Electrical Breakdown and Mechanical Ageing in Dielectric Elastomers

Shamsul Bin Zakaria
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Supervisor: Anne Ladegaard Skov

PhD Thesis
Danish Polymer Centre, Department of Chemical and Biochemical Engineering,
Technical University of Denmark, Kongens Lyngby

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ABSTRACT

Dielectric elastomers (DE) are used in various applications, such as artificial eye lids, pressure sensors and human motion energy generators. For many applications, one of the major factors that limits the DE performance is premature electrical breakdown. There are many approaches that have been reported to increase the breakdown strength of DEs such as compositing and pre-stretching. Some of the techniques, however, affect other parameters related to DEs negatively. For instance, the elastomers with *hard* filler particles (e.g. metal oxides) used as DEs experience difficulties to maintain their long-term mechanical reliability as they are susceptible to Mullins effects as the results of pre-stretching. Therefore, two strategies are developed in this thesis in order to produce DEs with high electrical performance and long-term electromechanical reliability. The first strategy is to study the mechanisms behind the electrical breakdown of DEs and the second strategy is to investigate the long-term electromechanical reliability of DEs. In the first strategy, the electrothermal breakdown in polydimethylsiloxane (PDMS) elastomers was modelled in order to evaluate the thermal mechanisms behind the electrical failures. From the modelling based on the fitting of experimental data, it showed that the electrothermal breakdown of the PDMS elastomers was strongly influenced by the increase in both relative permittivity and conductivity. In addition to that, a methodology in determining the parameters that affect the breakdown strength of the pre-stretched DEs was developed. Breakdown strength was determined for samples with and without volume conservation and was found to depend strongly on the strain and the thickness of the samples.

In order for DEs to be fully implementable in commercial products, the lifetime of elastomer materials needs further investigation. Therefore, in the second strategy, several DE parameters such as Young's moduli, breakdown strengths and dielectric permittivities of PDMS elastomers filled with *hard* filler particles were investigated after being subjected to pre-stretching for various timespans. The study showed that electromechanical reliability when pre-stretching was difficult to achieve with PDMS elastomers filled with *hard* filler particles. Subsequently, the long-term mechanical and electrical reliability was further investigated to the PDMS elastomers filled with the *soft* fillers (e.g. oils). Interestingly, the results also showed that *soft* fillers significantly influence the long-term electromechanical reliability of PDMS elastomers. However, despite the pre-stretched PDMS elastomers filled with *hard* and *soft* filler experience difficulties to maintain their long-term electromechanical reliability, the study paves the way for electromechanically reliable DEs by indicating that simply post-curing PDMS elastomers before use.

Therefore in the last part of this thesis, the effect of post-curing was investigated for PDMS elastomer thin-films as a means of improving the long-term elastomer film electromechanical reliability. The PDMS elastomers were found to contain less than 2% of volatiles but nevertheless a strong effect from post-curing was observed. Furthermore, the determined electrical breakdown parameters from Weibull analyses showed that greater electrical reliability could be achieved by post-curing the PDMS elastomers before usage, and this method therefore paves a way towards more electromechanically reliable DEs.

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