Spring 3-13-2015

The Effect of Stress- Relaxation Cycles on the Capacitance of Dielectric Electro Active Polymers

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Abstract

Dielectric Electro Active Polymers (DEAP) has the potential of converting mechanical energy into useful electrical energy. This material consists of a silicone dielectric film material with a special corrugated surface and a very thin layer of metallic electrodes on both sides of the surface. As these materials allow large mechanical deformations with low operating forces, potential applications include using this material to convert the energy from the ocean waves, and wind. This work examined the capacitance to provide useful information in optimizing the electrical properties for specific applications, and to investigate how the electrical properties are affected by electrical and/or mechanical breakdown.

Introduction

Dielectric electro-active polymers are thin films made of a silicon material that offers a large amount of deformation. This silicon material is covered on both surfaces with metal electrodes. An application of electrostatic forces across the film thickness will cause film compression across the thickness, thus inducing in-plane expansion. These characteristic have potential application as actuators and sensors.

Experimental Procedure

The DEAP sample, with gage length measuring 5.5 in and width 0.75 in width was cut in a way such that the stretching would be done in the compliance direction as shown in figure 1. Both faces of the DEAP film were silver coated with silver electrodes sputter coated to the silicone elastomer material. A secondary electron imaging of the silver electrodes on the silicone elastomer is shown in figure 2. Strips of copper tape were placed across the width of the sample to allow the measurement of the capacitance using a Hewlett Packard Model 4284A Precision LCR Meter.

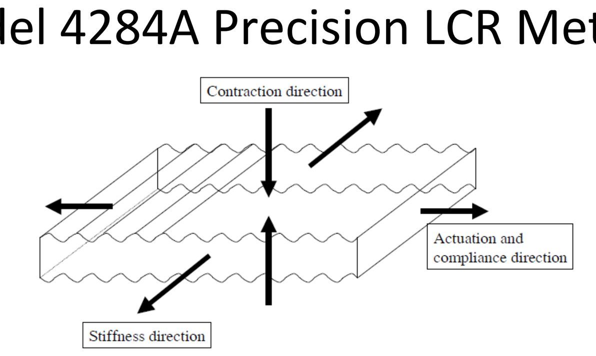

Figure 1. Schematic of the DEAP film with the metallic compliant electrodes deposited on both sides of the film. The material is been stretched along the compliance direction as shown in the diagram.

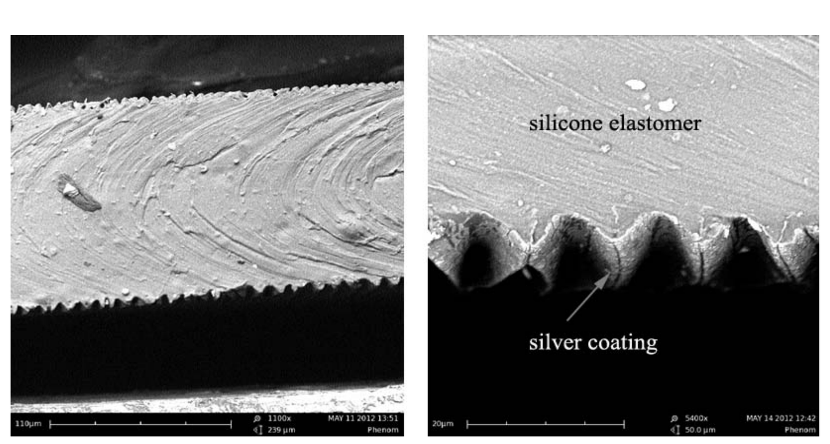

Figure 2. A low magnification of the corrugated edge of the DEAP is shown on the left and a higher magnification (on the right) shows the silver coating on the silicone elastomer film.

