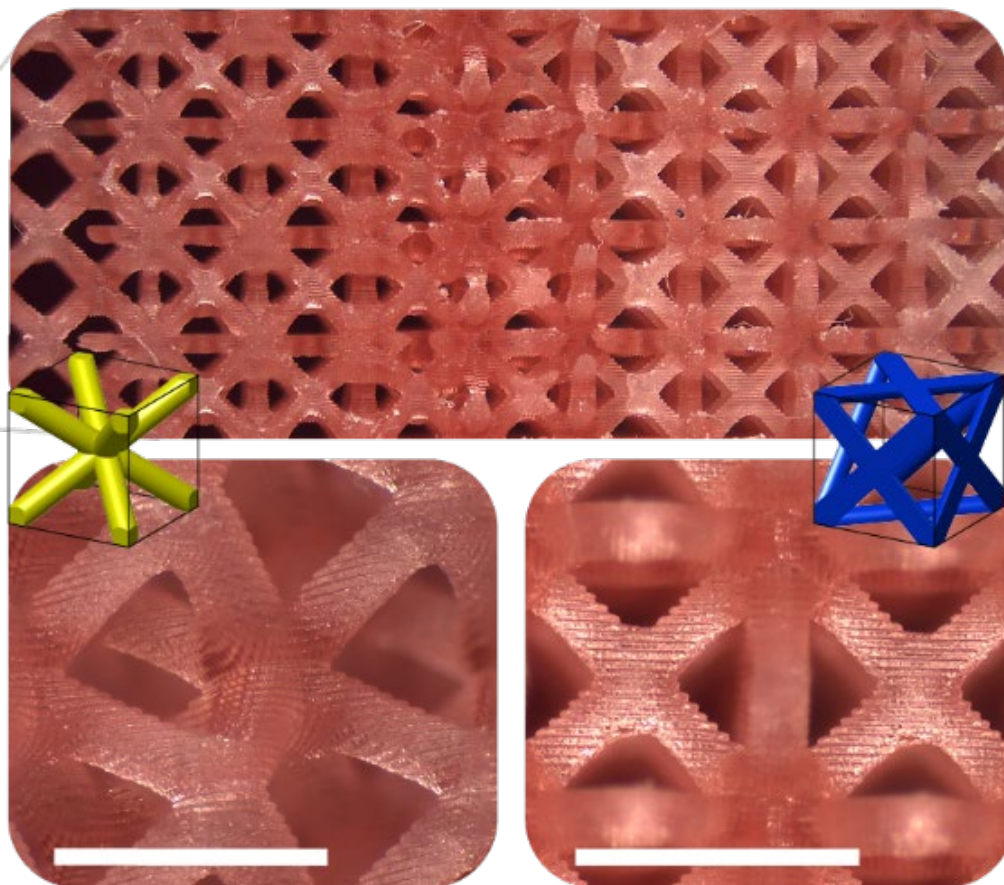
$$d_2^{\text{bar}} = 360 \mu\text{m}$$



$$d_1^{\text{bar}} = 360 \mu\text{m}$$

