Biomimetic Morphing Helix

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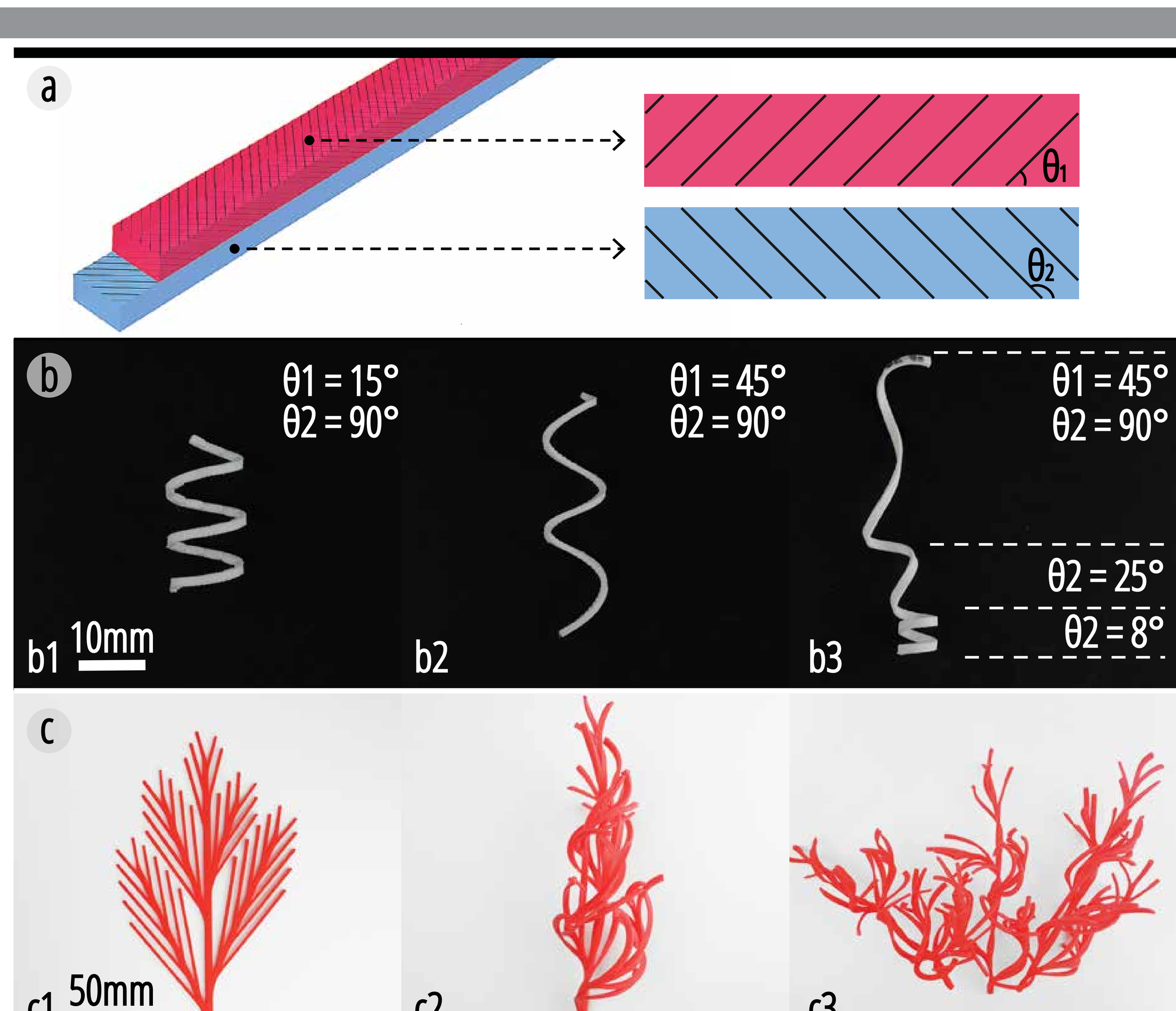
Motivation

Used by grape vines to grow, by seed pods to open, and by proteins to minimize their free energy, helical morphing supports functional and interactive artifacts across scales.

Naturally occuring helices. (a) cucumber tendril climbs into supporting structure; (b) dry erodium seed coils; (c) dry bauhinia seed pod turns into helices.

