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Simultaneously Strong and Tough Continuous Nanofibers for Next Generation Structural Supernanocomposites

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Modern advanced composites and fibers are strong but brittle. Optimization of damage progression in composites has led only to moderate toughening. The advent of novel nanomaterials such as CNT and graphene has raised hopes for the development of strong and tough structural materials. However, problems with dispersion, alignment, achieving high volume fraction of discontinuous nanoreinforcement, and interfacial stress transfer proved to be more difficult than was initially thought. Recently, a different class of nanomaterials, i.e. continuous nanofibers, has been shown to possess unusual mechanical properties. This presentation will review recent breakthroughs on ultra-high-performance continuous nanofibers and their composites. Controlled nanofiber manufacturing, characterization, and mechanical testing will be discussed. Examples of pioneering high-performance polymer, carbon, and ceramic nanofibers will be presented. Highly ordered 2D/3D macroscopic nanofiber assemblies produced by potentially low-cost integrated (one-step) nanofabrication processes will be reviewed. Unique, recently discovered dramatic simultaneous increases in strength, modulus, and toughness in nanofibers with their diameter decrease will be presented and analyzed for the first time. Unconventional mechanisms of superplasticity in the strong and stiff nanofibers will be elucidated and experimentally verified. Possibilities of further significant improvements in properties by judicial, mechanism-guided control of polymer chemistry and crystalline structure of nanofibers will be demonstrated. Prospects of supertough continuous nanofibers with strength and energy to failure several times higher than the strength and toughness of the best commercial fibers will be demonstrated for the first time. Recent progress on nanofiber-reinforced supernanocomposites (defined by the author as nanocomposites exceeding the properties of conventional advanced composites such as carbon-epoxy) will be also discussed. Finally, possibilities for the ultrastrong and tough continuous nanofibers to enhance or even replace carbon as a new reinforcement for the next generation strong AND TOUGH structural composites will be evaluated.

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