

THE Alan G. MacDiarmid NanoTech Institute PRESENTS

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Wednesday, March 23rd at 11 a.m.
Berkner 2.528



Carbon Nanotubes with Temperature Invariant Viscoelasticity from -196°C to 1000°C

Viscoelasticity describes the ability of a material to both dissipate energy (viscous) and reversibly deform (elastic) and permeates all levels of our lives from human tissue, shoe soles, ear plugs, mattresses to vibration isolators. Within all viscoelastic materials there are elements providing both elasticity through their bonding and viscosity through their motion. The most common element, such as in rubber, is cross-linked long-chain molecules that move via intermolecular motion. Long-chain molecules limit temperature stability because below the glass transition temperature, molecular motion is frozen and at sufficiently high temperature, the material decomposes. This even holds true for silicone rubber, which is one of the best heat resistant viscoelastic materials.

Here, we present a 100% CNT viscoelastic material by combining the inherent mechanical properties of CNTs into a structure of networked non-aligned and long CNTs that mimics the rubber structure of crosslinked and traversing polymer chains. It shows temperature invariant rubberlike energy dissipation ability from -196°C~1000°C, which has not been shown by typical materials. Characterization at room temperature (RT) by dynamic mechanical analysis (DMA) revealed that this CNT material possessed same level of viscoelastic properties (storage modulus: 1MPa, loss modulus: 0.3 MPa) as silicone rubber. However, in difference to silicone rubber, the CNT material maintained the viscoelastic properties demonstrated by the temperature invariant storage and loss moduli, frequency stability (0.1-100Hz), reversible deformation level (critical strain 5%) and fatigue resistance (1,000,000 cycles, 100Hz) from -140°C to 600°C. The testing temperature range (-140°C~600°C) was limited to the commercial DMAs as no existing viscoelastic materials required tests beyond ~300°C. The intertube structures were observed to resemble a three-dimensional highway network, where each CNT made contact with innumerable other CNTs. This structure was critical for energy dissipation and structural cohesiveness that allowed for large deformations, which could not be achieved by typical bundled CNT material such as aligned forests where CNTs were straight and contact the same CNTs over long spans. Examination of the strained CNT materials by SEM and TEM suggested an energy dissipation mechanism governed by the vdW between contacting CNTs. The temperature invariance of the vdW interactions^[1] and the mechanical properties of CNTs explain these temperature invariant viscoelastic properties.

[1] Lenaz, G. & Milazzo, G. *Bioelectrochemistry of Biomacromolecules*, (1st ed., Birkhäuser Basel, Switzerland, 1997).

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