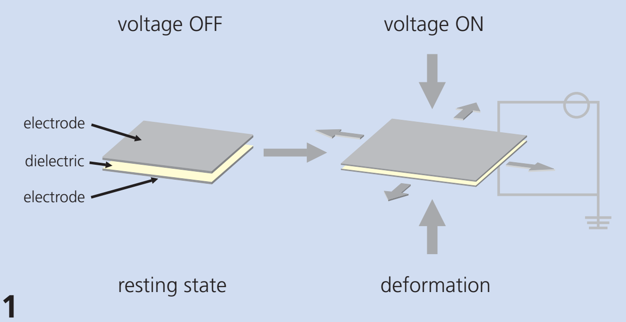
INTEGRATION OF CARBON NANOTUBES IN SILICONES TO PRODUCE ELASTOMERIC ACTUATORS

THE TASK

Dielectric elastomeric actuators (DEA) are very interesting material systems for industrial applications and thus present an important field of current research efforts. A DEA consists of at least three layers with a dielectric layer (to prevent electric breakdown) being sandwiched between two electrically conductive layers. The working principle of a DEA is based on electrostatic pressure generated by the charged electrodes. This pressure elastically deforms the system.

Principle of a dielectric elastomer actuator



1

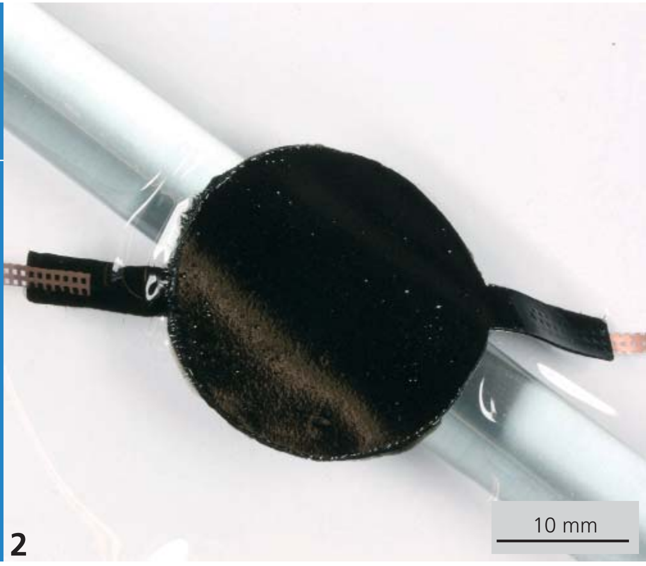
The electrodes can be made from metals, which are significantly stiffer than the dielectric layer. This difference in stiffness limits the expansion as well as the lifetime of the actuator. To avoid these disadvantages one can build the system completely from polymers. The concept is to use one and the same polymer for both the dielectric and the electrically conductive layers. Lifetime and actuator function can be improved if the layers are well matched. Depending on the desired layer properties the elastomer can be modified with conductive or dielectric nanoscale filler materials.

OUR SOLUTION

A two component additively networked silicone material was selected for the actuator material. The elastomeric electrode material incorporates carbon nanotubes (CNT). The dielectric properties were improved by the use of ceramic particles. The individual materials for the actuator layers have to follow certain conditions, which have to be considered during filler material integration. Such conditions include for example the breakup of agglomerates and the homogeneous distributions of freed particles. The properties of dispersion, the networked layers and layer stacks need to be well controlled.

Experiments were performed to investigate various processes. For particle dispersion we used an agitator, a speed mixer, an ultrasonic sonotrode, a calender and a high pressure dispersant. Single wall carbon nanotubes (SWCNT) and ceramic particles require different approaches. Particle type, their degree of agglomeration and their filling degree all affect the process. The different layers and particle types required optimization including different process sequences. The experiments yielded long-term stable and reproducible dispersions, which can be assembled into individual layers, composite layers and stacked layers.

Specific material knowledge was obtained from numerous characterizations of individual layers and layered stacks. It was essential to the success of the project that dispersion and layer fabrication were jointly optimized.



2

3

RESULTS

SWCNT were successfully dispersed into silicone. This reduced the specific resistance from 10^{14} Ω cm to 10 Ω cm. The so modified silicone is now suitable as an electrode material. Further optimization can reduce the resistance even more.

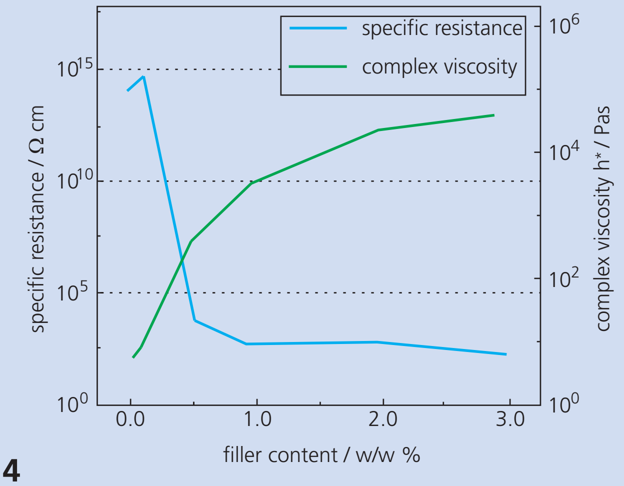
The deagglomeration and homogenization of SWCNT changes the dispersion viscosity as a function the filler material concentration. This has an effect on processing since the viscosities increase from 4.7 Pas to 43.3 kPas.

The manufacturing process had to be designed so that such dispersions can be handled for the reproducible fabrication of DEA.

The stiffening of the electrodes due to SWCNT can be counter acted to make layer composites with identical or comparable properties. For example, large elasticity modulus differences between layers can prevent or affect the actuator function.

The developed DEA with nanoscale filler materials proved to function according to the laws of electrostatic pressures. This successfully demonstrates the possibility of making actuator from polymers based on modified silicones. These DEA also showed an improved lifetime compared to conventional DEA. This project was funded by the BMBF (No. 13N10661 and 13N10660).

Specific resistance and complex viscosity versus SWCNT filler material concentration



4

2 *Flexible three-layer actuator with circular electrodes*

3 *SEM image of a three-layer actuator after cryofracture*

CONTACT

Dipl.-Ing. Tilo Köckritz
phone +49 351 463-34052
tilo.koeckritz@iws.fraunhofer.de