# Carbon Nanotube Actuators

**S. Geier, T. Mahrholz, J. Riemenschneider, P. Wierach, M. Sinapius;**

**German Aerospace Center (DLR) - Institute of Composite Structures and Adaptive Systems, Lilienthalplatz 7, 38106 Braunschweig, Germany, Contact: Sebastian.Geier@dlr.de**

## Motivation

Carbon Nanotubes as a new class of nanoparticles are very interessing for structural applications due to thier excellent properties like low density, high Young's modulus and stiffness. Therefore this new kind of actuator has great potential as electro-mechanical transducer among other already established systems like shape memory alloys (SMA), electro active polymers (EAP) and piezo-electric transducers (PZT, see Fig. 1) for adaptive applications. The active behaviour of CNT-actuators is caused by an electric field and ion transfer. Figure 2 presents a possible model of the elongation mechanism. Two CNT-electrodes are positioned with one another, the space in between is filled up with an electric isolating, but ionic conductable electrolyte. It is a capaciter-like build up. An electrical source charges the electrodes, so that the electrolyte-ions form a double layer around the CNTs. This causes on the one hand a decrease of the C-bonds and on the other hand the double-layer ions diffuse between the C-atoms, elongating their bonds. Calculations and experiments suggest that it will be a combination of these two effects, until today this it is not proven in depth. Nevertheless due to the model low voltages <10V cause strains up to 1%.

