EuroEAP 2012
International conference on Electromechanically Active Polymer (EAP) transducers & artificial muscles
Potsdam, 29-30 May 2012

Organized and supported by 'European Scientific Network for Artificial Muscles – ESNAM' (www.esnam.eu) COST Action MP1003

Poster ID: 1.2.10

Study on mechanical and dielectric behavior of VHB 4910 for sensors and actuators applications

Contact e-mail: Kpatra@iitp.ac.in

R. k. Sahu (1), B. Pramanik (1), K. Patra (1), S. Bhaumik (2), A. K. Pandey (3), D. K. Setua (3)

(1) Indian institute of Technology Patna, Department of Mechanical Engineering, Patna, India; (2) Indian institute of Technology Patna, Department of Electrical Engineering, Patna, India; (3) Defense Materials and Stores R & D Establishment (DMSRDE), Kanpur, India

Abstract

This paper describes the experimental investigations to characterize mechanical and dielectric behavior of VHB 4910 at large deformations. Attempts are made for accurate and precise experimental determination of mechanical behaviours such as nonlinear stress-strain, strain rate dependent hysteresis, cyclic softening and stress relaxation of this material. This paper also reports experimental study on frequency and stretch dependent dielectric constant of VHB 4910 film. Copper tapes are implanted on two opposite sides of a stretched elastomer film and dielectric constant of this material is estimated from measured capacitance using LCR meter. Variations of dielectric constant with different stretch ratio and with different applied voltage frequency are studied. Results show that the dielectric constant decreases with increasing frequency and stretch ratio. In this work we also explore the possible application of dielectric elastomer as sensor. Due to application of force, the thickness of the elastomer changes resulting change in capacitance. The change of capacitance is sensed with the help of electronics oscillator circuit which produces square wave whose frequency depends on the capacitance of the sample. The frequency to voltage converter circuit is used to obtain output DC voltage. So the thickness versus voltage curve is obtained which may be used to measure the capacitance hence the input force, elongation, pressure, etc. All these presented experimental results may be helpful for designers to characterize the performance of actuators and sensors fabricated with the dielectric elastomer material.

Recent works on dielectric elastomer (DE)

- **Kofod [2001]** applied both Ogden and Mooney-Rivlin models to fit force-strain data upto 500% strain value for a commercially available acrylic material, VHB 4910.
- **Patrick et al. [2007]** proposed a hyperelastic film model corresponding to Ogden to predict the uniaxial tensile behavior of VHB 4910 upto a stretch ratio 8.
- **Jung et al. [2008]** developed self sensing actuator which can sense its own displacement using capacitive characteristics of DE
- **Goulbourne [2011]** proposed a modified Ogden strain energy function to describe mechanical behavior of a new synthesized interpenetrating polymer networks (IPN) of acrylic elastomer.
- **Keplinger et al. [2012]** recently reported that giant voltage induced expansion of area by 1692% could be achieved with the VHB 4910 .

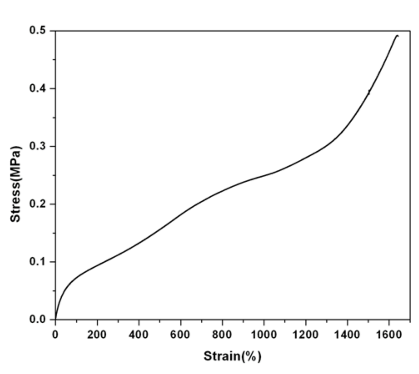
Challenges for realization of DE actuators and sensors

- Nonlinear time dependent material responses to mechanical and electrical stimulation.
- Electromechanical instability (pull in or snap through) of DE material.
- Multiple design parameters.
- Difficulties in measurement of the actuator performance characteristics.
- Viscoelastic deformation of DE is difficult to model.
- Maintaining electrode compliance for large deformation is difficult.
- Requirement of very high voltage source for actuator applications.
- Frequency dependent capacitive property.
- Non-linear response curve for sensor applications.

Experimental investigation of different mechanical as well as electrical behavior is necessary for actuators and sensors applications.