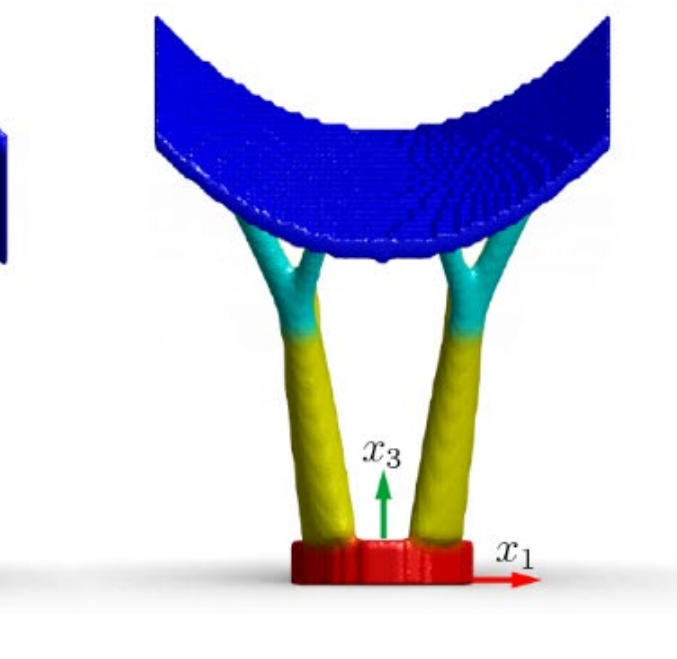
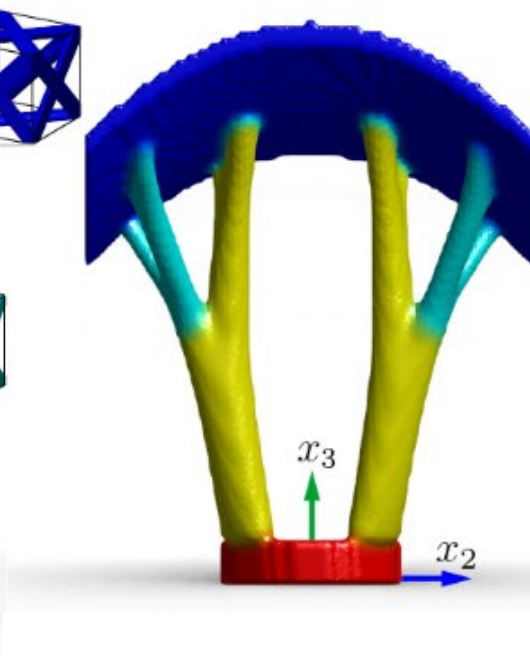
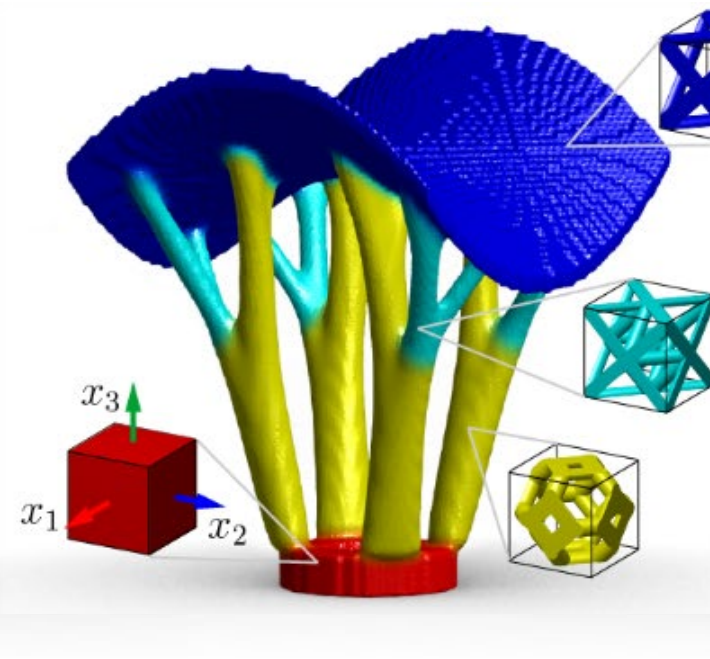