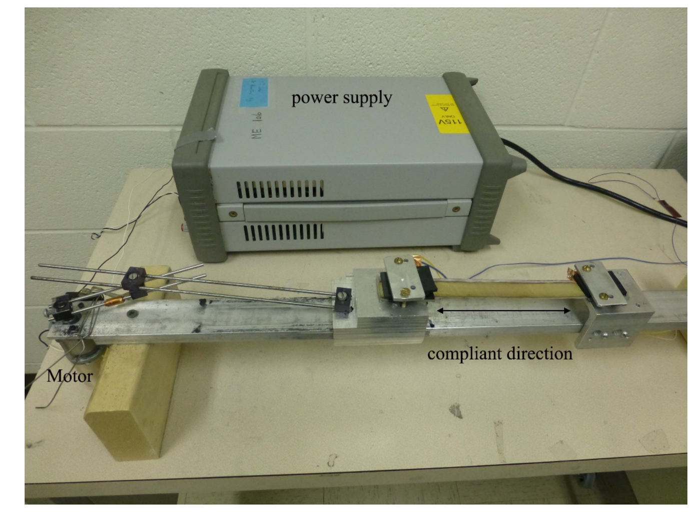

Figure 3 Image of the apparatus (motor and linkages powered by a power supply) used to stretch the DEAP material.

Results and Discussion

The 80% strain DEAP sample was stretched to 80% of its length and relaxed with a strain rate of 7 rev/min for 15,000 cycles. The capacitance of the DEAP measured, at intervals of about 1000 cycles, during the relaxed and stressed level is shown in table 1. The capacitance increase as it stretch and on average there is an increase of around 52%. This percentage increase is much larger than a previous experiment [that stressed the sample to only 25% with yield of only 6% increase in the capacitance. A plot of the data is shown in Figure 4. Although the data showed a continuous overall decrease in the capacitance, it is normal and if the material is allow to sufficient time to recover, the capacitance measurement would increase. Nevertheless, the change in the capacitance had remained about constant.

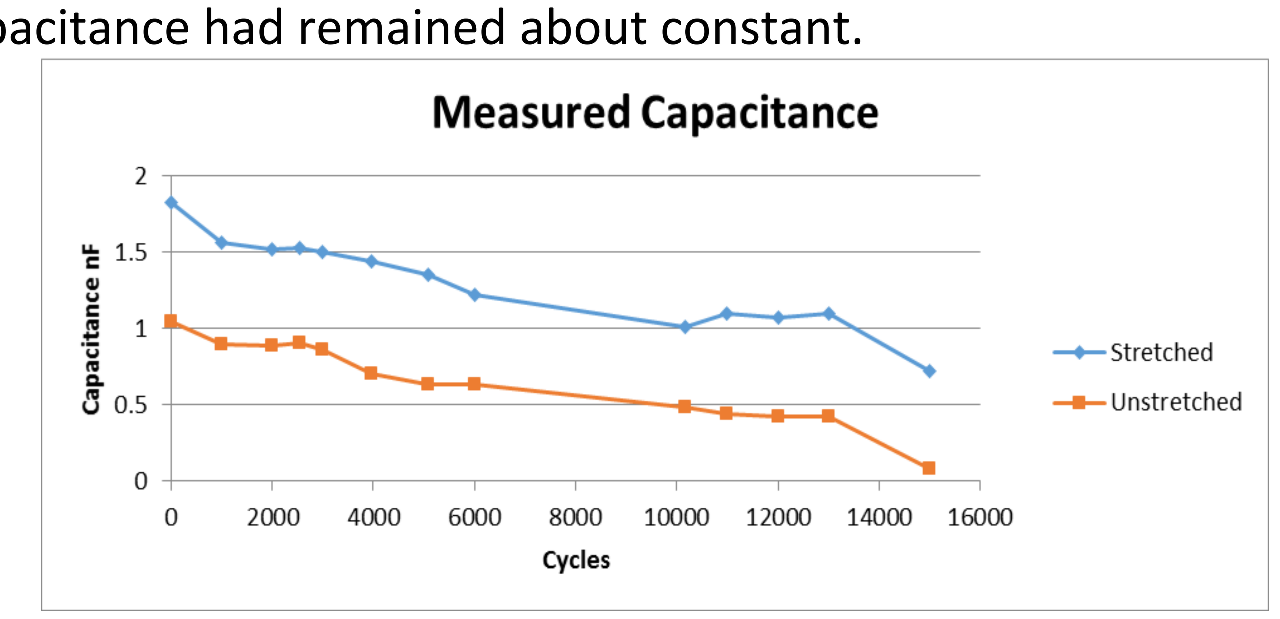

Figure 4. Plot of the capacitance at both the relax and stressed level during the stress relaxation cycles.