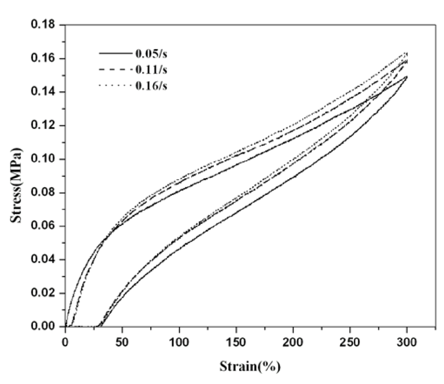
Mechanical characterization

Tensile Testing

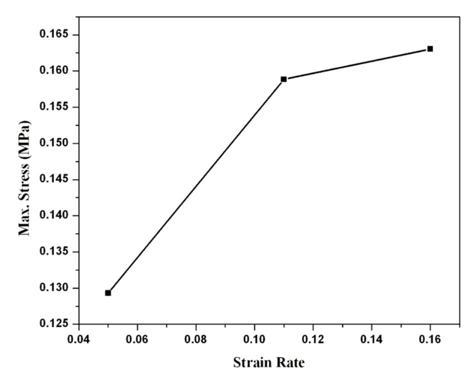


Stress-strain curve for VHB 4910(3M)

Hysteresis Testing

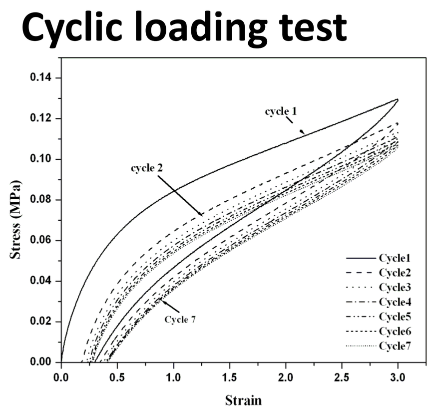


Hysteresis at different strain rates

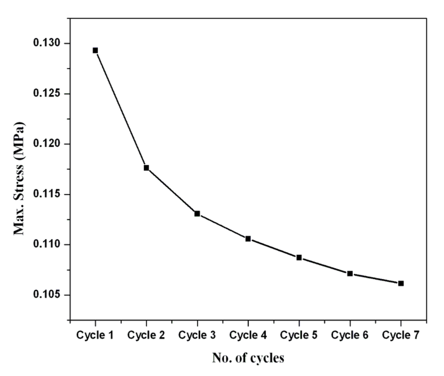


Max. stress v/s Strain Rate

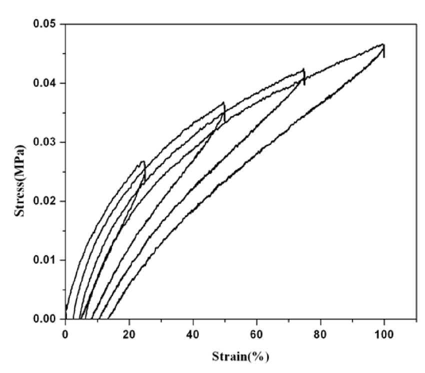
Cyclic loading test



Stress softening in cyclic loading test

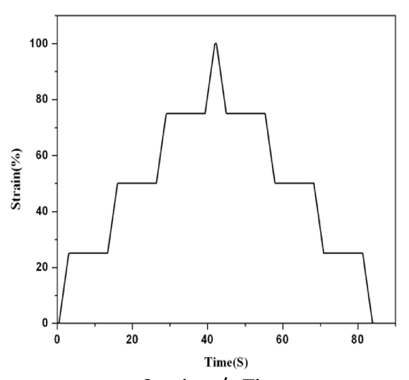


Max. Stress v/s No. of cycles

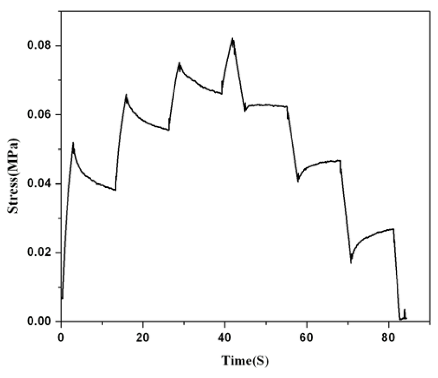


Hysteresis at the increment of 100% straining

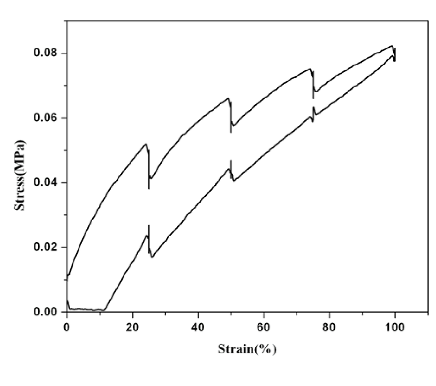
Stress relaxation test



Strain v/s Time

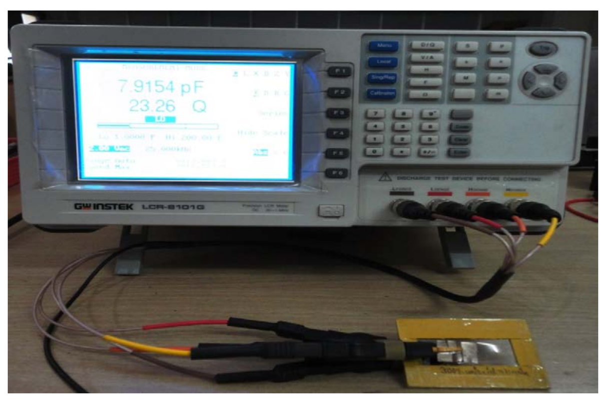


Stress v/s Time with number of intermittently stops within 100% strain value

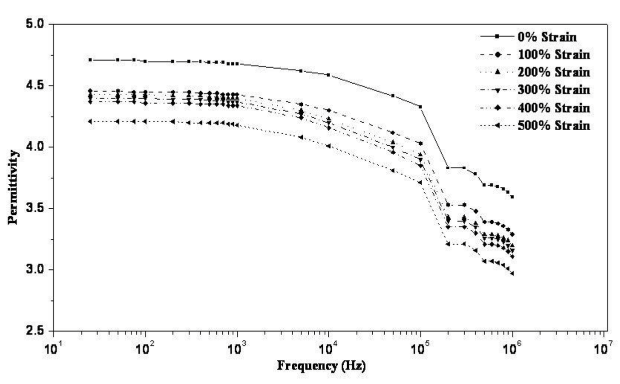


Stress v/s Strain curve for the same test

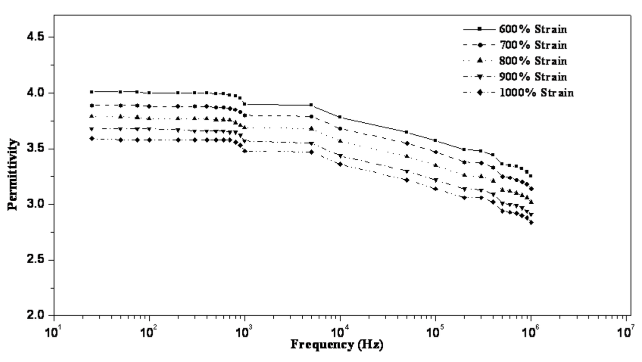
