Composition- and ion- depending actuation mechanism of carbon nanotube architectures

Sebastian Geier*, Thorsten Mahrholz*, Peter Wierach* and Michael Sinapius†

* Institute of Composite Structures and Adaptive Systems
  German Aerospace Center (DLR)
  Lilienthalplatz 7, 38108 Braunschweig, Germany
  e-mail: Sebastian.Geier@dlr.de, web page: http://www.dlr.de/fa/

† Institute of Adaptive Systems and Function Integration
  Technical University of Braunschweig
  Am Langen Kamp 6, 38114 Braunschweig, Germany

ABSTRACT

State of the art smart materials such as piezo ceramics or electroactive polymers cannot feature both, mechanical stiffness and high active strain. Future adaptive applications in e.g. transport systems require materials featuring low density, high mechanical stiffness, high active strain but low energy consumption. These properties are well combined by carbon nanotubes (CNT). Their active behaviour was observed 1999 [1] using a paper-like mat made of CNT. Therefore the CNT-papers are electrical charged within an electrolyte thus forming a double-layer. The measured deflection of CNT material is based on the interaction between the charged high surface area formed by carbon nanotubes and ions provided by the electrolyte. Although CNT-papers have been extensively analysed there is still no generally accepted theory for the actuation mechanism of all kinds of CNT-architectures.

This paper focuses on investigations of the actuation mechanisms of CNT-papers in comparison to vertically aligned CNT-arrays. One reason of divergent results found in literature and experiments might be attributed to composition of the tested CNT samples. The CNT-papers represent architectures of randomly distributed CNTs without continuous CNT in the direction of testing whereas CNT-arrays feature continuous CNTs which are tested along their mean axis.

Both sample types are tested within an actuated tensile test set-up under different conditions. While the CNT-papers are tested in water-based electrolytes with comparably small redox-windows the hydrophobic CNT-arrays are tested in ionic liquids. Furthermore different ions are used to investigate the influence of the ion-radius.

It was found that the mechanical performance of CNT-papers strongly depends on the test conditions. The weak linking of the tubes is dominated by friction and Van-der-Waals forces which can be significantly be reduced by the good wettability of CNT papers. A swelling of the paper causes further reduction of the mechanical stiffness. In addition, it is observed that charging the tubes also reduces the mechanical stability of the papers.

In contrast CNT-arrays are mechanically unaffected by conditions and. A comparison of both types of specimen points out that the actuation mechanism of CNT papers depends more on weak Van-der-Waals-bonds between tubes whereas the active properties of CNT arrays might be controlled by quantum mechanical effects.

REFERENCES