A series of images of the sample, after the experiment, is shown in figure 5. Note that a small piece of the coating had ripped off from the edge. This might have been the result of residual chemicals left behind after the initial removal of the coating on the edge to prevent any shorting between the two surfaces. Other than that, the sample is still intact and there are no other visible tears.

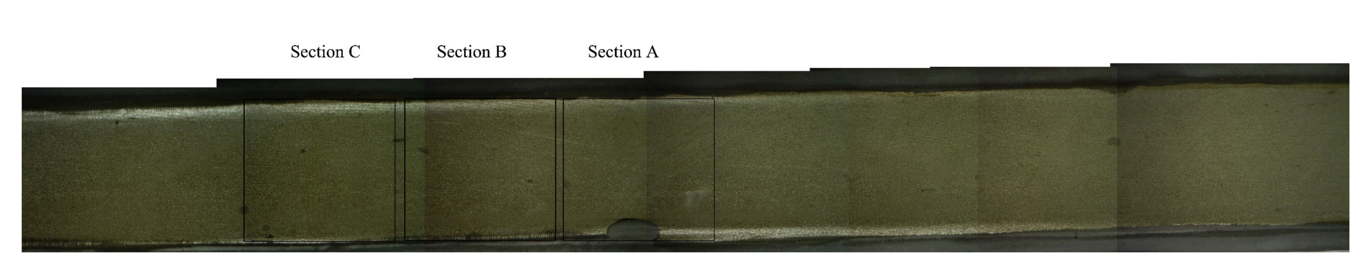

Figure 5. Snap shots of sample were piece together. A small piece of the coating had been ripped at the edge. Sections had been identified as A, B and C. These regions are observed in the scanning electron microscope for farther evaluation.

The used sample was cut into small pieces and were observed in the scanning electron microscope. Figure 6 – 8 show a typical secondary electron image of the surface of the coating. In these figures, the first left image was an optical micrograph of the section that was cut from the sample. A highlighted square was insert in this optical micrograph showing where higher magnification imaging were done to observe the coating surface in that region. All the images (figure 6-8) showed varies stages of micro tears and micro fractures or peeling of the coating from the silicone elastomer. In spite of the large numbers of creases in the silver coating or breaks in the coating and possibly in the sputtered electrodes observed in this material, there was no sudden change in the capacitance reading. These damaged or cracked electrodes were 'traces which were still sufficiently bridge to maintain conductive paths across the electrodes.

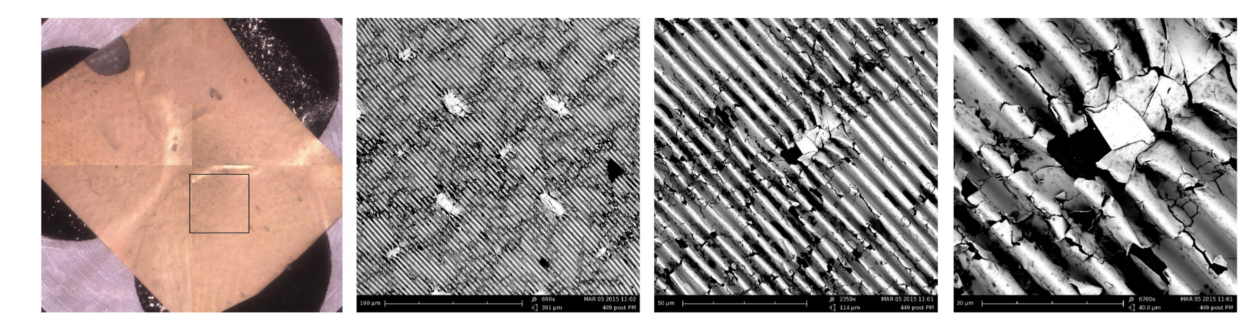

Figure 6. SE images of section A along the sample.