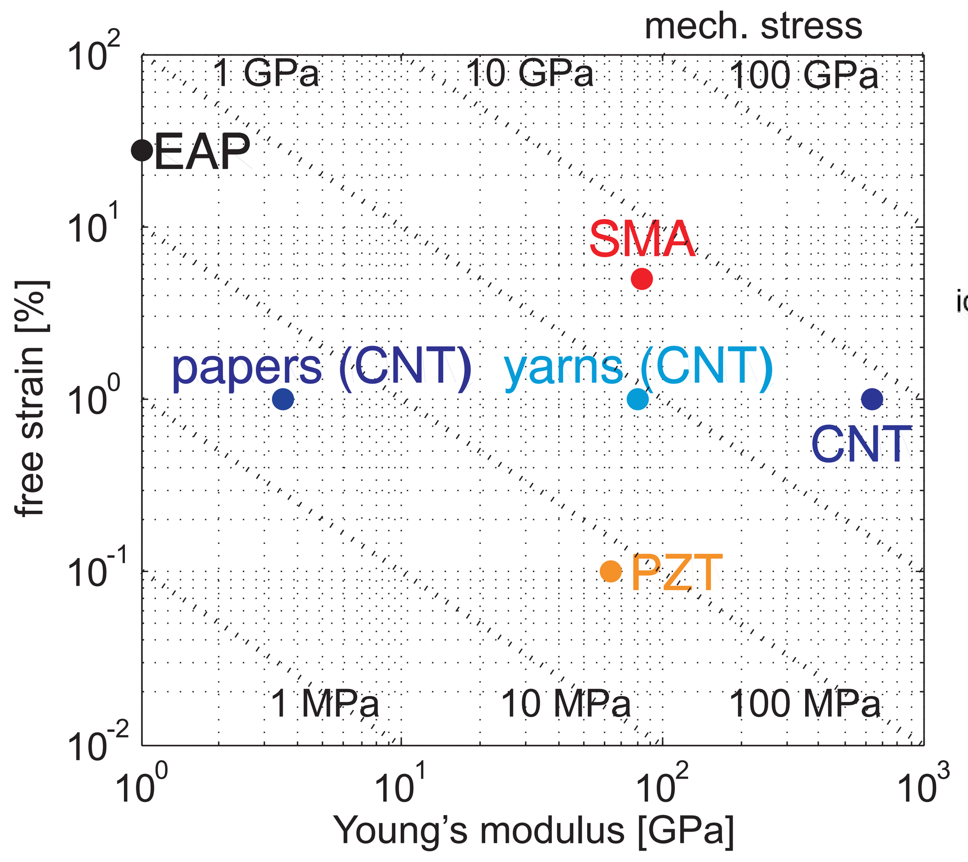


Figure1 : potentials of CNT-transducers

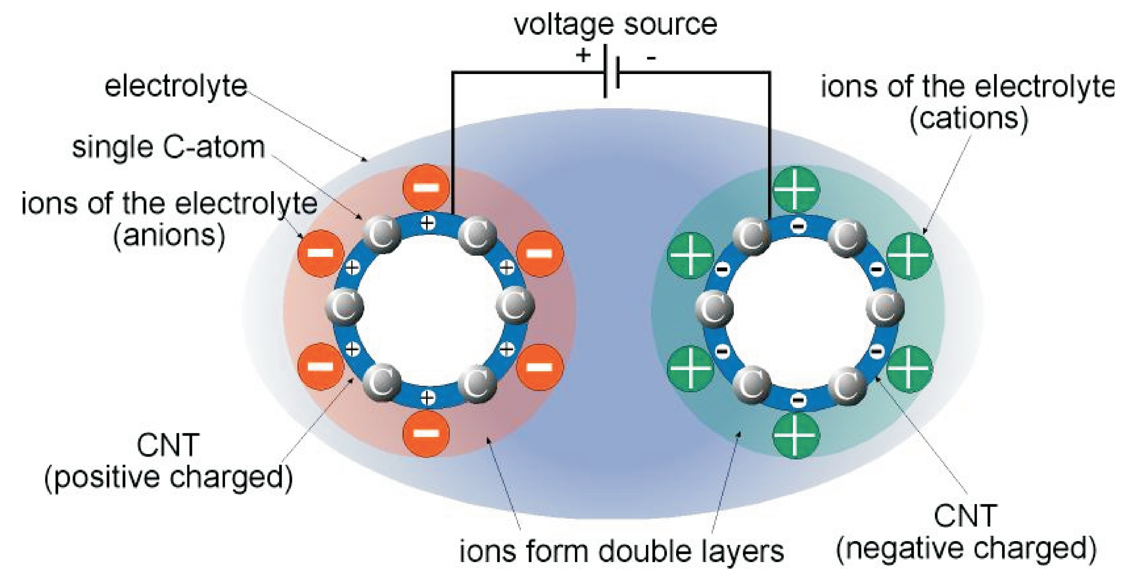


Figure 2: model of actuation-mechanism

## Qualitymanagement of CNT-powder and produced CNT-papers

the purity of the basic CNT-powder is crucial for the properties of the produced CNT-papers (Table 1). Therefore the powder is tested by SEM and TGA-measurements (see Fig. 3). The CNT-dispersion is analysed by CPS-method (see Fig. 4). The quality of the later on produced paper is optical tested by SEM (see Figure 5) again, its density and specific surface area (BET-method) are measured. Via an optical devices (see Fig. 6) the topology of a CNT-paper is tested. The results are compared for getting an idea of the quality of the paper manufacturing process, possible improvements and the internal structure of the individual Bucky-Paper.

| supplier | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| offered purity [%] | 70 | 97 | 95 | 90 | 90 |
| conductibility [S/cm] | 241 | 75 | 90 | 21 | 58 |

