ULTRA-HIGH ELASTIC STRAIN ENERGY STORAGE IN HYBRID METAL-OXIDE INFILTRATED POLYMER NANOCOMPOSITES

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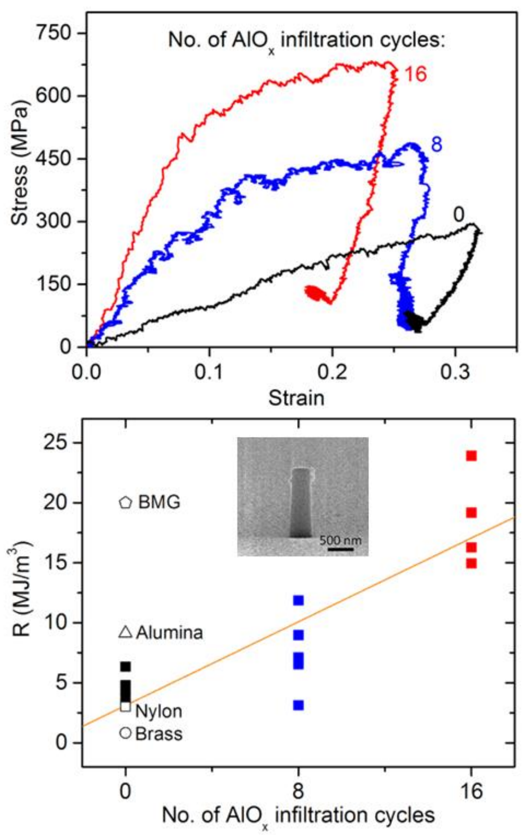

Figure 1: Stress-strain curves and modulus of resilience values (R) as a function of infiltration cycles with AlO_x, highlighting the strong, yet compliant nature of the hybrid nanocomposite as well as the tunability of R with processing route.

An understanding of the mechanical properties of materials at nanometer length scales, including a material's ability to store and release elastic strain energy, is of great significance in the effective miniaturization of actuators, sensors and resonators for use in micro-/nano-electromechanical systems (MEMS/NEMS) as well as advanced development of artificial muscles for locomotion in soft robots. The measure of a material's ability to store and release elastic strain energy, the modulus of resilience (R), is a crucial parameter in realizing such advanced mechanical actuation technologies. Typically, engineering a material system with a large R requires large increases in the material's yield strength yet conservative increase in Young's modulus, an engineering challenge as the two mechanical properties are strongly coupled; generally, strengthening methods results in considerable stiffening or increase in the Young's modulus. Here, we present hybrid composite polymer nanopillars which achieve the highest specific R ever reported, by utilizing vapor-phase aluminum oxide infiltrations into lithographically patterned polymer resist SU-8. In-situ nanomechanical measurements reveal high, metallic-like yield strengths (~500 MPa) combined with a compliant, polymeric-like Young's modulus (~7 GPa), a unique pairing never observed in known engineering materials. It is these exceptional elastic properties of our hybrid composite which allows for realization of R per density (R_s) values ~ 11200 J/kg, orders of magnitude greater than those in most engineering material systems. The high elastic energy storage/release capability of this material, as well as its compatibility with lithographic techniques, makes it an attractive candidate in the design of MEMS devices, which require an ultra-high elastic component for advanced actuation and sensor technologies. Furthermore, an opportunity for tunability of the elastic properties of the SU-8 polymeric material exists with this fabrication technique by varying the number of infiltration cycles or the organometallic precursor