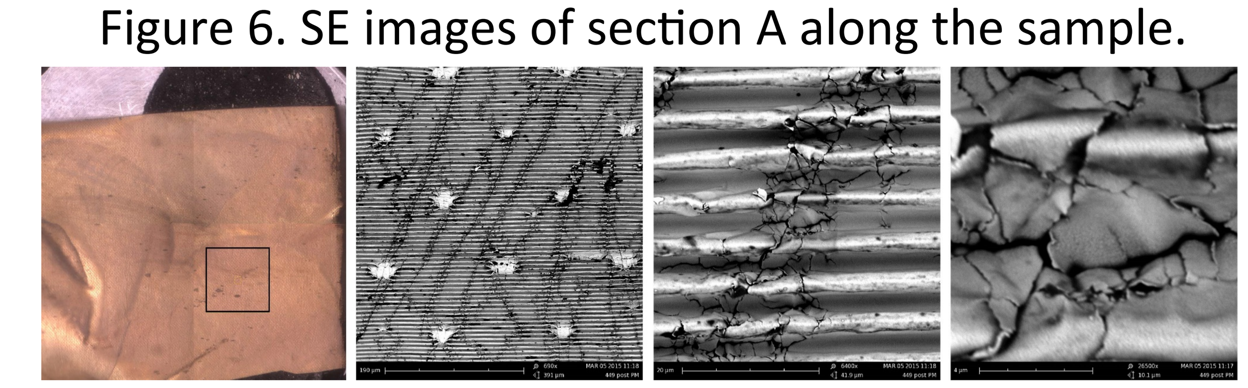

Figure 7. SE images of section B along the sample.

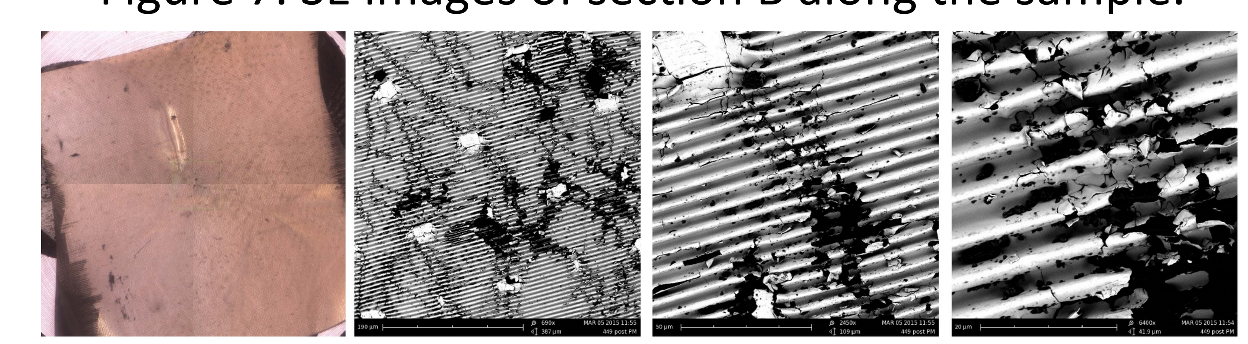

Figure 8. SE image of section C along the sample

Conclusion

An 80% strain DEAP material was subjected to 15,000 stress and relax cycles and their capacitance was measured both at the relaxed and the stressed region.

- Capacitance increases as the sample is stretch and the average increase is about 52%.
- Coating surface showed varies stages of micro tears, micro fractures or peeling of the coating from the silicone elastomer due to the stress and relax cycles but the damaged or cracked electrodes continue to bridge to maintain conductive paths across the electrodes to provide the integrity of the electrical properties of the material.

Acknowledgement

The 80% strain di-electric electro active polymer, DEAP, was provided by Mohamed Benslimane, Danfoss PolyPower. This project is funded by the Andrews University Internal Faculty Research Grant.