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Microstructural Evaluation of DEAP Material after Stress Relaxation

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Microstructural Evaluation of DEAP Material after Stress Relaxation Cycles

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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 8.3 in and width 0.6 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.

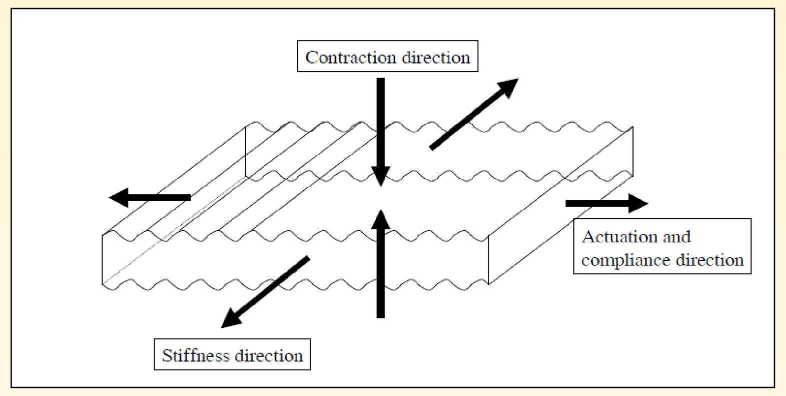

Figure 1. Schematic of the DEAP film with the metallic compliant electrodes deposited on both sides of the film. The material is been stretched along the compliance direction as shown in the diagram.

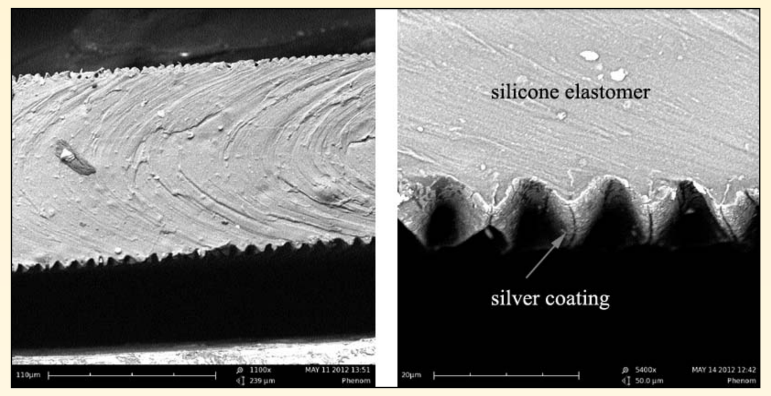

Figure 2. A low magnification of the corrugated edge of the DEAP is shown on the left and a higher magnification (on the right) shows the silver coating on the silicone elastomer film.

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Results and Discussion

The DEAP sample was stretched to 80% of its length and relaxed at a strain rate of 7 rev/min for a total of15,000 cycles. A plot of the capacitance at relaxed and stressed level is shown in figure 3. The capacitance increase as it stretched and on average there is an increase of around 52%. This percentage increase is much larger than a previous experiment that stressed the samples to only 25% with yield of only 6% increase in the capacitance.. 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.