Dielectric characterization



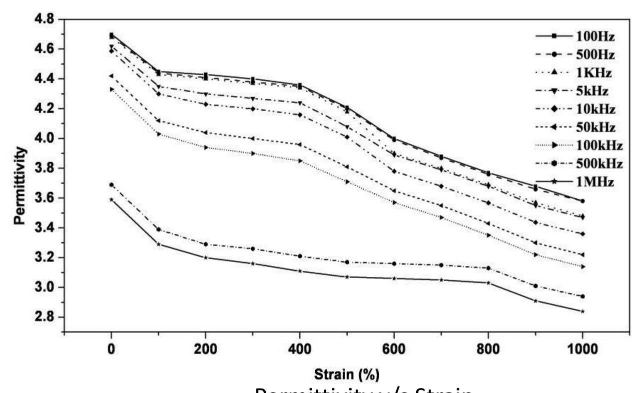
Permittivity measurement setup



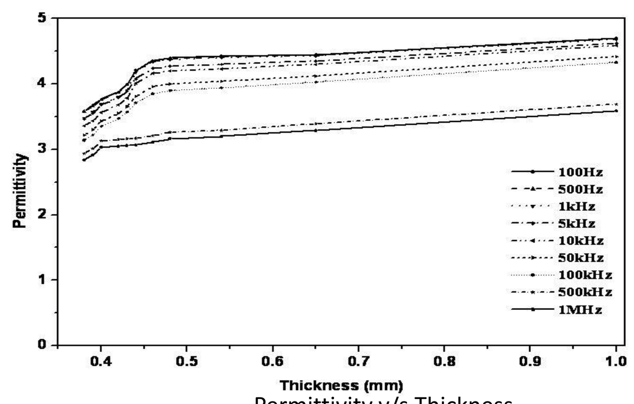
Permittivity v/s Frequency



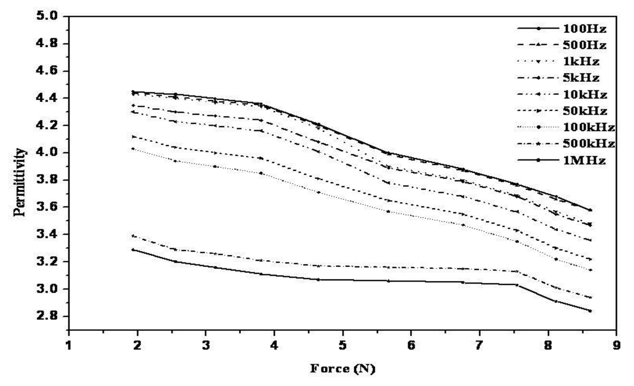
Permittivity v/s Frequency



Permittivity v/s Strain

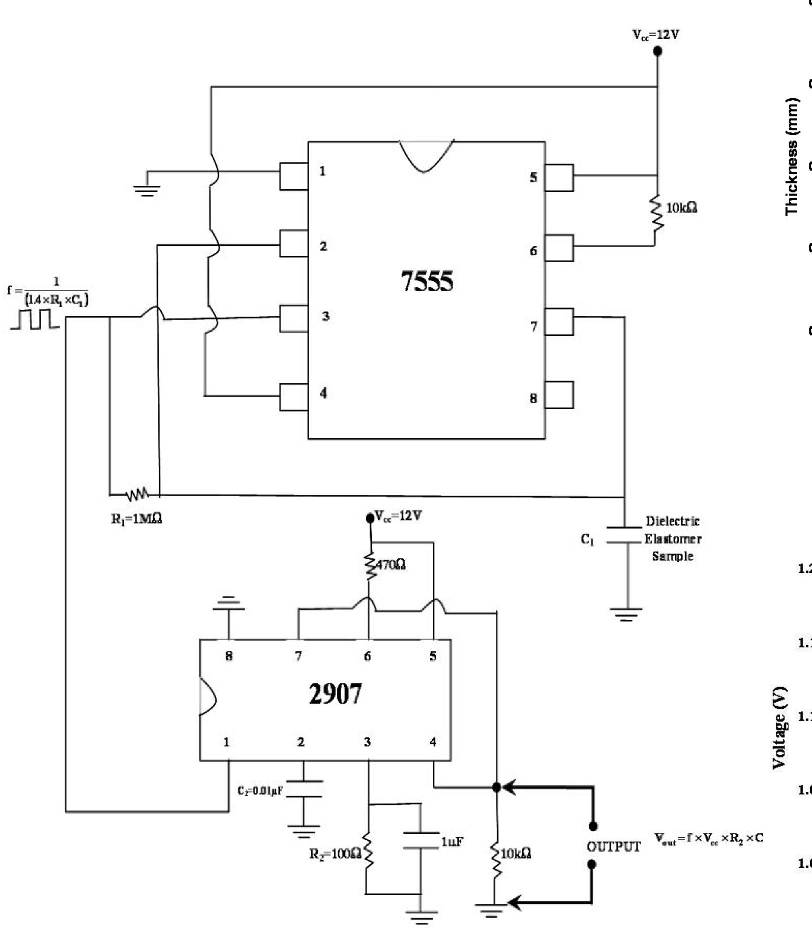


Permittivity v/s Thickness

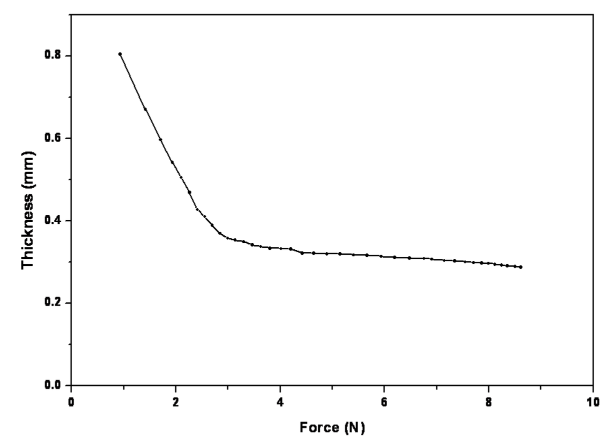


Permittivity v/s Force

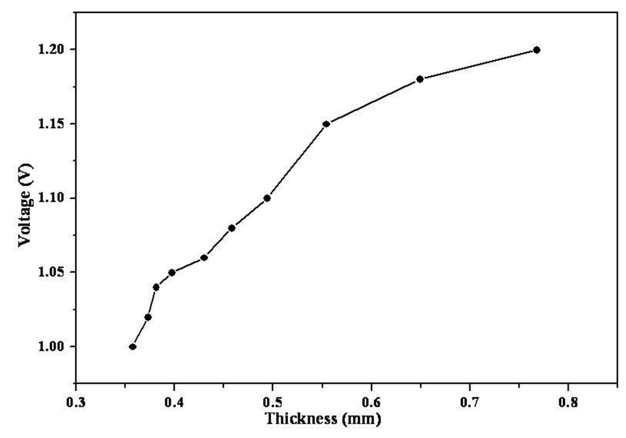
VHB 4910 as a sensor



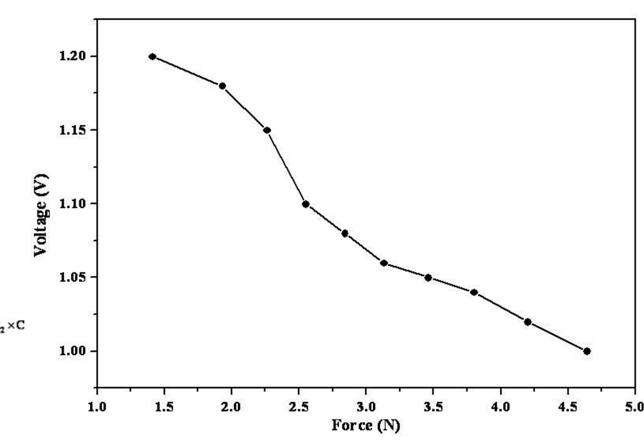
Circuit Diagram



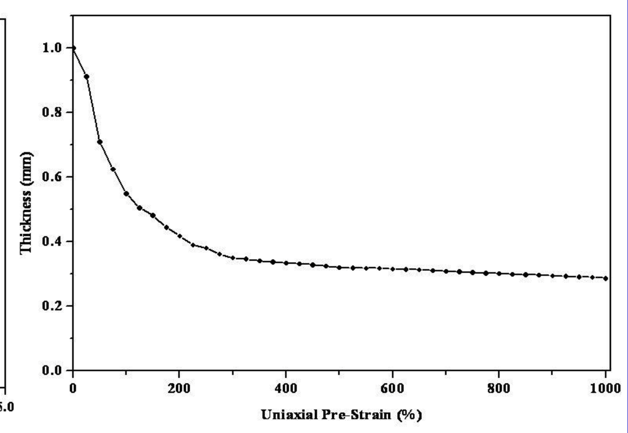
Thickness v/s Force



Voltage v/s Thickness



Voltage v/s Force



Thickness v/s Uniaxial Pre-strain(%)

Conclusions

- Experimental investigation reveals that acrylic elastomers exhibit large non-linear deformation, strong hysteresis, cyclic softening and stress relaxation. These mechanical parameters may largely affect the performance of DE actuators.