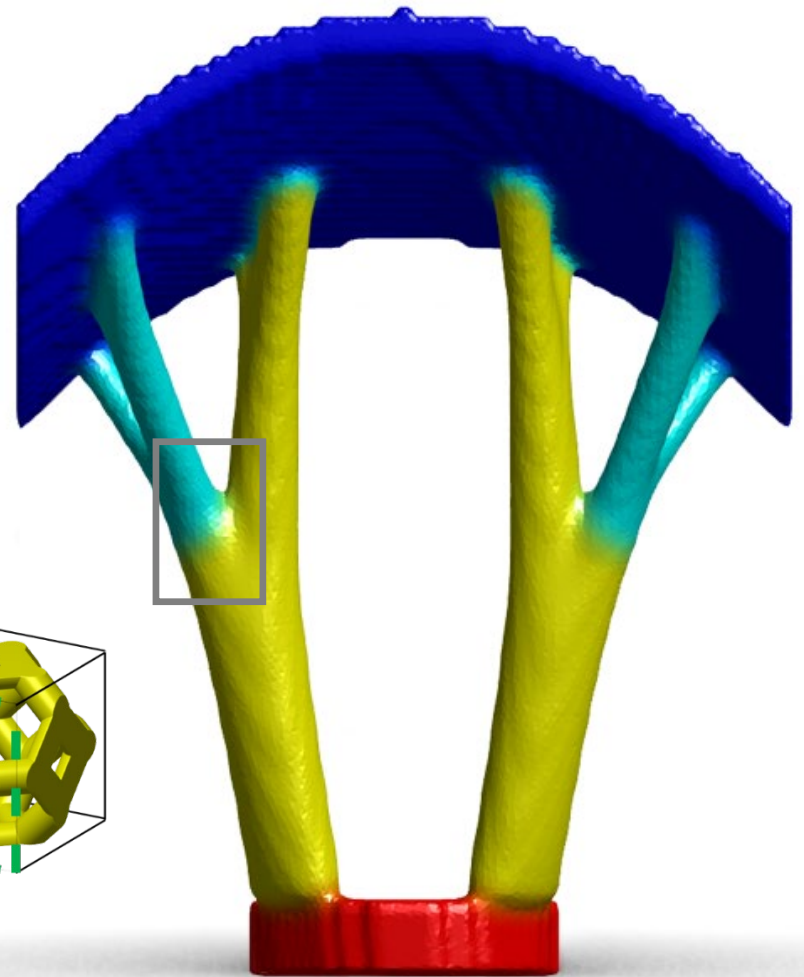
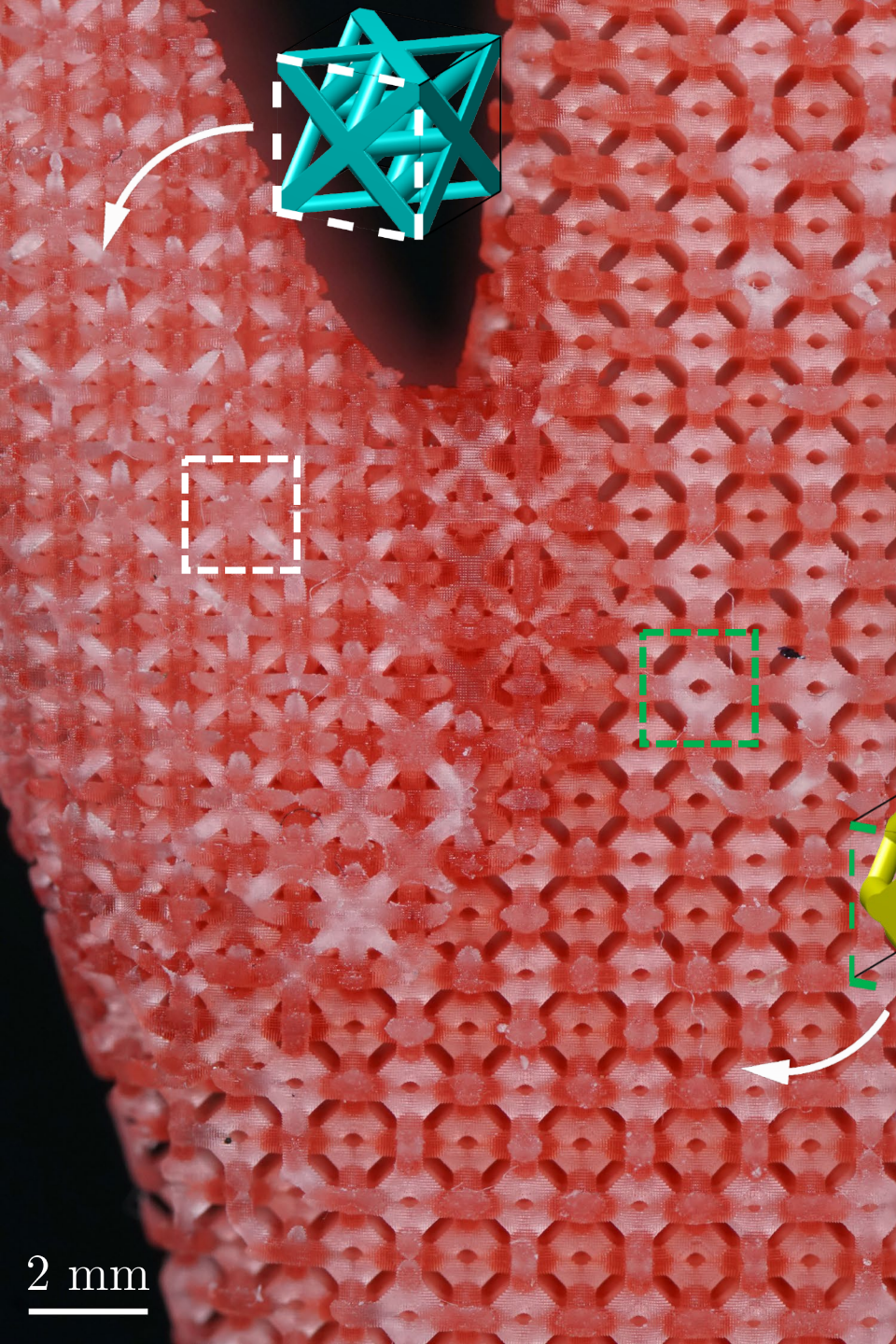
(height = 14.5 cm)
(scale bars = 1.5 mm)