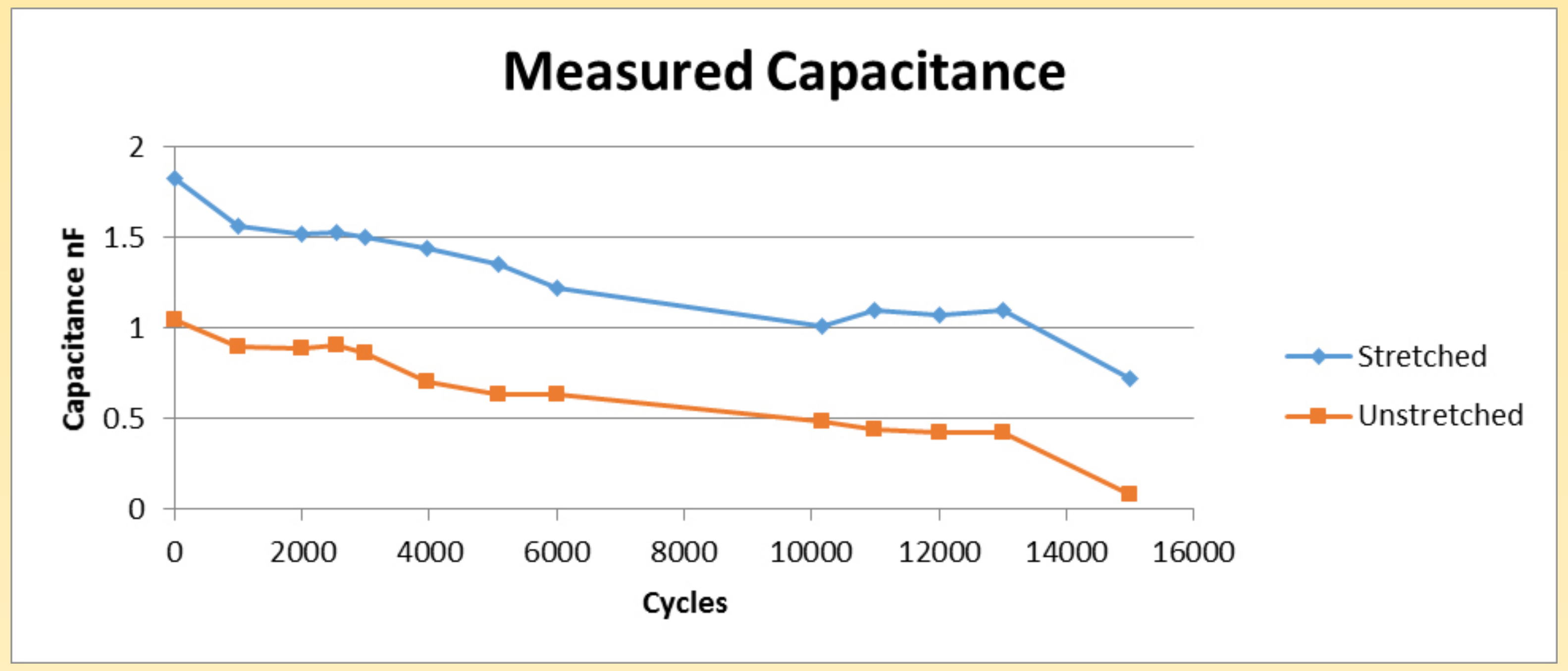

Figure 3. A low magnification of the corrugated edge of the DEAP is shown on the left and a higher magnification (on the right) shows the silver coating on the silicone elastomer film.

Image of the test sample, after the experiment, is shown in figure 4. 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. Sample was cut into smaller pieces for observation under the scanning electron microscope.

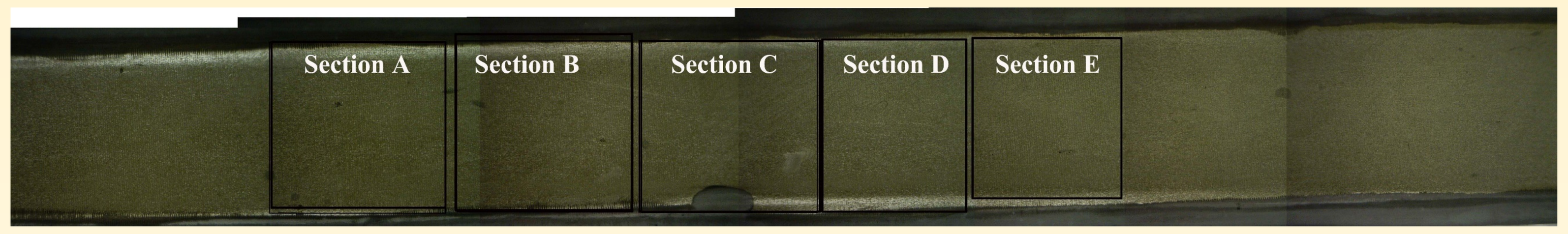

Figure 4. A low magnification of the sample showing the small tear. Sample is cut into small pieces for SEM imaging.

