RECENT ADVANCES FOR CARBON NANOTUBE ELECTROCHEMICAL ACTUATORS

Anvar A. Zakhidov, R. H. Baughman, Alan Dalton, Edgar Munoz, Steve Collins

Dept. of Chemistry and NanoTech Institute, University of Texas at Dallas, TX 7

Yuri Gartstein,

Xerox Research Center, 800 Phillips Road, Webster, NY 14580

We have previously described a promising new type of electromechanical actuator, which is based on electrochemical double-layer charging of carbon nanotubes. It was not clear if physics of this actuation effect in carbon nanotubes is qualitatively different from that in graphite. In this presentation we will show that actuation in CNTs strongly depends on their chirality. To accommodate extra electrons/holes on a carbon nanotube, carbon-carbon bonds adjust their length resulting in dimensional and torsional changes of the tube. We show that modulation of the electron kinetic energy by the lattice distortions results in a quite unique picture of such changes. The salient features of the lattice deformations are anisotropy and strong dependence on the nanotube geometry. Nanotubes upon charge injection can exhibit both expansion and contraction, as well as non-monotonic size changes. The magnitude of the response of semiconducting carbon nanotubes may be substantially larger than that of graphite. Therefore we predict that if semiconducting tubes of certain chirality can be selectively separated from metallic ones, the actuation can be dramatically enhanced. On experimental side the previously realized performance was limited by the low modulus and low strength of nanotube sheets. We here describe methods for obtaining carbon nanotube sheets and fibers having order-of-magnitude higher mechanical properties and show that these property improvements lead to nanotube actuators providing an actuation force of 26 MPa (which is two orders of magnitude higher than for natural muscle) and an isometric gravimetric work/cycle that is 3X higher that for the best hard ferroelectric. Theoretical analysis of actuator strain versus charge agree with experiment at large changing levels and indicate that electrostatic charges in bond length dominates over band-structure effects, and that reversible slip occurs between inner and outer tubes in a nanotube bundle when strain is large. The obtained increase in actuator performance with modulus increase, support our arguments that carbon nanotubes will eventually provide order-of-magnitude higher work/cycle and stress generation than any prior art technology.