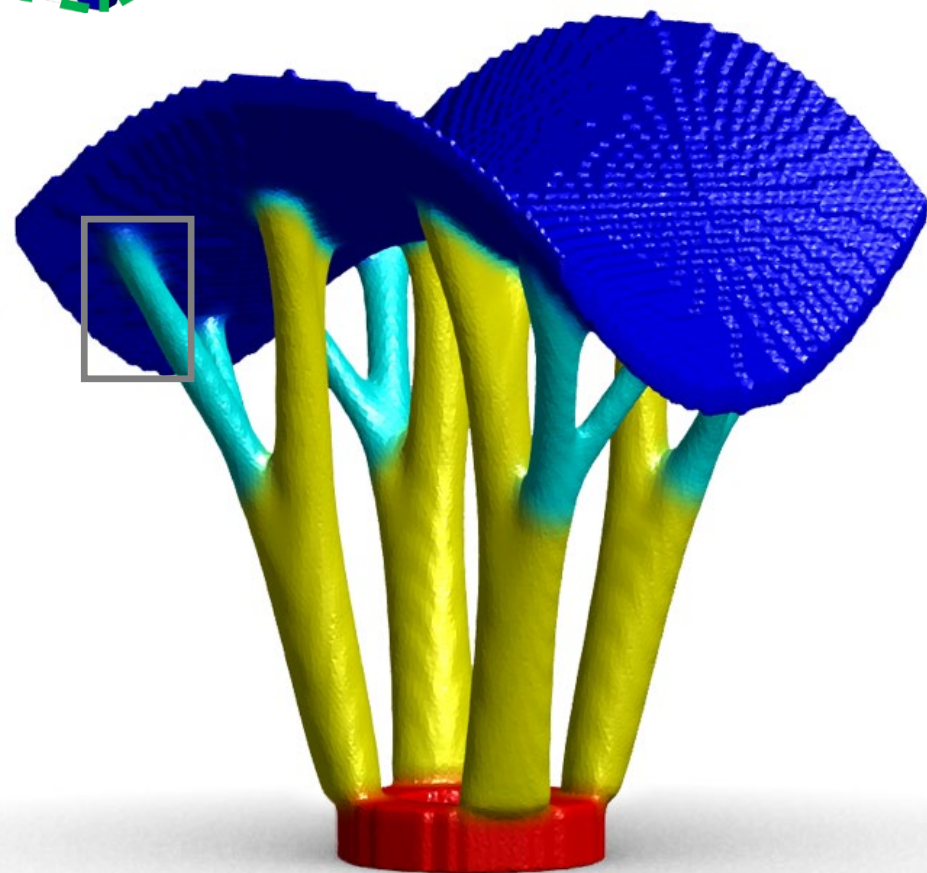
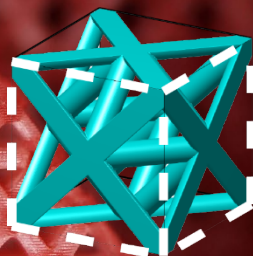