Figures 5-9 are secondary electron SE images of the highlighted section shown in figure 4. All the SE image 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 coating continued to bridge to maintain conductive paths across the electrodes.

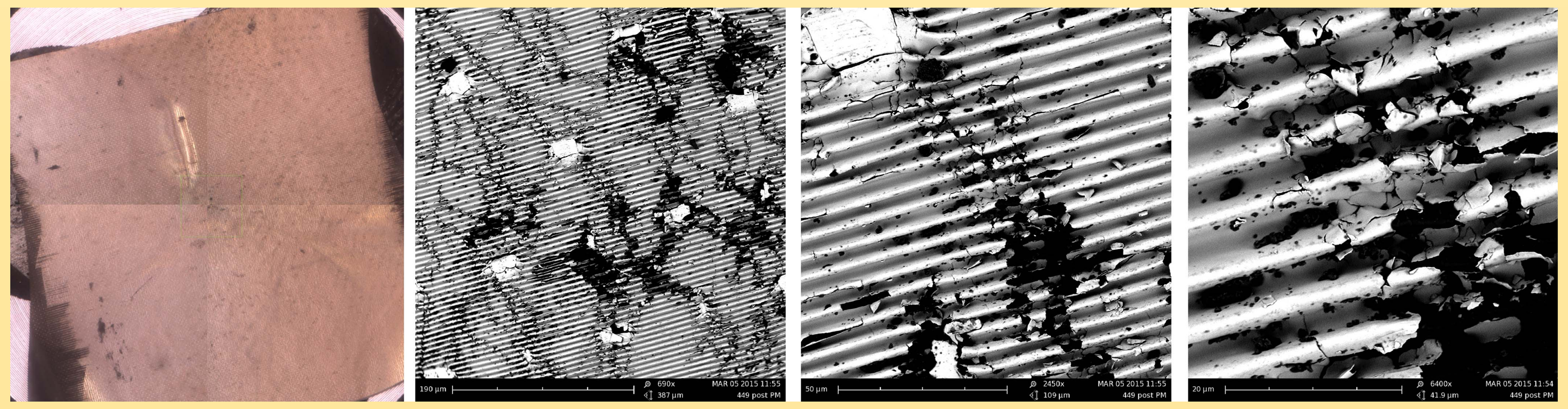

Figure 5. SE images of section A of the sample.

