

# Carbon Nanotube-based Actuators using solid and liquid Electrolytes: Investigations of key mechanisms and their differences

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## Introduction

Since the first CNT-based actuation-experiments were carried out 1999 by Baughman <sup>[1]</sup> a great research-driven development has taken place till today. Because of the fact that Carbon Nanotubes (CNTs) need ions for their significant deflection the first generation of actuators were implemented by ions containing liquid electrolytes. Their electro-mechanical characterization is intensively analyzed and partly well known <sup>[2]</sup>. For structural applications it is essential to replace the liquid by a solid electrolyte like Nafion. Although there have been some successful implementations of solid CNT-based actuators <sup>[3]</sup> unfortunately the manufactured composites (Fig. 1 a) show no time-constant repeatable characteristics (Fig. 1 b and c). Therefore it is necessary to study the characteristics of the single components in more detail and especially the effects of their modification on the global actuation-system-response.

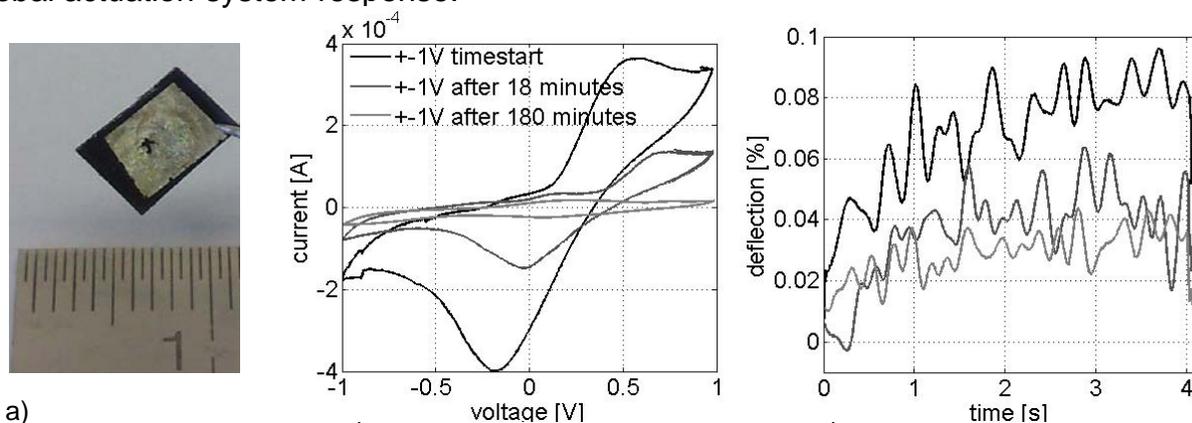


Fig. 1 a): CNT-based composite; b), c): experimental results of the solid actuator;

## Experiments

The CNT-based materials which are almost used for CNT-research are CNT-mats called Bucky-Papers. These mats are produced at the DLR by a homogenised and sonicated dispersion of solvated CNTs <sup>[4]</sup> filtered by a high pressure technique. In preparation of this procedure CNT-powder of different purity was analysed by SEM, process-parameters were adjusted and the step of dispersion-centrifugation was added. It was possible to produce a series of Bucky-Papers, which show significant difference in their mechanical (density, Young's modulus), geometrical (volume, thickness profile), electrical (conductibility) and active (see Fig. 2 a) behaviour <sup>[5]</sup>. SEM-micrograph of the Bucky-Paper surface and the cross-sections (Fig. 2 b) are made to get an idea of the internal structural morphology and to find a correlation with respect to former results. The free deflection was measured in an in-plain measuring test stand using a monomolare NaCl-solution.

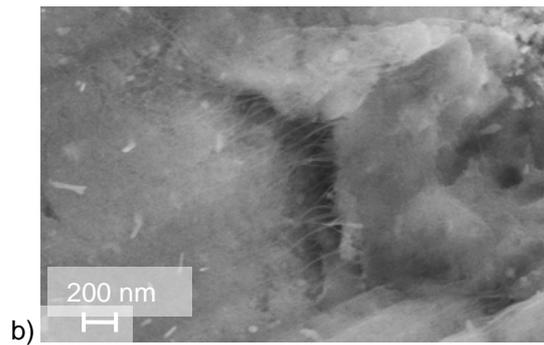
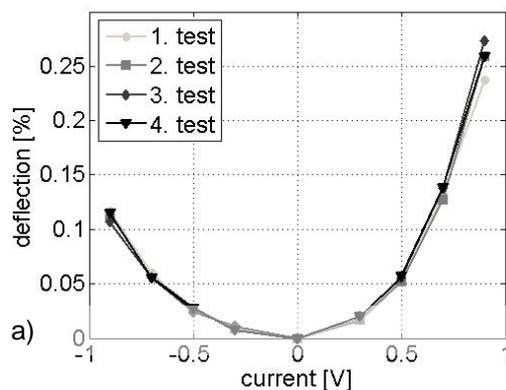


Fig. 2 a): free deflection of CNT-Bucky-Paper in NaCl-solution;  
b): SEM-micrograph of a Bucky-Paper-surface;

Beside these investigations focussed on the CNT-Bucky-Paper the solid electrolyte itself was tested for its active response as well. As already shown <sup>[6]</sup>, Nafion itself can be an electro-active-polymer (EAP). This fact demands a parallel test of the Nafion as EAP-actuator with the same conditions in the out-of-plane test stand, like they were carried out with the solid electrolyte based CNT-actuator. With this approach it will be possible to attach the fractions of deflection to the different parts of the composite.

## Results

It can be shown that the quality of the pure CNT-powder and the manufacturing process-steps have major influence on the Bucky-Paper-characteristics. Especially the concentration of CNTs in the finally tested Bucky-Paper is crucial for the active behaviour but not necessarily for electrical and mechanical properties. For excellent results an extensive quality-management of the basic-materials like the CNT-powder as well as the later on produced CNT-dispersions and Bucky-Papers are essential.

The preliminary tests show that Nafion creates small deflections at high voltages. Therefore it can be used as an actuator. The needed voltages are beyond the band used for solid CNT-actuators. Nevertheless the influence of Nafion on the measured deflections of solid CNT-actuators might be significant.

## Acknowledgements

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## References

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