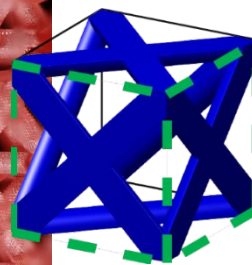
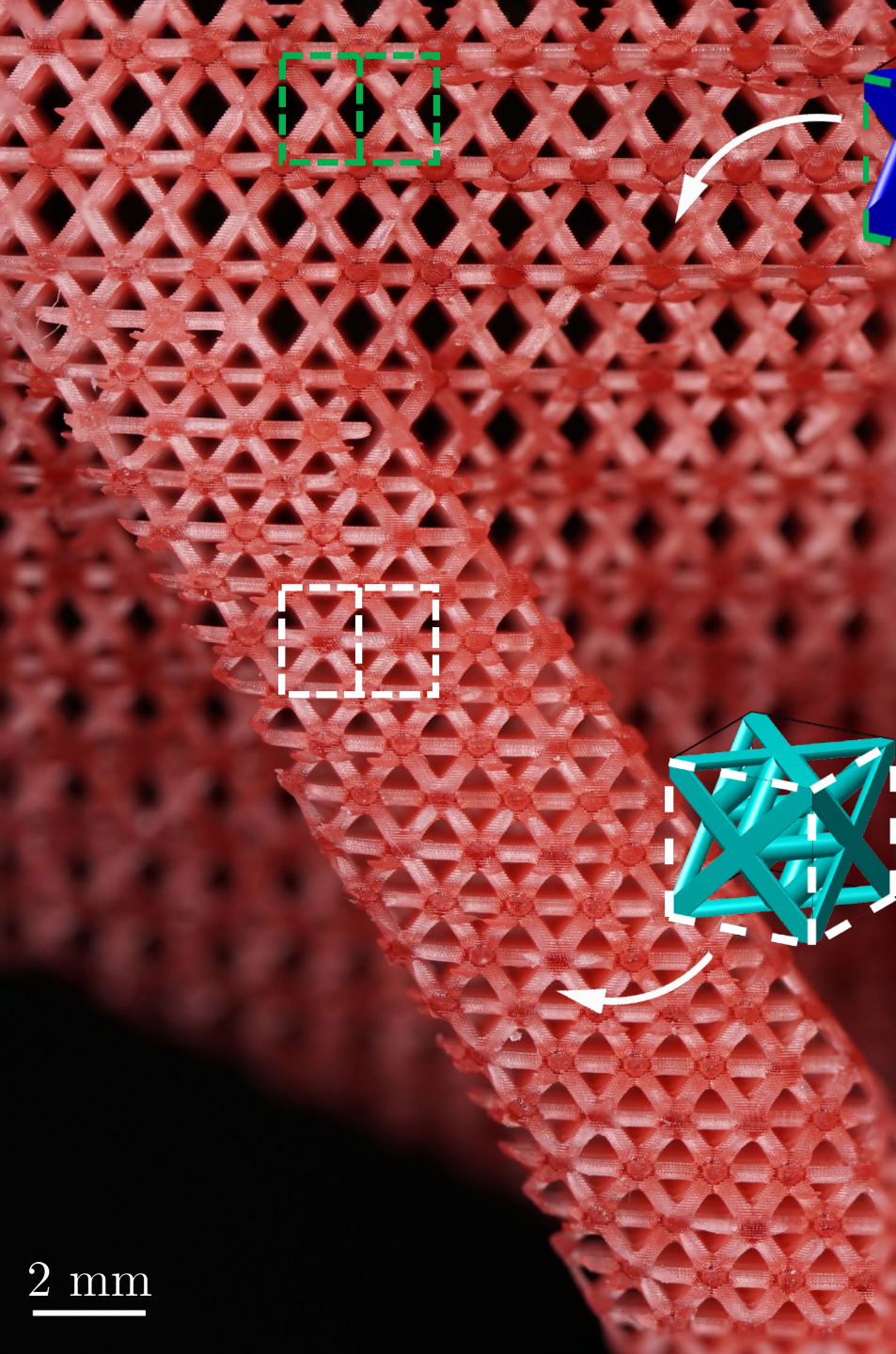


