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Mechanics of helical mesostructures from polymer-nanoparticle hybrids JONATHAN PHAM, JIMMY LAWRENCE, GREGORY GRASON, TODD EMRICK, ALFRED CROSBY, University of Massachusetts Amherst —
We describe the fabrication and mechanics of polymer and nanoparticle (NP)-based high-aspect ratio mesostructures, which we refer to as ribbons, with nm-scale cross-sections and up to cm-scale lengths. When placed into a fluid like water, interfacial tension associated with the ribbons' intrinsic geometric asymmetry balances the elastic cost of bending, turning ribbons into helices with tunable preferred curvature. This universal, elastocapillary-based mechanism enables the reversible formation of helices from a variety of polymer and NP compositions, as demonstrated with specific examples of poly(methyl methacrylate), CdSe quantum dots, and gold NPs with polystyrene-azide or undecene ligands. Using custom-designed characterization methods, we quantitatively show that helices are highly stretchable with force-displacement relationships described by a nonlinear spring of finite extensibility. At small strains, these helices generate nN forces, affording mesostructures with a stiffness similar to single polymer chains (ca. 10^{-6} N/m), and when fully stretched, they display properties similar to synthetic polymer nanofibers. These mesostructures offer a novel platform for engineering tunable materials with a broad range of mechanical properties and organic or inorganic functionality.

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