

Architected Interfaces in Bimaterial Attachments

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Abstract: Nature's materials feature several strategies to mitigate stresses at bimaterial junctions, making soft-to-hard attachments long lasting. Some biological interfaces, like the bone-tendon junction, display a transition in mechanical behavior occurring over a micrometer-sized region and failure resistance is obtained by introducing, among other strategies, local interface patterning [1]. In this work, we investigated bimaterial attachment in synthetic systems obtained by voxel 3D printing and featuring local interface patterning at the mesoscale, i.e. at a length scale smaller than the component size but much larger than the microstructure. We used a polyjet printer (Object 260, Stratasys), which deposits and UV-cures photopolymer droplets in a layer-by-layer fashion. Using different inks, the printer allows fabricating structures composed of individual stiff or compliant cuboid voxels having minimum dimensions of 40 x 80 x 30 μm^3 . In a previous work we have shown that, owing to the printing process, the spatial transition in elastic properties across bimaterial interfaces can be fairly broad (around 150 μm), hence even larger than voxel size [2]. Here, we manufactured centimeter-sized bimaterial samples featuring voxels having side length of 420 μm . This dimension is chosen such that a voxel can retain its mechanical character. Samples were fabricated by assigning to the stiff voxels a rigid glassy polymer (Young's modulus of 2 GPa) and to the soft voxels a rubber-like material (Young's modulus of 40 MPa). We architected bimaterial interfaces based on the general idea of introducing minimal interface patterning, i.e. the width of the perturbed region at the interface between stiff and compliant materials (mesoscale) was at least one order of magnitude smaller than sample length (macroscale). Stiff and compliant voxels were rearranged to form either geometrical patterns or compositional gradients. Starting from a flat interface, we considered chessboard, rectangular and triangular designs as well as gradients with different slopes. We performed failure tests to measure strength and fracture toughness. Our results indicated that minimal interface perturbation in the form of triangular patterns outperformed compositional gradients to enhance failure resistance. Finite element simulations were done to characterize stress concentration. More relevant, simulations highlighted that while a flat interface led to the smallest stress values, the triangular patterns minimized stress localization and helped to redistribute peak stress away from the edges of samples. Our results shall provide guidelines to improve failure resistance of bimaterial junctions using voxel-based interface patterning.

References

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