$d_2^{\text{bar}} = 300 \mu\text{m}$

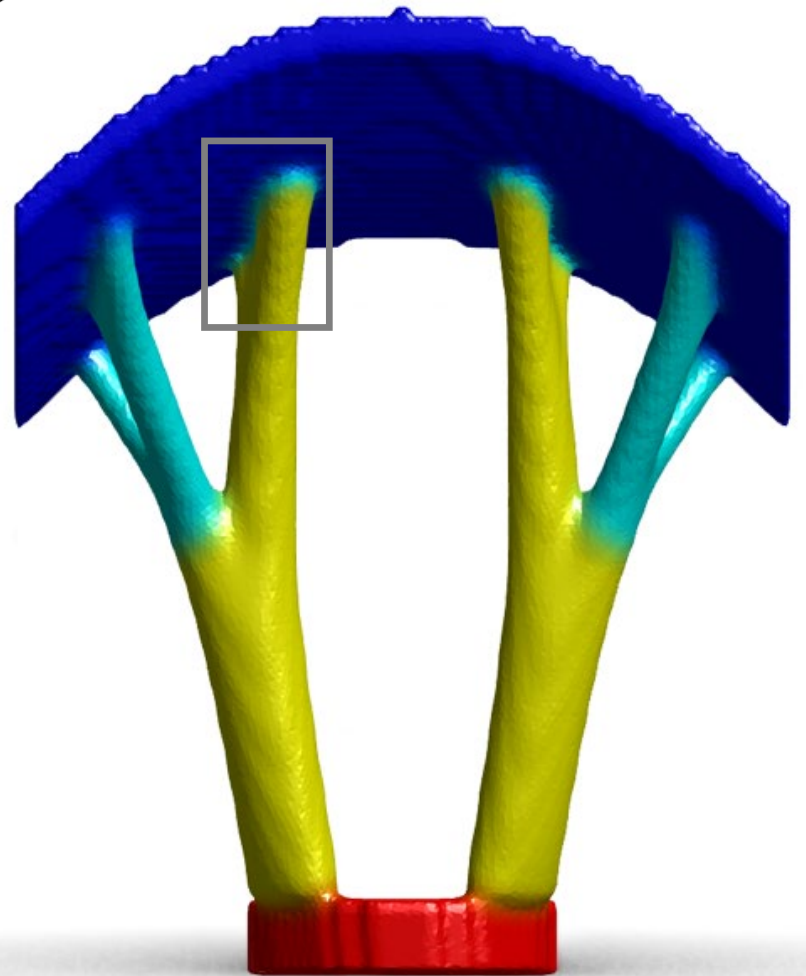
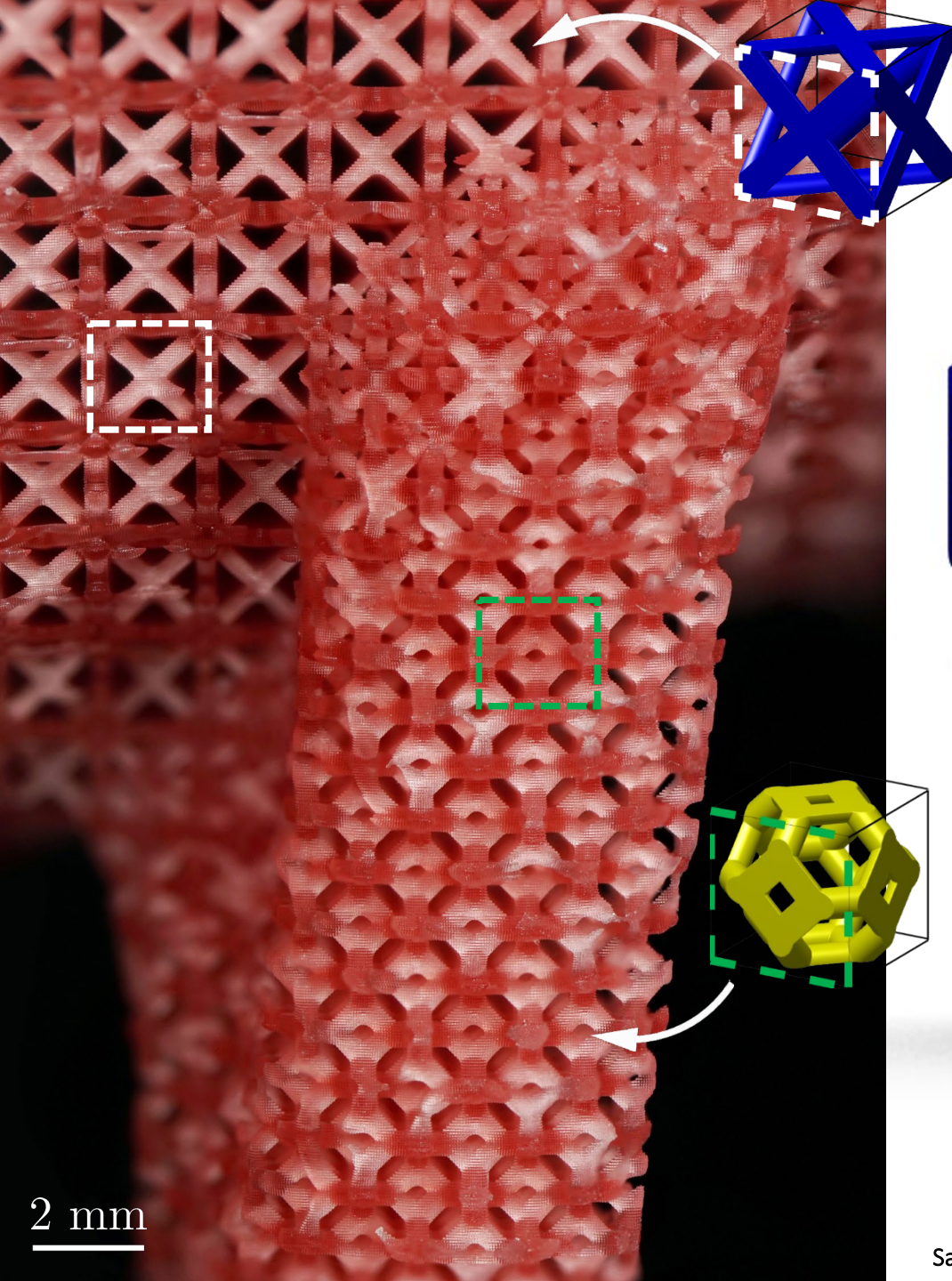
$d_1^{\text{bar}} = 300 \mu\text{m}$