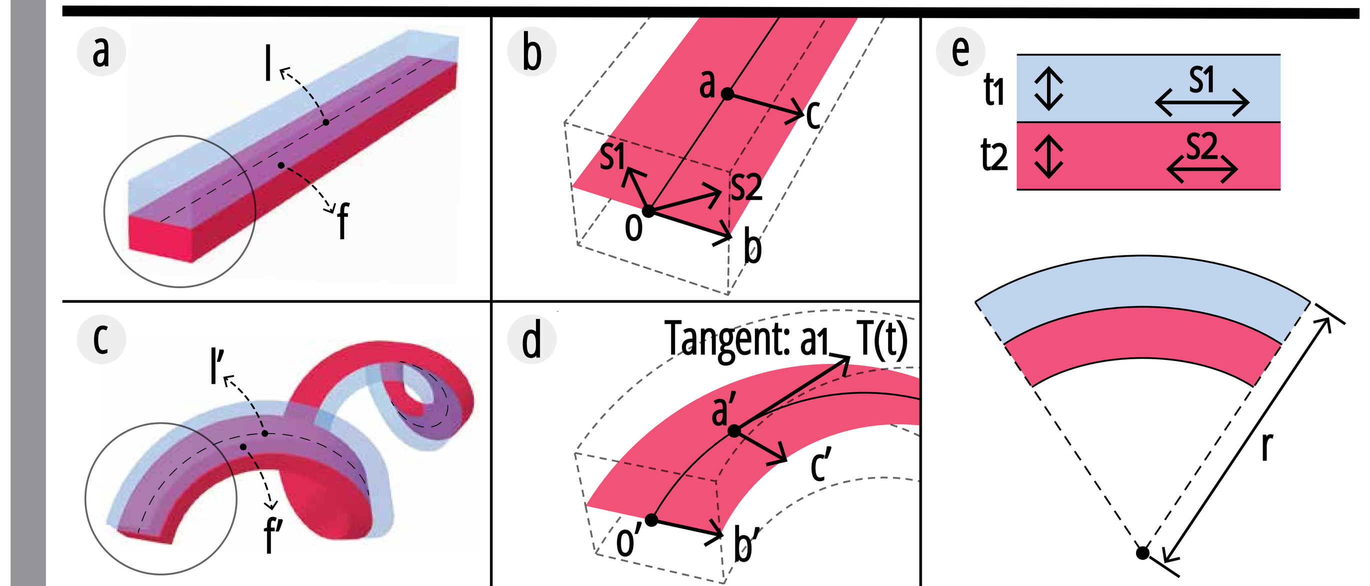
Key Contributions

- A geometry-based model that skips low-level physical mechanisms
- An extended library of materials systems that emphasize low-cost, safe handling, versatile stimuli and planar manufacturing
- A sensitizing design space around helical transformation through various applications



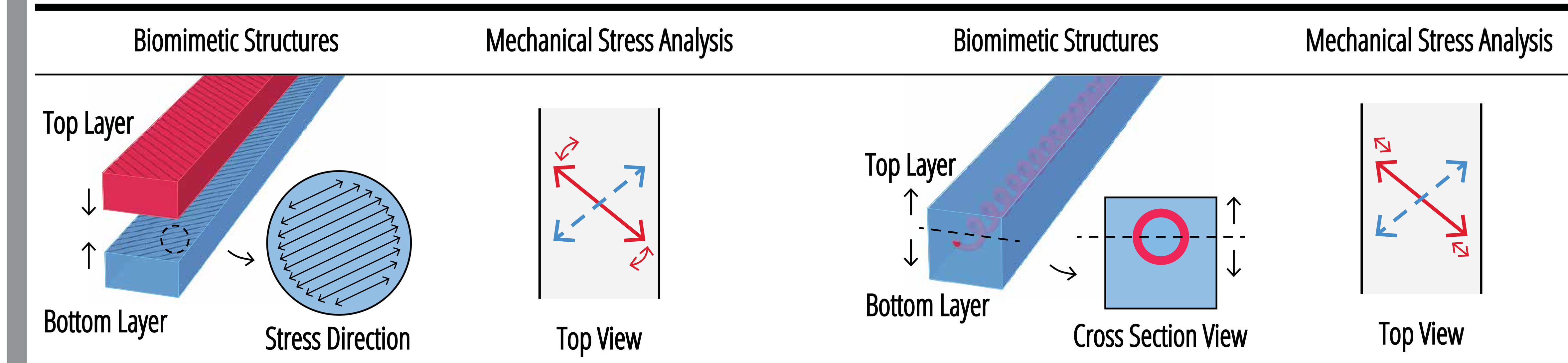
PLA morphing primitives prepared by FDM. (a)The printing path and speed define the shrinking direction and stress; (b) morphing helices with different printing angle combinations; (c) an artificial coral cluster designed with PLA helical primitives.

