Direction sensitive deformation sensing with CNT/epoxy nanocomposites

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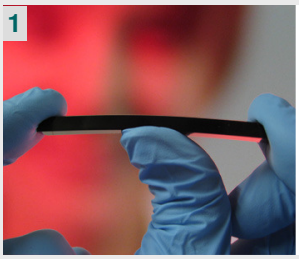
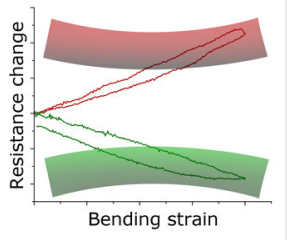
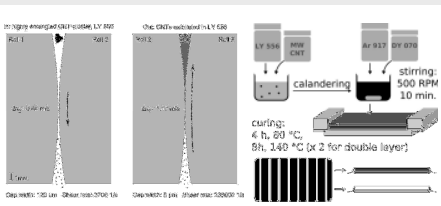




1 Introduction & Features

A simple and effective method for producing carbon nanotube and epoxy based smart materials is presented. The nanocomposite exhibits excellent piezoresistive properties which allow for integrated deformation sensing:

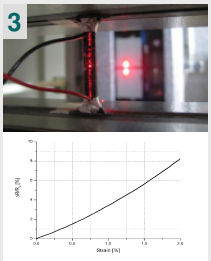
- Positive (tensile) strain increases resistance
- Negative (compressive) strain decreases resistance
- Directional sensitivity can be achieved (e.g. in bending beams)
- Only small amounts (< 0.1 wt.%) of multiwalled carbon nanotubes are necessary
- Simple processing procedure
- Straightforward signal interpretation



2 Materials & Methods

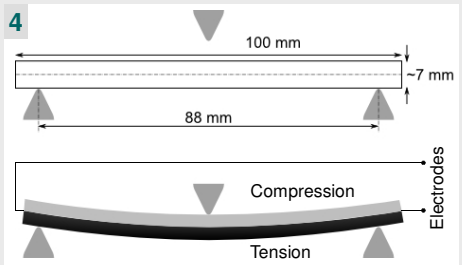
■ Epoxy component: Araldite LY 556, Aradur 917, Accelerator DY 070 (Huntsman,Switzerland)
■ CNT component: Graphistrength C100 (Arkema, France)

■ The materials were mixed and dispersed using a 120 E three roll mill (Exakt, Germany). They were cured in a panel heated oven using an open aluminum mold. Coupons for tensile tests and bending beam samples were produced to 0.1 wt. % CNT content. More details in [1,2]



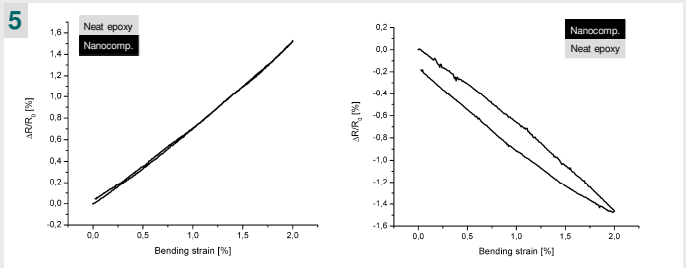
3 Tensile Setup

Unixial tensile strain experiments showed a nearly linear relationship between strain and resistance in the elastic regime.



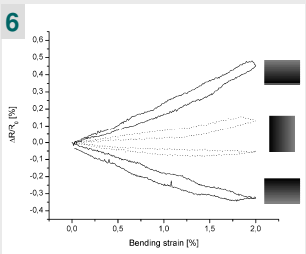
4 Bending Beam Setup

■ Double layer samples were beams which consisted of a layer neat epoxy on top of a layer containing CNTs. The neutral surface of the beam coincided with the two layers' interface.
■ Single layer samples were produced using only one layer of nanocomposite. The electrical contacts were arranged at the ends of the samples.



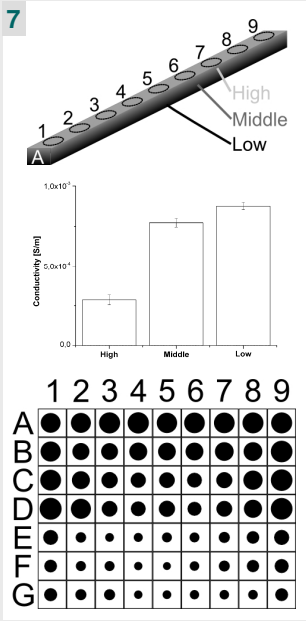
5 Double Layer Samples

■ The samples were beams consisting of a layer of neat epoxy on top of a layer of nanocomposite. The neutral surface of the beam coincided with the layers' interface and two electrical contacts were painted on the ends of the samples using conductive silver paint.
■ In line with the tensile tests the resistance increased with tensile strain in the conducting layer, and resistance decreased with compression in the conducting layer. The magnitude of resistance change was comparable.



6 Single Layer Samples

■ Beams cast out of one layer of nanocomposite *also* exhibited direction dependency.
■ The deformation sensitivity was lower than what was achieved in double layer samples.
■ A nearly linear relationship between strain in the extreme surface and resistance change was observable.
■ The dashed line shows the resistance change for a beam set up on edge, which is significantly weaker.



7 Sample Characterisation

A detailed characterisation was performed on the sample material.
■ The material was dissected in order to give information on the conductivity distribution within the beams.
■ Fig. 7 illustrates the position of the sample material in the bending beam.
■ A conductivity gradient was found to exist from the high to the low layer of the material.
■ The bottom of Fig. 7 shows how the samples were arranged in one half of the mould. It represents relatively high conductivity as larger spots.
■ A systematic variation of the conductivity depending on the distance to the aluminum mold was found.
■ Modified curing cycles led to significantly different conductivity distributions, see [2].

Conclusions

■ A host of parts with inherent strain/direction sensing capabilities can be produced using small amounts of CNTs and very simple methods.
■ Control of the curing behavior, especially while the nanocomposite is in a liquid state, can be used to optimize material properties.

References

1. F.H. Gojny, M.H.G. Wichmann, U. Köpke, B. Fiedler and K. Schulte *Composites Science and Technology* ***64***, 2363-2371 (2004).
2. M.H.G. Wichmann, S.T. Buschhorn, L. Böger, R. Adelung and K. Schulte *Nanotechnology* **19,** 475-503 (2008).

Acknowledgements

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