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A new approach for high performance fiber manufacturing via simultaneous fiber spinning and UV initiated polymerization

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Synthetic fibers have been manufactured for decades using solvents or heat to reduce the viscosity of pre-formed polymers and promote drawing. However, nature has engineered spiders and silkworms with benign ways of making silk fibers with high strength and toughness. Conceptually, their approach of chemically linking small functional units (i.e., proteins) into long chain molecules and solid fibrillar structures "on-demand" is fundamentally different from current synthetic fiber manufacturing methods. Drawing inspiration from nature, a method will be described that uses light to trigger a thiol-ene photopolymerization to rapidly transform reactive liquid mixtures into solid thread-like structures as they are forced out of a capillary at high speeds. Besides being manufactured without using solvents/volatile components or heat, these fibers are mechanically robust and have excellent chemical and thermal stability due to their crosslinked nature. During processing, the balance between curing kinetics, fiber flight time, and monomer mixture viscoelasticity is essential for the formation of defect free fibers. This work focuses on developing a universal operating diagram to show how the intricate interplay of gel time, flight time, and fluid relaxation time leads to the formation of uniform fibers and other undesirable fiber morphologies such as beads-on-string, fused fibers, non-uniform fibers, and droplets. This predictive capability enables adaptation of this spinning concept to all existing fiber spinning platforms, and customization of monomer formulations to target desired properties.