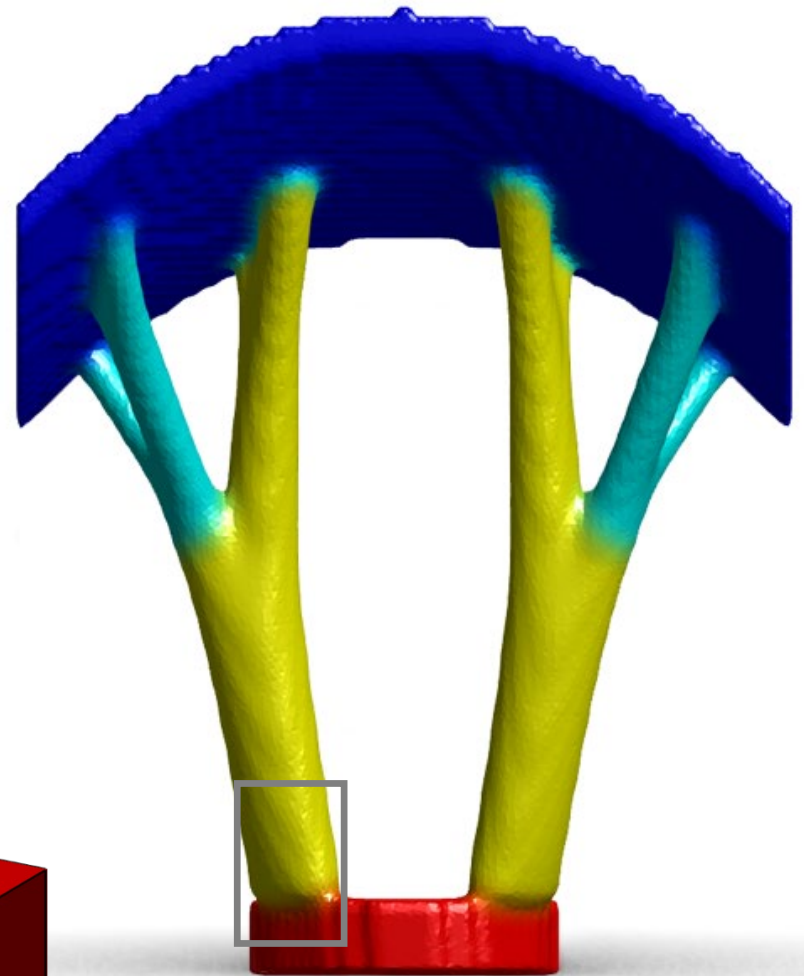
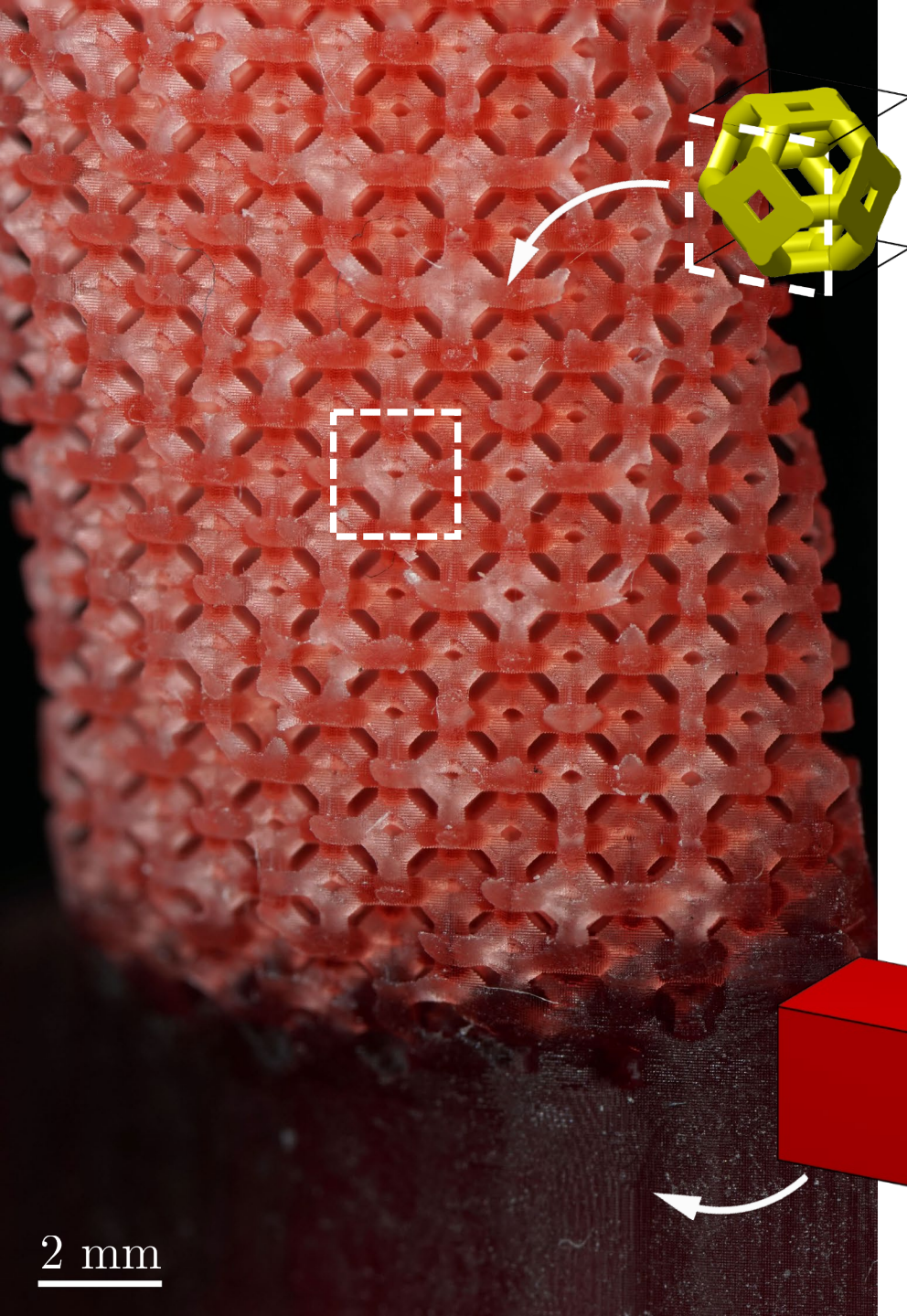