Grammar



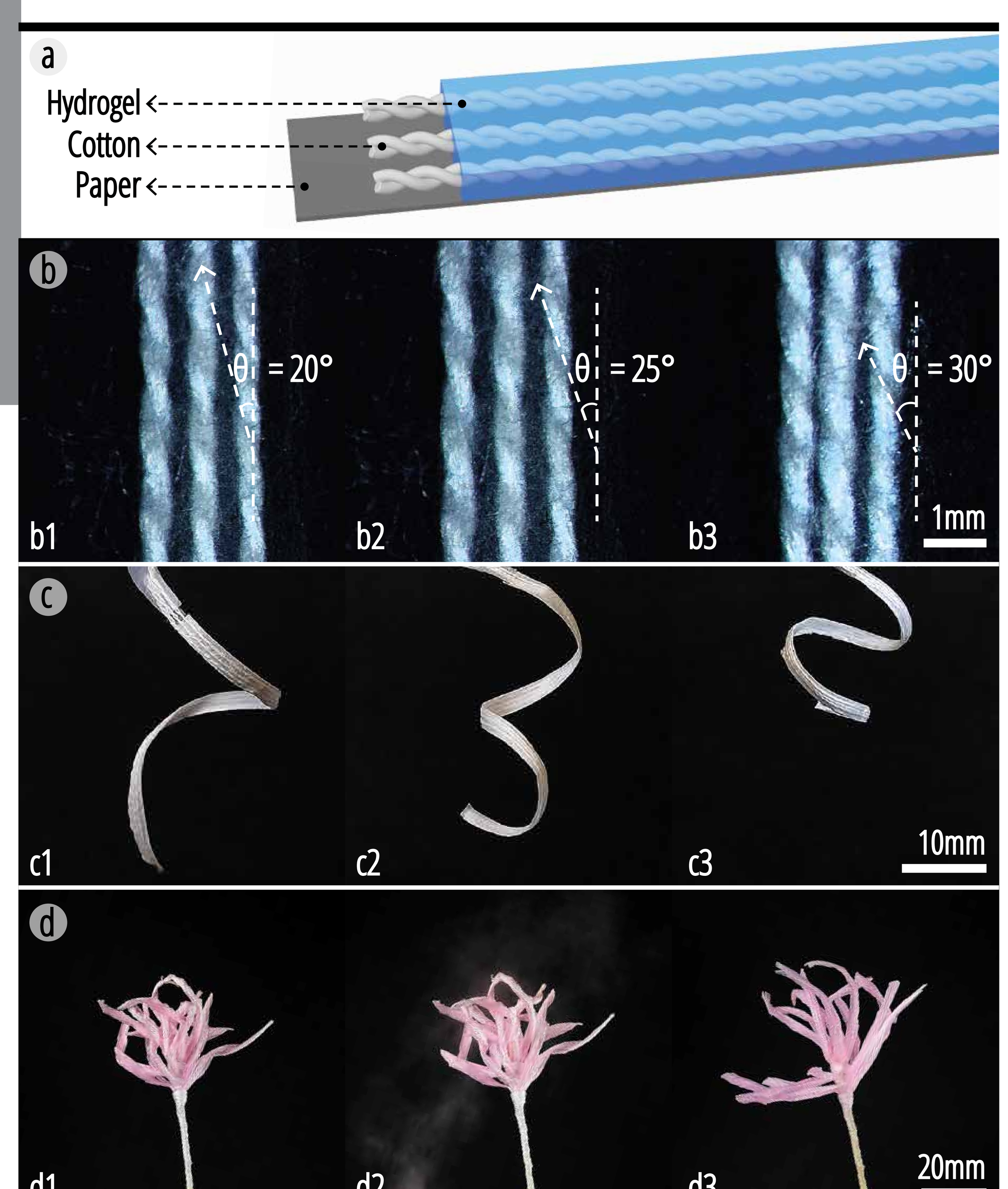
Stress field and geometrical evolution from a flat print to a helical shape: (a) flat stripe; (b) local stress condition and geometric features; (c) helical stripe mapped with (a); (d) local geometric feature mapped with (b); (e) mono-direction bending curvature.

