Kristin Trommer
Maren Lehmann

FILK Forschungsinstitut Leder und Kunststoffbahnen

SYNERGISTIC BEHAVIOUR BETWEEN CNTs AND CF IN POLYMER MATRICES

It is well known that carbon nanotubes (CNTs) are homogeneously distributed in polymers forming electrically conductive pathways and impart the polymeric material a conductivity. Furthermore, the addition of microscale carbon particles in small amounts yields in an increase of the conductivity. Usually Carbon black is used as synergist. In the present work, the influence of carbon fibres (CF) in combination with CNTs on the conductivity of a polymeric matrix was investigated. Two variations are possible. On the one hand, the CNTs form the network and carbon fibres act as a synergist and vice versa, the carbon fibres building up a network and the CNTs playing the role of the synergist.

POLYMERIC MATRIX CONTAINING **CNT-NETWORK + CF**

Preparation of the composite

An appropriate way to exfoliate and separate the primary CNT particles from each other in a low viscous polymer formulation is the treatment of an unidirectional low shearing process. By means of a three roll mill common CNT particles, that are available as particle agglomerates in large scales on the market, and the carbon fibres were simultaneously incorporated into a polyurethane dispersion. The percolation graphs for PU-matrices containing 3 % and 5 % of CNT, respectively, and increasing amounts of CF starting from 1 % to 8 % were measured. Apparently the highest synergistic impact has a CF-content between 6 %-6,5 % CF. The conductivity increased 3.5 times for the material with 5 % CNT and approx. 5 times for the material with 3 % CNT.

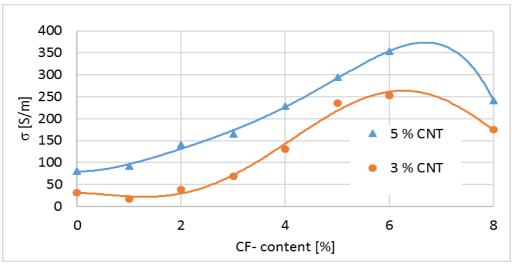
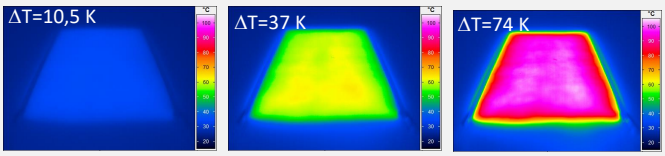


Fig 1: Percolation graphs of PU with CNT network and CF synergist

Heating properties of PU-sheets containing CNT-network and CF synergist

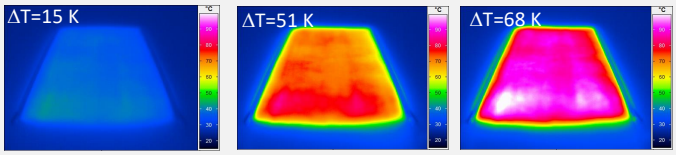
PU-coatings containing 5 % CNT + 1 % CF
thickness: 130 µm, distance of electrodes: 10 cm

U=12 V U=24 V U=36 V



PU-coatings containing 5 % CNT + 3 % CF,
thickness: 130 µm, distance of electrodes: 10 cm

U=12 V U=24 V U=28V



Results

Addition of CF to a CNT-network in a polymer system led to an increase of conductivity and thus improved the heating behaviour. Applying a voltage of more than 24 V increased the temperature by more than 50 K. Using voltages between 12-24 V caused an increase of temperature between 10 – 50 K depending on the content of CF. This temperature range is suitable for applications close to the human body. The last one allows to enlarge the electrode distance to 20 cm. The targeted temperature can be achieved by using higher voltages up to 48 V.

POLYMERIC MATRIX CONTAINING **CF-NETWORK + CNT**

Preparation of the composite

A non-woven of carbon fibres was used to ensure a homogeneous network of carbon fibres for the investigations of the synergistic effect that can be realized by embedding the CF network in a CNT containing polymer matrix. The CF-network was infiltrated with a CNT containing waterborne PU-dispersion. As displayed in the cross section (Fig. 2 left), the carbon fibres were encased by the polymeric mass as well as the surface is covered on both sides. But the cross section is not completely filled with polymer. Optimizing the infiltration is ongoing. First investigations showed, the better the fibres are embedded the higher is the electrical performance of the material. The AFM phase image (Fig. 2 right) shows the strong interaction of the CNTs and CF (light regions) in the polymeric matrix (dark regions).

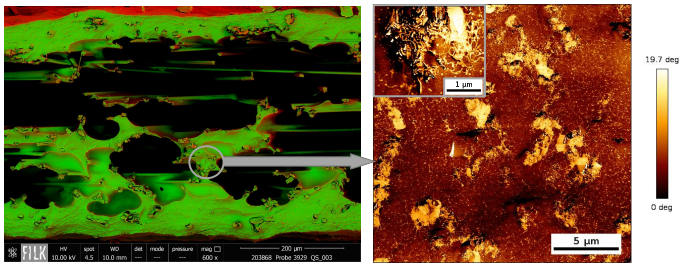
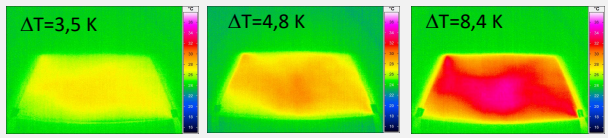


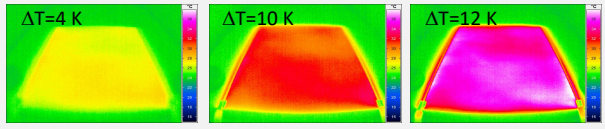
Fig 2: cross section CF network and CF synergist; left: SEM image; right: AFM-image (phase image)

U=2 V U=3 V U=4 V

CF-network, distance of electrodes: 20 cm



CF-network+ CNT- PU coating, distance of electrodes: 20 cm



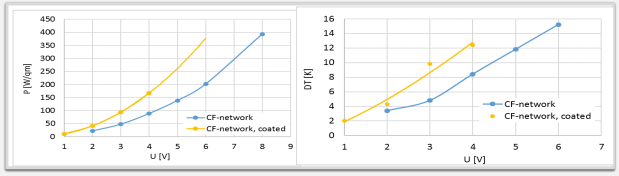


Fig 3: Influence of the applied Voltage towards Performance (left) and temperature increase (right)

Results

Materials having a CF network and additional CNTs in the polymeric matrix show an extremely high conductance. Therefore they are suitable for low voltage applications. Already at 2 volt and an electrode distance of 20 cm, a heating effect can be achieved. Compared to the unprocessed CF network, the composite consisting of CF network and CNT-containing polymer shows a more homogeneously heating behaviour and a considerably higher heat output, especially at voltages >2 V. Versus the systems with CNT network and CF synergist, the current flow is much higher for the composites having the CF network.

CONTACT **Dr. Kristin Trommer**
Telephone: +49 3731 366, Email: kristin.trommer@filkfreiberg.de
Forschungsinstitut für Leder und Kunststoffbahnen (FILK) gGmbH
Meißner Ring 1-5, 09599 Freiberg / GERMANY /www.filkfreiberg.de

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