Technical University of Denmark

Favorable electrical breakdown strengths of prestretched elastomers with and without sample volume conservation

Zakaria, Shamsul Bin; Skov, Anne Ladegaard

Publication date:
2014

Document Version
Publisher's PDF, also known as Version of record

EuroEAP 2014
International conference on
Electromechanically Active Polymer (EAP)
transducers & artificial muscles
Linköping, 10-11 June 2014
Organized and supported by
'European Scientific Network for Artificial
Muscles – ESNAM' (www.esnam.eu)
COST Action MP1003

Favorable electrical breakdown strengths of elastomers with and without volume conservation

Zakaria Shamsul, Anne Ladegaard Skov

Technical University of Denmark, Department of Chemical and Biochemical Engineering, Lyngby, Denmark

Large actuation strains may be achieved using dielectric elastomers but they must firstly be prestretched. The effects of prestretch on the actuation performance of DEA have been studied [1–4]; for instance, for the most common studied dielectric elastomer, the acrylic elastomer produced by 3M corporation, VHB, it has been reported that the breakdown field increases from 18 to 218 V/µm when biaxially prestretched up to 6 times [3]. It is believed that defects introduced through fatigue or during manufacture or processing are generally seen as a factor strongly related to premature electrical breakdown of DEA. The defects turn the breakdown strength in particular area lower which can lead to localized or permanent device failure. Furthermore, the maximum actuation strains for DEA are limited by the electrical breakdown. Therefore the effect of thickness on electrical breakdown strength is practical importance especially in prestretch condition or during actuation. From a practical perspective, the variation of thickness in response to prestretch poses a challenge to how to measure the electrical breakdown field accurately. Tröls and coworkers [4] investigated the effect of different configurations of electrodes on electrical breakdown strength of acrylic VHB elastomers supplied by 3M which have been prestretched up to 5 times. They reported that the breakdown strengths were increased from 100 V/µm to 163 V/µm and 25 V/µm to 143 V/µm for rigid electrodes and compliant electrodes, respectively, as the elastomers were radially prestretched up to 5 times. Noticeably in their study the tested volumes were not conserved during the measurements of electrical breakdown. Therefore the results may be not telling the entire truth since the tested volumes were plummeting into 35 times lower than initial tested volumes. For this reason, the effects of volume conservation on the electric breakdown strength as function of prestretch were studied on two types of (Polydimethylsiloxane) PDMS materials with different size of permittivity enhancing fillers (titanium dioxide). The volumes were conserved by enlarging the areas of applied fields according to the percentages of prestretch by sputtering silver electrodes within the areas on the top and the bottom of the films. The different approaches for electrical breakdown measurements for with or without volume conservation are shown in figure 1.

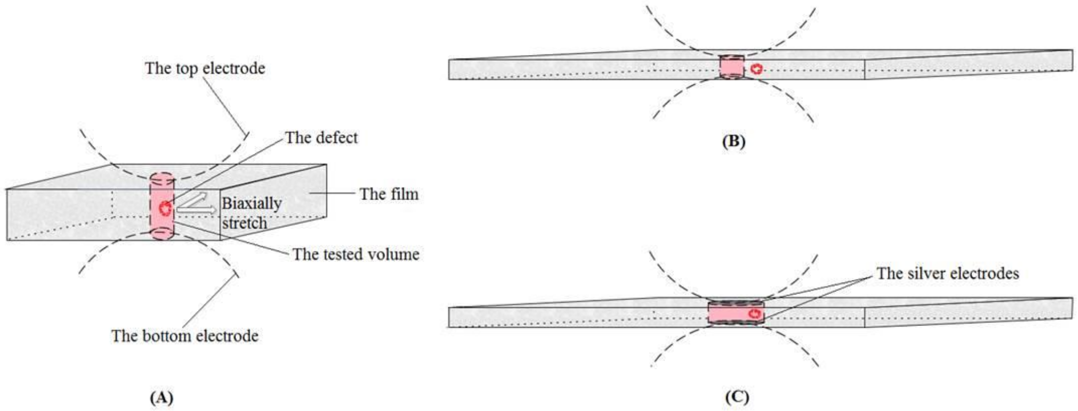

Figure 1: How the breakdown measurements were performed on the film before stretching (A) and after stretching; (B) without volume conservation and (C) with volume conservation.

From the study, we found that breakdown fields increase as films were stretching to certain percentages for either with or without volume conservation. However there are prominent differences for the breakdown fields for both conditions where with conservation of the volume, the breakdown fields are significantly lower contrast to without conservation of the volume.

References

[1] J.-S. Plante and S. Dubowsky, "Large-scale failure modes of dielectric elastomer actuators," *Int. J. Solids Struct.* **43**(25–26), 7727–7751 (2006) [doi:http://dx.doi.org/10.1016/j.ijsolstr.2006.03.026].

[2] C. Jordi, A. Schmidt, G. Kovacs, S. Michel, and P. Ermanni, "Performance evaluation of cutting-edge dielectric elastomers for large-scale actuator applications," in *Smart Mater. Struct.* **20**, p. 075003 (2011) [doi:10.1088/0964-1726/20/7/075003].

[3] G. Kofod, P. Sommer-Larsen, R. Kornbluh, and R. Pelrine, "Actuation Response of Polyacrylate Dielectric Elastomers," in *J. Intell. Mater. Syst. Struct.* **14**, pp. 787–793 (2003) [doi:10.1177/104538903039260].

[4] A. Tröls, A. Kogler, R. Baumgartner, R. Kaltseis, C. Keplinger, R. Schwödiauer, I. Graz, and S. Bauer, "Stretch dependence of the electrical breakdown strength and dielectric constant of dielectric elastomers," *Smart Mater. Struct.* **22**(10), 104012 (2013).