Method Overview

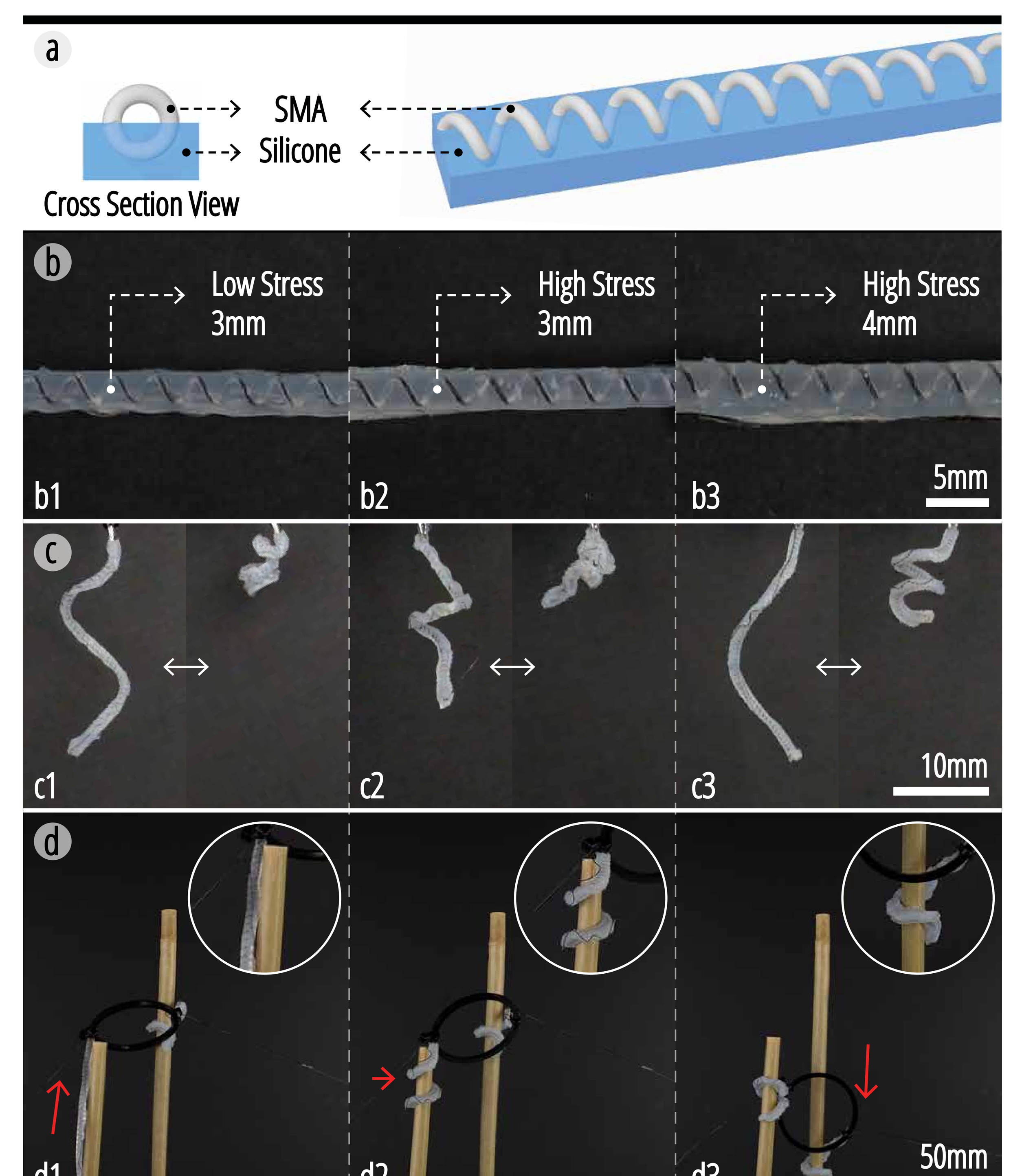


Inspired by different types of helical structures in nature, we designed four morphing primitives with different application scenarios based on various material compositions and fabrication methods guided by our helical transformation grammar. We have leveraged two biomimetic systems to reflect on our theory. Both use accesible fabrication to produce helical morphing interfaces with either directional linear constraint or continuous chiral constraints for actuation that respond to different stimuli.

