Efficient Electrodes for Applications in Dielectric Elastomer Actuators: Carbon Nanotubes *vs* Graphite

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Abstract

Over the past decade, fundamental and technological interest on "smart materials" has dramatically grown due to their capacity to respond to a variety of external stimuli (temperature, light, pH, magnetic, electric fields...). One of the most attractive applications is based in the development of actuators, or "artificial muscles", able to reversely transform electrical energy into mechanical work[1]. **Soft dielectric elastomer actuators (DEAs)** are progressively emerging as strong candidates due to their toughness, lightness, easy processability and generally low cost. DE actuators are basically compliant variable capacitors. They consist of a thin elastomeric film coated on both sides with compliant electrodes. When an electric field is applied (see Fig.1), the electrostatic attraction between the opposite charges on opposing electrodes and the repulsion of the like charges on each electrode give rise to an electrostatic pressure which forces the DE to contract in thickness and expand in area[2]. This electrostatic compressive stress p is given by:

$$p = \varepsilon_0 \varepsilon_r E^2$$

Where ε_0 is the dielectric permittivity of vacuum (8,85 x 10^{-12} F/m), ε_r is the relative dielectric permittivity of the DE and E is the applied electric field across the electrodes[3].

Looking at the expression derived by Pelrine *et al.*, it is obvious to think that an increment in the charge stored by unit of area of the electrodes will increase the compressive stress, thus increasing the strain suffered by the DE. Although during the past years research effort has been focused in the development of the right elastomers, compliant electrodes are also fundamental to DEAs development. The ideal electrode material must: *i)* Be low-cost and easy to fabricate, *ii)* maintain uniform contact over the entire active region of the elastomer in order to

ensure an homogeneous electric field during the electro-mechanical actuation and *iii)* deform with the dielectric elastomer without generating an opposing stress or losing conductivity.

The principal aim of this work is to study the role of different carbonaceous particles as compliant electrodes in a PDMS based actuator (see Fig.2). More specifically, graphite powder and carbon nanotubes are here evaluated with respect to their conductivity in order to achieve optimum strain and efficiency for a given electric field. The results obtained show that the higher conductivity of the carbon nanotubes here employed leads to a substantial increment in the actuation strain percentages compared to graphite.

References

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2. Carpi, F.; Gallone, G.; Galantini, F.; De Rossi, D., Enhancing the dielectric permittivity of elastomers. In *Dielectric Elastomers as Electromechanical Transducers*. Elsevier: Amsterdam, 2008; pp 51-68.

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Figures

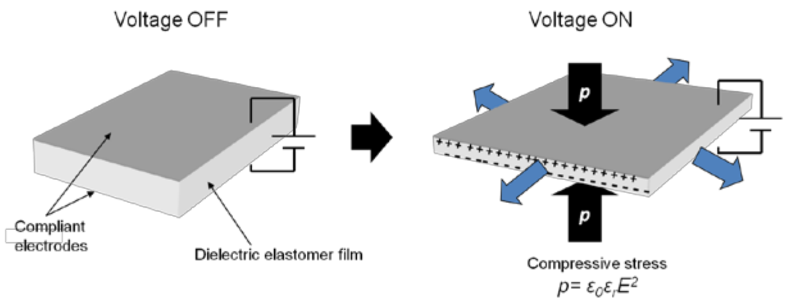

Fig 1. Squematical view of DEA operating principle

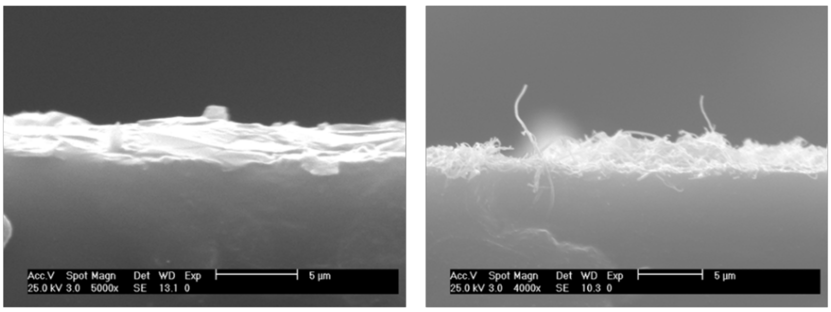

Fig 2. Graphite (left) and Carbon Nanotubes (right) as compliant electrodes