Table 1:characteristics of different compared CNT-powders

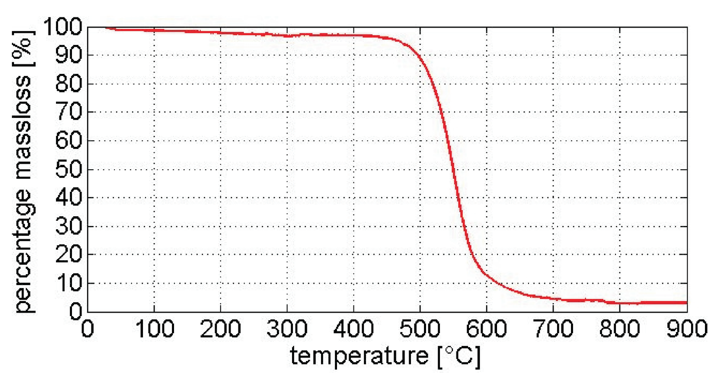


Figure 3: TGA-test of CNT-powder

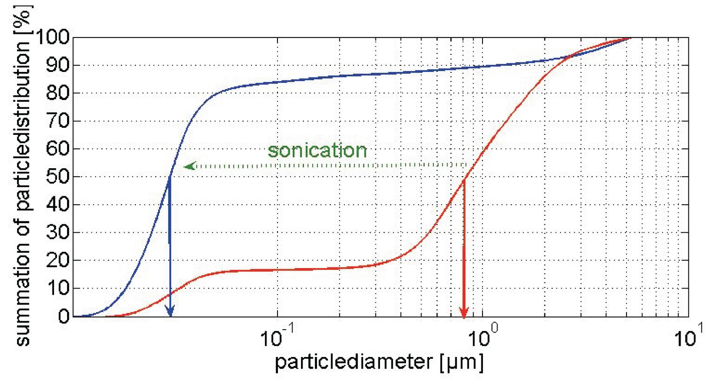


Figure 4: CPS-measurement of CNT-dispersion

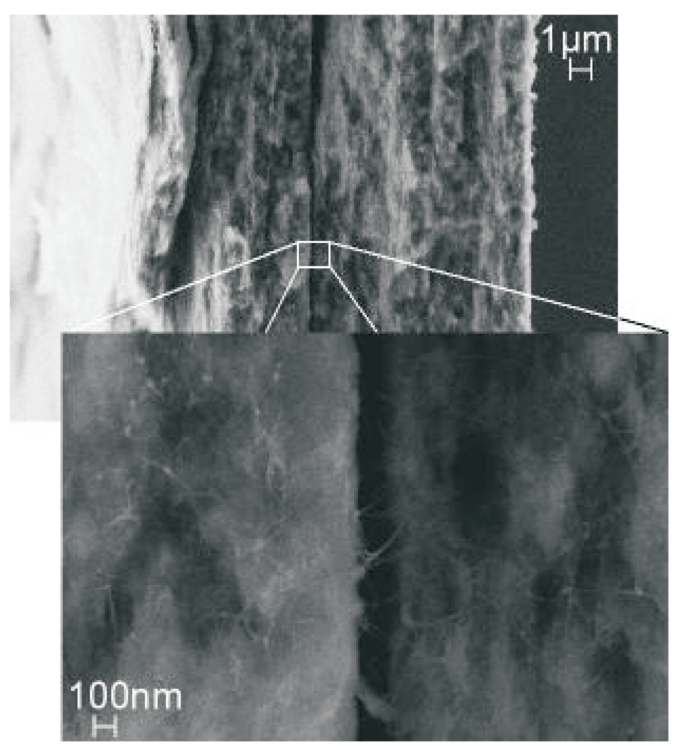


Figure 5: crosssection of a cryogene-broken CNT-paper

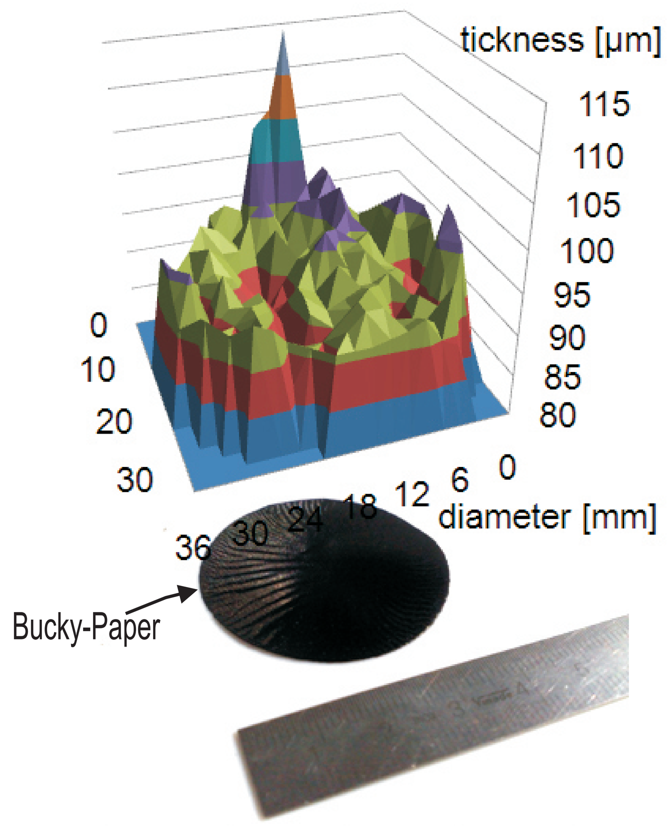


Figure 6: optical measurement of a CNT-paper surface

## Results of electro-mechanical testing

All CNT-papers, whose results are presented in the following, are made out of the powder of supplier 1 and fabricated by a high-pressure filtration of a homogenised, sonicated SWCNT-dispersion. The free strain of the CNT-papers are analysed in an in-plain test set-up (Fig. 7 ). Table 2 shows results of the electro-mechanical tests (Fig. 9). An improvement in conductibility and Young's modulus with every additional process step (centrifuge time) can be shown. Measurements in the in-plain test set-up suggest an inverse behavior between strain and Young's modulus (Fig 9). For significant statements about the actuation mechanism the paper-configuration has to be analysed in depth. Anisotropic CNT-materials like CNT-arrays or single CNTs should be preferred working on this issue.