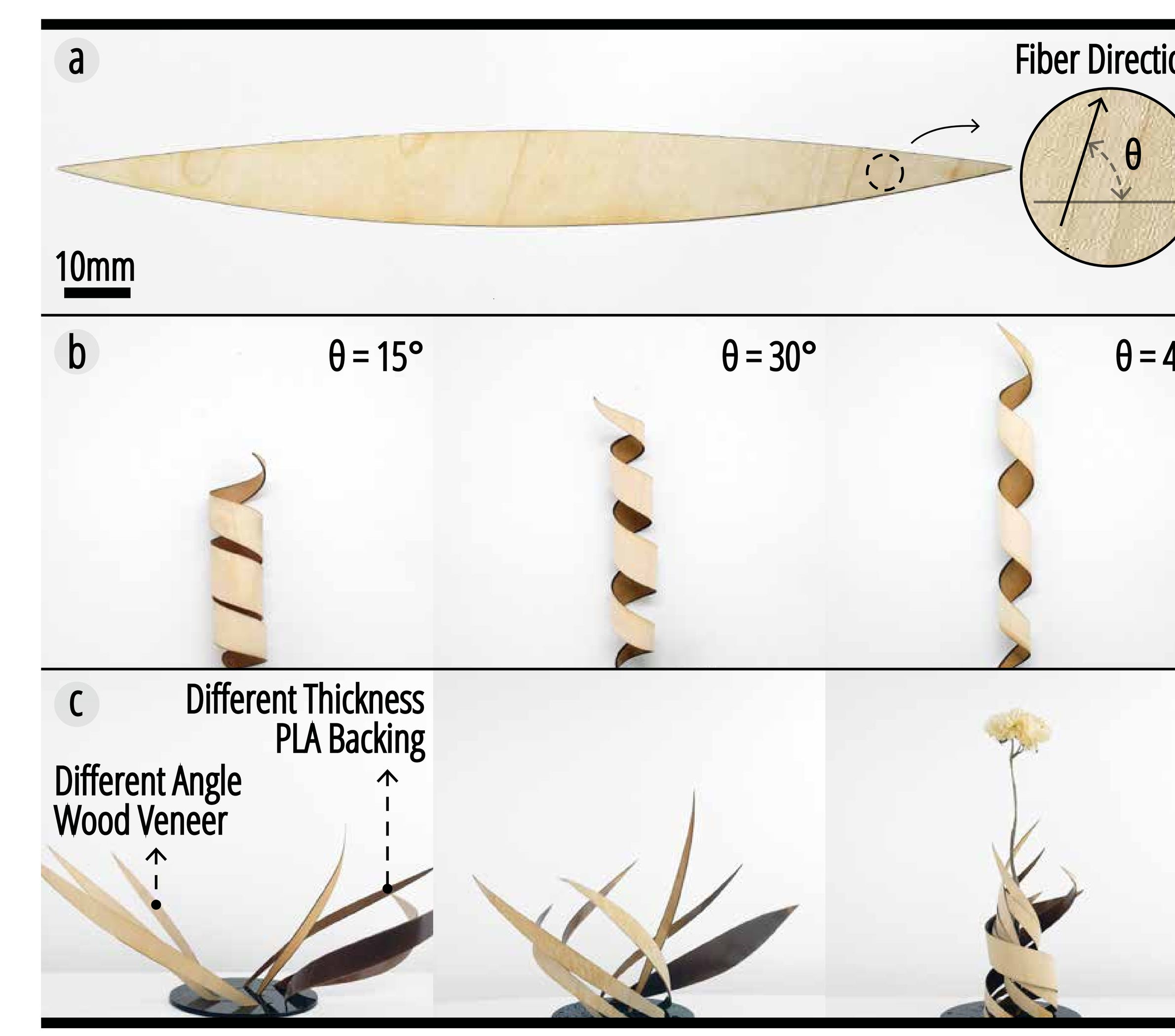
Application Design



Cotton-based helical morphing primitives prepared by coating. (a) Layers of materials; (b) twisted cotton yarns with different fiber direction, assembled in the arrangement shown in (a) will transform into helical shapes in (c); (d) a moisture-triggered artificial flower for humidity indication.



SMA-silicone composite helical morphing primitives prepared by casting. (a) primitive construct; (b) thickness tuning for changing the stress field; (c) corresponding helical morphing behaviors; (d) soft-leg climbing robot.



Wood veneer heat-pressed with backing material for tunablehelical morphing primitives. (a) A sample leaf-shaped wood veneer, with the particular fiber direction allowing the wood to helically morph into the corresponding shape with a different pitch; (c) flat-cut wood veneer pieces transform into a wood vase when hydrated.

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