Carbon Nanotube Actuators

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It is not without reason that Carbon Nanotubes (CNTs) are called the "black gold of the 21st century" because this material combines some extraordinary characteristics such as low density, high tensile strength and Young's modulus, as well as an outstanding thermal and electrical conductibility. This unique material generates new impulses for material science and opens up a wide field of new applications. Analysing CNT-mats for their use as electrodes, it was discovered, that CNTs show a similar behaviour like electro-mechanical actuators [1]. Within an electric field and the presence of ions the CNTs are able to transform electrical energy into mechanical energy. Although the actuation mechanism has not yet been clarified in detail, it is scientifically proven that ions form chemical double layers around the charged electrodes based on CNTs. Basically two mechanisms are discussed in the literature as reasons for the measured strain: interactions between the ions and covalent Carbon-bonds [2] or pure electrostatic effects [3].

Throughout extensive research at the German Aerospace Center (DLR) reliable manufacturing- and analysing-processes [4] were established to study CNT actuators in detail. CNT-based structures as component of actuator are manufactured by two different ways. On the one hand a high-pressure-filtration process to get randomly oriented CNT-mats, called Bucky-papers was developed. This process is adaptive for using different kinds of CNTs. The produced mats show good properties like a conductibility of 250 S/cm or Young's modulus of 5GPa. On the other hand in cooperation with the Technical University of Hamburg-Harburg and the ETH Zurich new methods were developed to generate aligned CNT-structures for better exploitation of their electro-mechanical potentials (see figure 1).

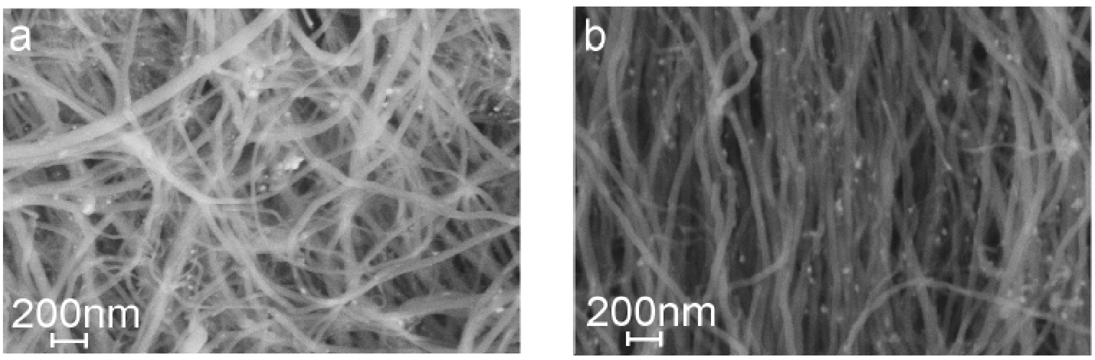

Figure 1: Comparison between different CNT-based structures
a: randomly oriented CNT-mat,
b: aligned CNT-mat, based on CNT-arrays.

Moreover the active behaviour of CNT-based materials were analysed by two different test-rigs depending on the symmetry of the actuator assembly. The design of the test facilities avoids the detection of secondary effects, which could influence the test results. Symmetrical actuators mostly used in liquid electrolytes were analysed in an in-plain test rig (see figure 2). Asymmetrically built actuators, e.g. with solid electrolytes like Nafion, were tested in an out-of-plain measuring facility. By using a consistent test program of cyclovoltametry, static and dynamic electrical excitation liquid based CNT-actuator induced a free stroke up to 0,25%. The transferability of results between liquid and solid electrolytes is still difficult because of the unstable character of Nafion.

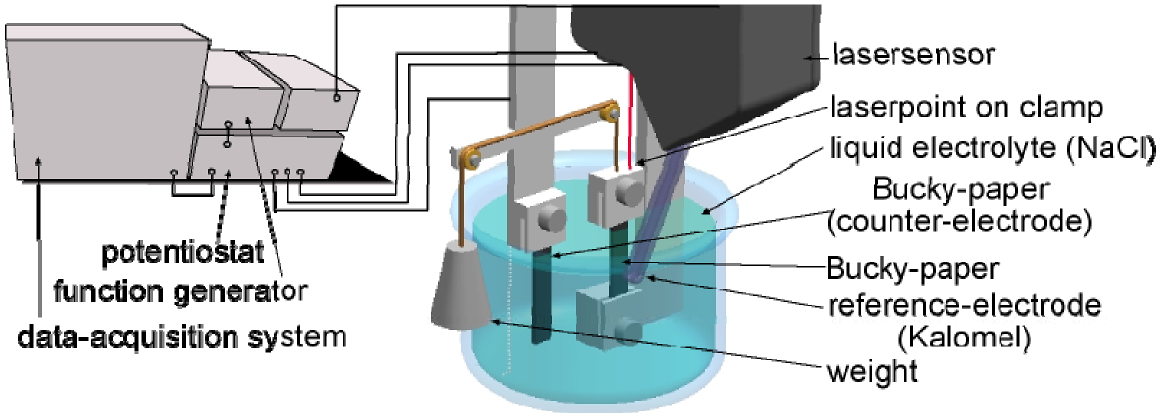

Figure 2: In-plain-Measuring facility.

For a better understanding of CNT-based actuators, especially of the dominating actuation-mechanism, the German Aerospace Center supports a series of fundamental oriented research. By using several high resolution-techniques (Raman, STM etc.) a definite scientific statement should be found to describe the actuation mechanism at a single CNT up to the composites like Bucky-papers. In a second step simulations should enable the predictability of CNT-based actuators for future applications.

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[2] S. Ghosh, V. Gadagkar, A. K. Sood: “Strains induced in carbon nanotubes due to the presence of ions: Ab initio restricted hatree-fock calculations”, Chemical Physics Letters 2005, 406, 10-14;

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