The presented work was supported by the German Research Foundation (DFG PAK 355) and the German Federal Ministry of Education and Research (BMBF Aktu_Komp).

| sample | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| centrifuge time [min] | 0 | 0 | 0 | 10 | 15 |
| conductibility [S/cm] | 118 | 151 | 86 | 224 | 241 |
| density [mg/mm^3] | 0,73 | 0,64 | 0,66 | 0,72 | 0,68 |
| Young's modulus [MPa] | 979 | 1122 | 1142 | 2414 | 3424 |
| standard deviation [MPa] | 178 | 82 | 18 | 207 | 202 |
| free strain at +0,7V [%] | 0,11 | 0,16 | 0,15 | 0,03 | 0,02 |

Table 2: result overview

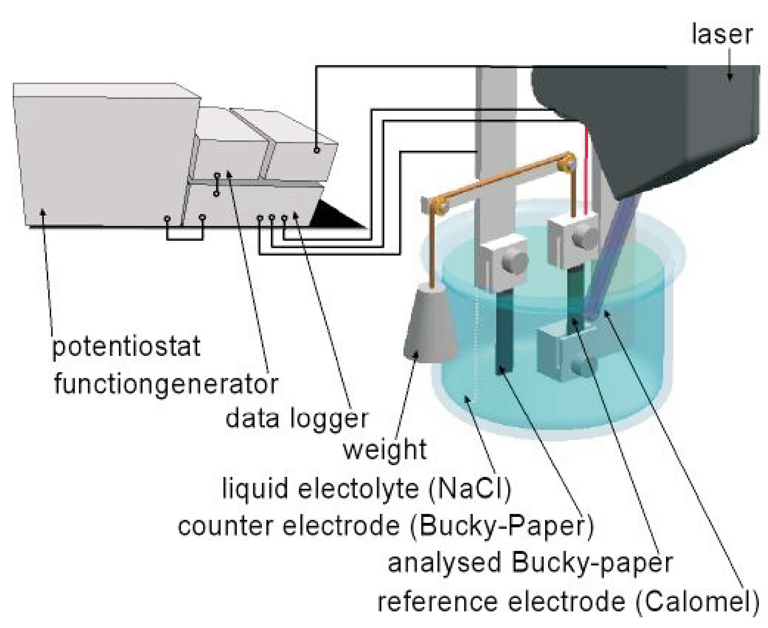


Figure 8: experimental set-up for CNT-papers in liquid electrolytes

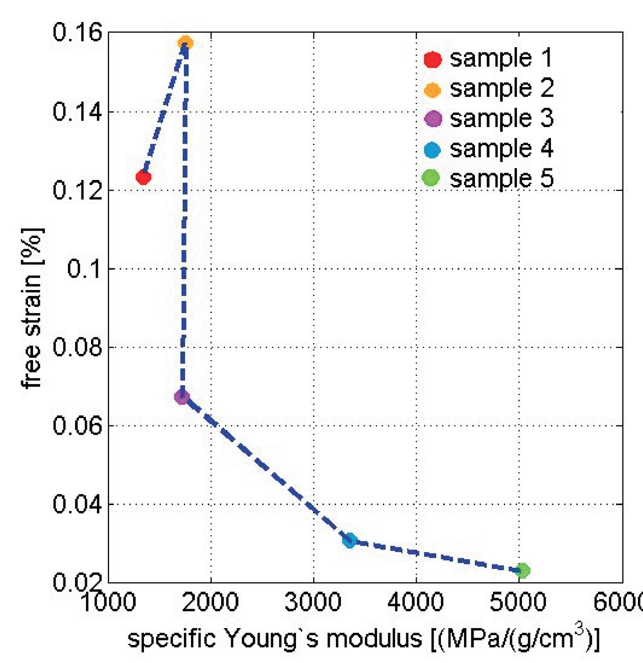


Figure 9: exposure of the results