Modelling of Nanotube Based Actuators and Experimental Validation

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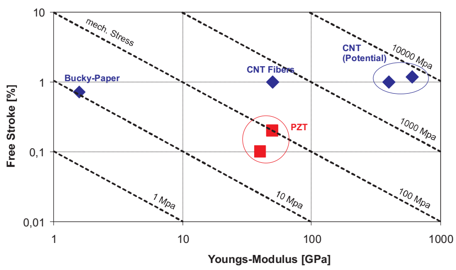
Potential of Nanotubes as actuators

Properties of Nanotube based actuators:

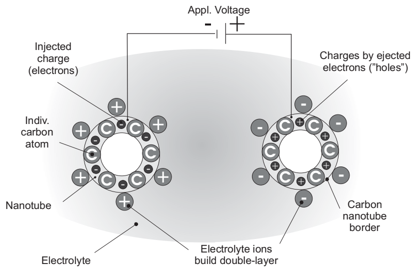
- High stress generation
- High free stroke
- Low density
- Low voltage
- Low dynamics



Effect of Nanotube actuation

Effects[1]:

- Electrostatic interaction between CNT π - band and ions (major effect)
- Charge transfer from ions to the nanotube



[1] Shankar Gosh, Vikram Gadagkar, A.K. Sood, Chemical Physics Letters 406 (2005) 10-14

Basis of analytical model

Conservative energies:

$$E = \frac{Q^2}{2C} - U^e Q + \kappa \frac{S^2}{2} - F^e S$$

Dissipating forces:

$$\dot{S} = -\gamma \cdot F$$
$$\dot{Q} = -\sigma \cdot U$$

Variation of Energy regarding S und Q leads to:

$$F = \frac{Q^2}{2}\frac{d}{dS}C^{-1} + \kappa S - F^e$$
$$U = \frac{Q}{C} - U^e$$

Approximation:

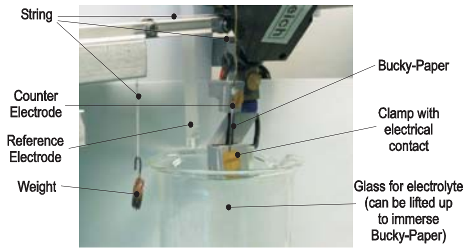
$$C^{-1} = C_0^{-1} - \alpha \cdot S$$

Inclusion of energy dissipation yields the system equations:

$$\dot{S} = -\gamma(\kappa \cdot S - F_e - \frac{Q^2}{2}\alpha)$$
$$\dot{Q} = -\sigma\left(\frac{Q}{C_0} - U_e\right)$$

Electrical Properties

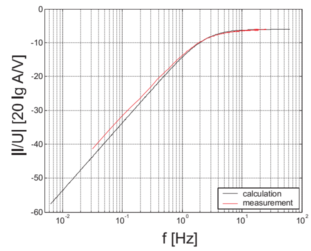
Experimental Test Setup



Analytical formulation:

$$R \cdot \dot{Q} + \frac{1}{C_0} \cdot Q = U_e$$
$$\tau_{el} = \frac{C_0}{\sigma} = R \cdot C_0$$

Good description of experimental results

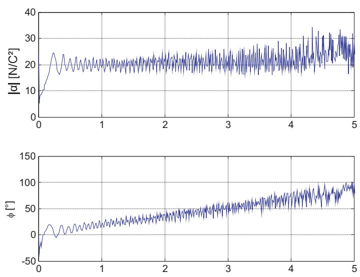


Mechanical and Coupling Properties

Mechanical System: $\frac{1}{\gamma} \cdot \dot{S} + \kappa \cdot S = F_e$ $\quad \tau_{mech} = \frac{1}{\kappa \cdot \gamma}$

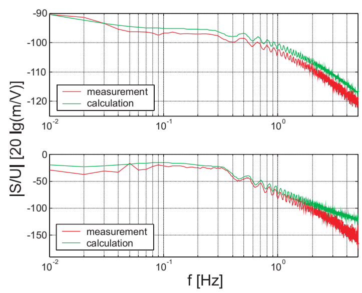
Koefficients determined by DMA

Coupling Koefficient: $\alpha = \frac{2 \cdot \kappa \cdot S}{Q^2}$



Full electro-mechanical System

Transfer function: Input: Voltage, Output: Displacement



Next Steps:

- Application for other voltage ranges
- Refinement of model e.g. by use of CPE
- Application to solid electrolyte systems

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