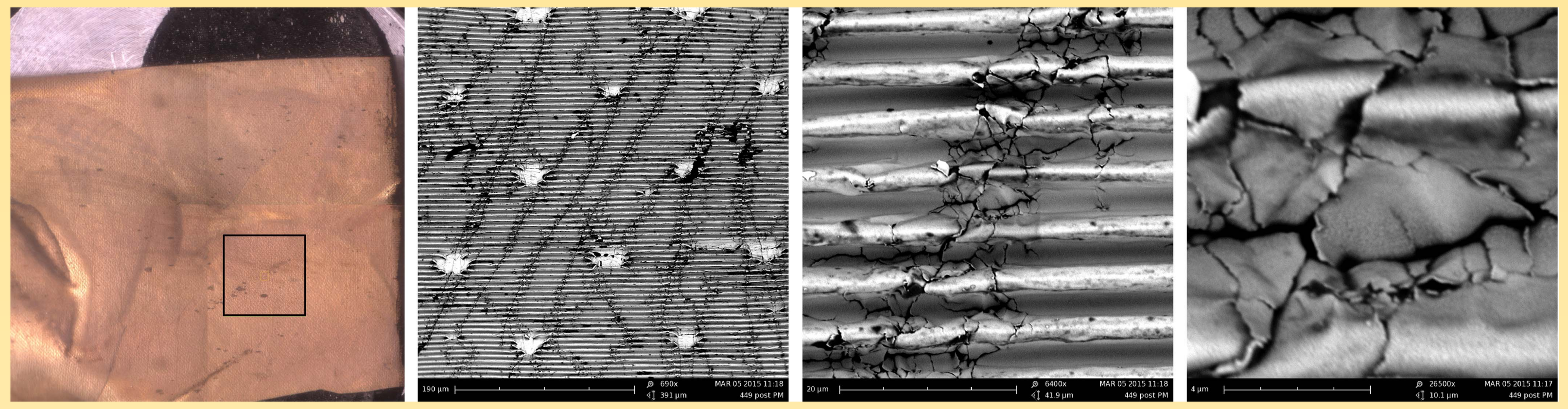

Figure 6. SE images of section B of the sample.

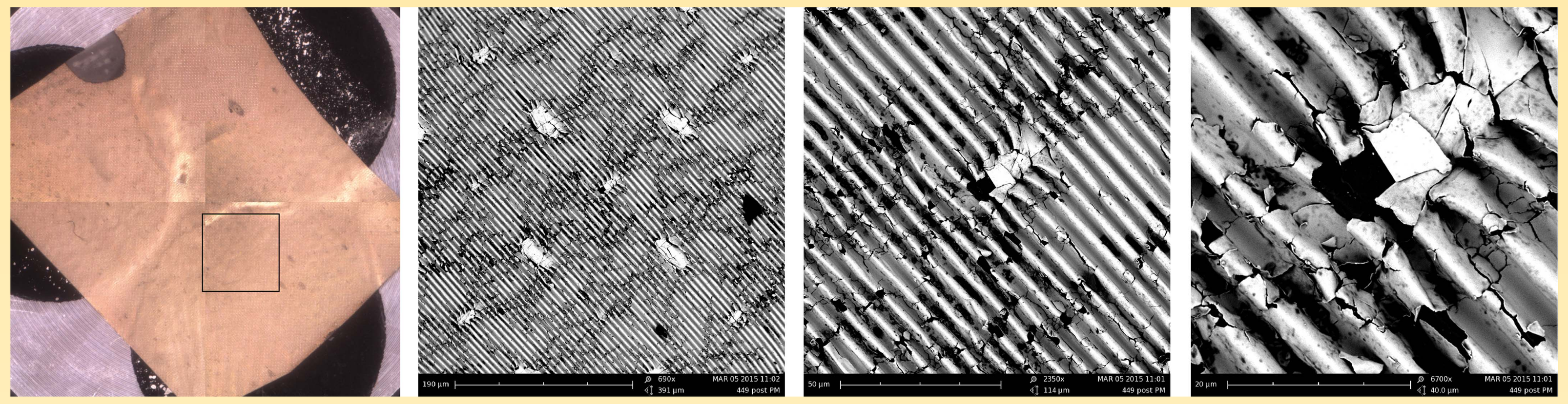

Figure 7. SE images of section C of the sample.