- Experimental study and modeling of deformation behavior may be the stepping stone to realize the application of this material for future sensors and actuators.
- Permittivity decreases with increasing strain and frequency.
- Dielectric characterization of DE material may be useful for the realization of capacitive, thickness and tactile sensor.

Acknowledgment

The authors sincerely express acknowledgement to DMSDRE, DRDO, Kanpur for the financial support for this work (Project number: TR/0569C/CARS-53, 2010-11).

References

1. G. Kofod, "Dielectric Elastomer Actuator", PhD thesis, Technical University of Denmark (2001).
2. Lochmatter Patrick, Kovacs Gabor and Michel Silvain, "Characterization of dielectric elastomer actuators based on a hyperelastic film model, Sensors and Actuators", A 135: 748–757 (2007).
3. Kwangmok Jung, Kwang J. Kim and Hyouk Ryeol Choi , "A self-sensing dielectric elastomer actuator", Sensors and Actuators A 143 343–351(2008).
4. Christoph Keplinger, Tiefeng Li, Richard Baumgartner, Zhigang Suo and Siegfried Bau, "Harnessing snap-through instability in soft dielectrics to achieve giant voltage-triggered deformation", Soft Matter 8 285-288 (2012).
5. Ronald E. Pelrine, Roy D. Kornbluh and Jose P. Joseph, "Electrostriction of Polymer Dielectrics with Compliant Electrodes as a Means of Actuation", Sensors and Actuators A 64 77-85 (1998)
6. Nakhiah C. Goulbourne, "A constitutive model of polyacrylate interpenetrating polymer networks for dielectric elastomers", International Journal of Solids and Structures, 48 1085-1091 (2011).
7. G. Kofod , P. Sommer-Larsen, R. Kornbluh and R. Pelrine, "Actuation response of polyacrylate dielectric elastomers", J. Intell. Mater. Syst. Struct. 14 787–93 (2003).
8. M. Wissler and E. Mazza, "Electromechanical coupling in dielectric elastomer actuators", Sensors and Actuators A 138: 384–93 (2007).