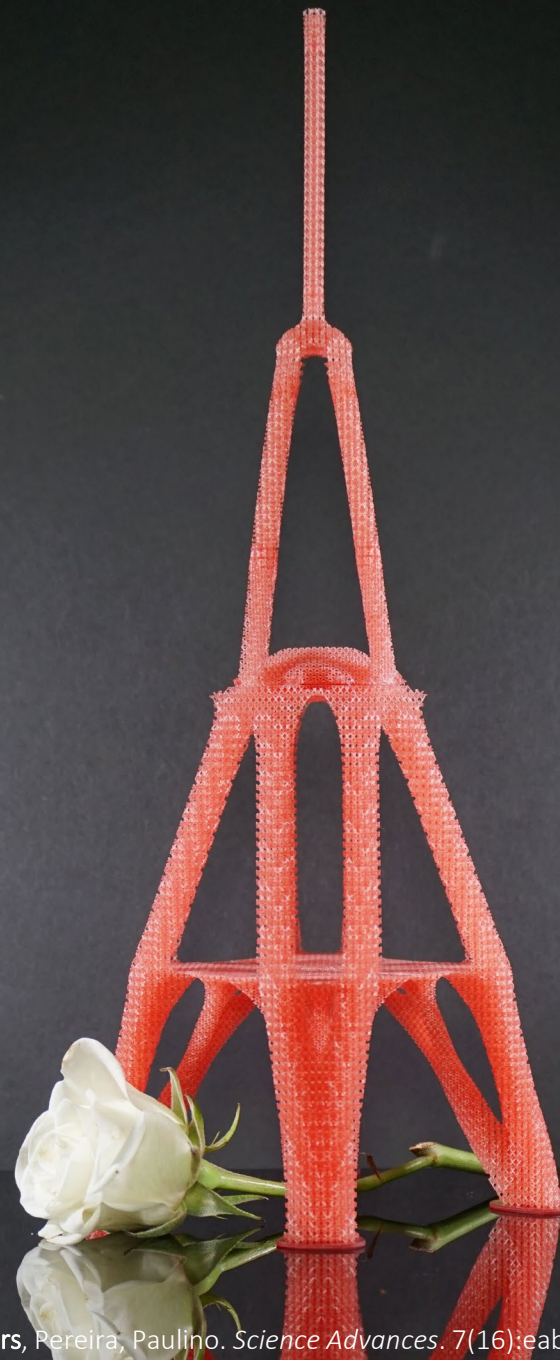
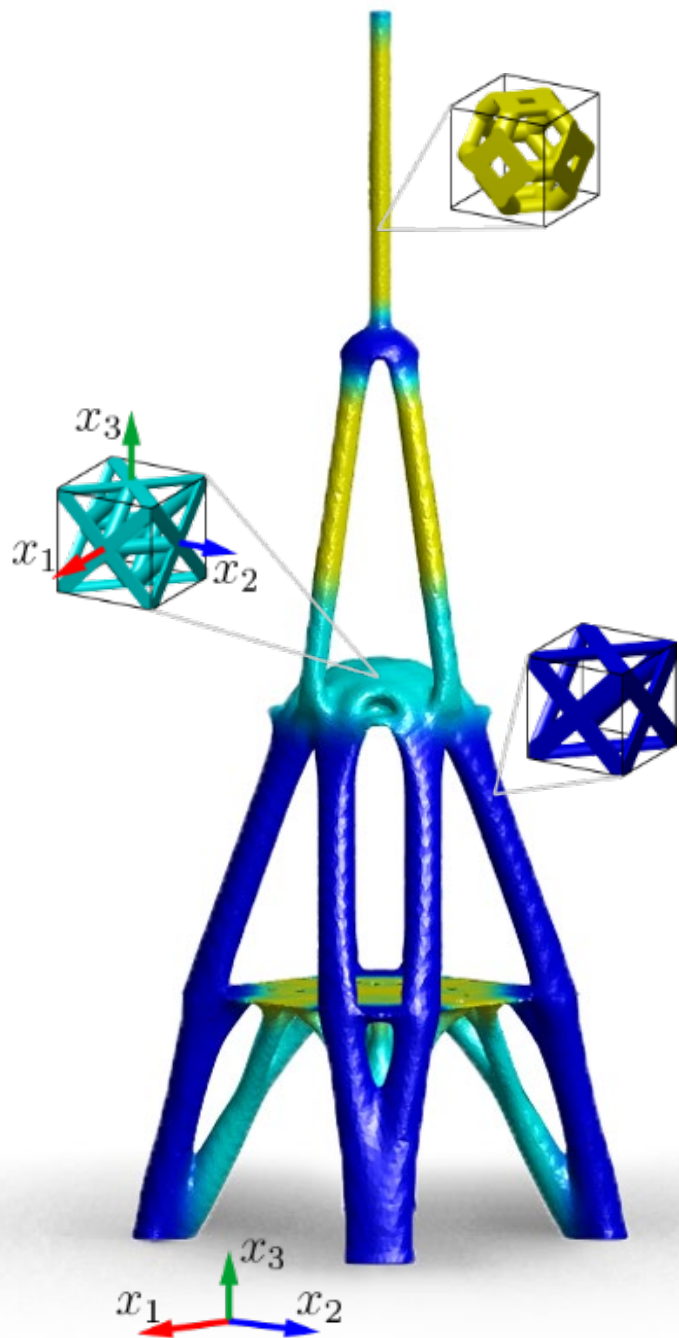




2 mm







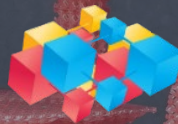


Thank You



Sandia
National
Laboratories

Georgia
Tech



SHAP3D



Emily D. Sanders, Anderson Pereira, and Glaucio H. Paulino. "Optimal and continuous multi-lattice embedding." *Science Advances*. 7:16, eabf4838, 2021.