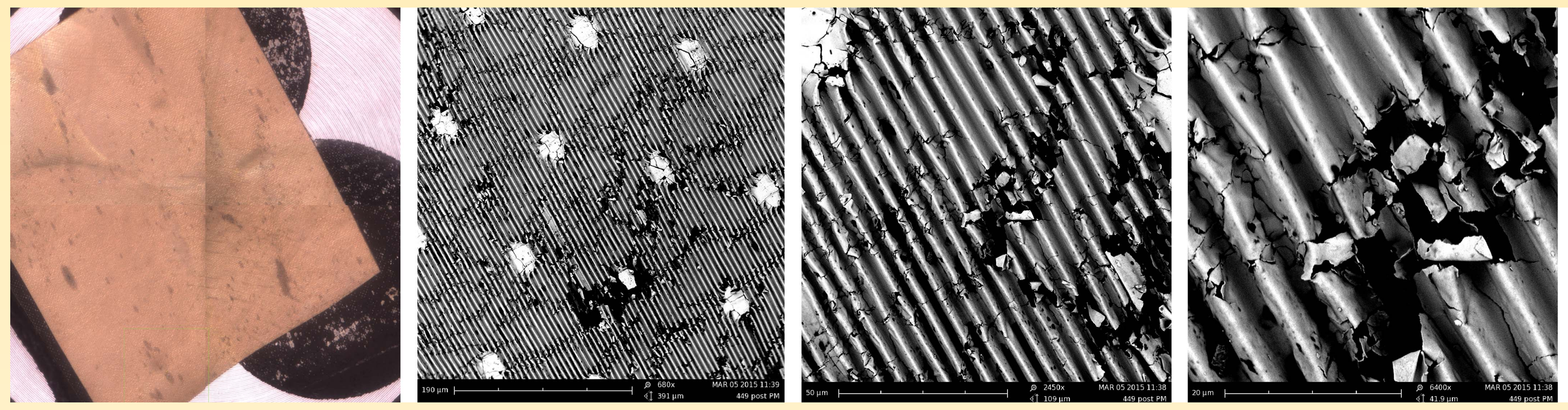

Figure 8. SE images of section D of the sample.

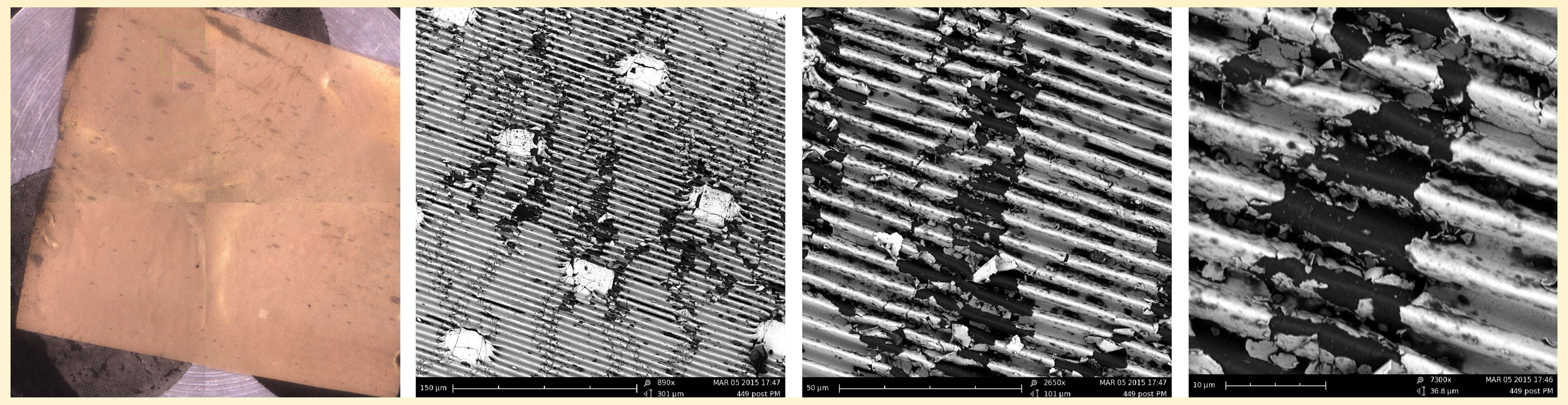

Figure 9. SE images of section E of the sample.

Conclusion

Samples of a 80% strain DEAP material were subjected to 15,000 relax and stress cycles and their capacitance was measured both at the relax and the stress regions.
Change in capacitance during the 15,000 cycles is about 52%. Damaged or cracked coating continued to bridge to maintain conductive paths across the electrodes.

Acknowledgement

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