

Development of Dielectric Elastomer Nanocomposites as Stretchable and Flexible Actuating Materials

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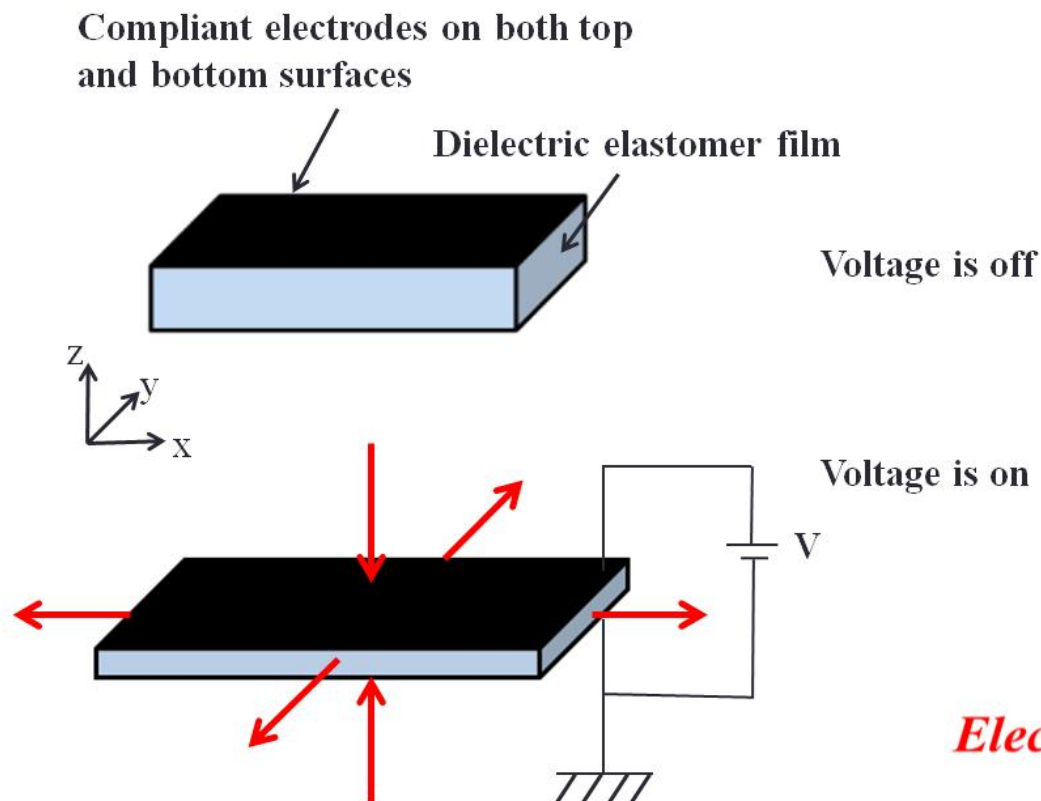
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Dielectric elastomers (DEs) are...

- One type of “Smart Materials”
- Dielectric elastomers change their size, and shape when subjected to applied electric fields.

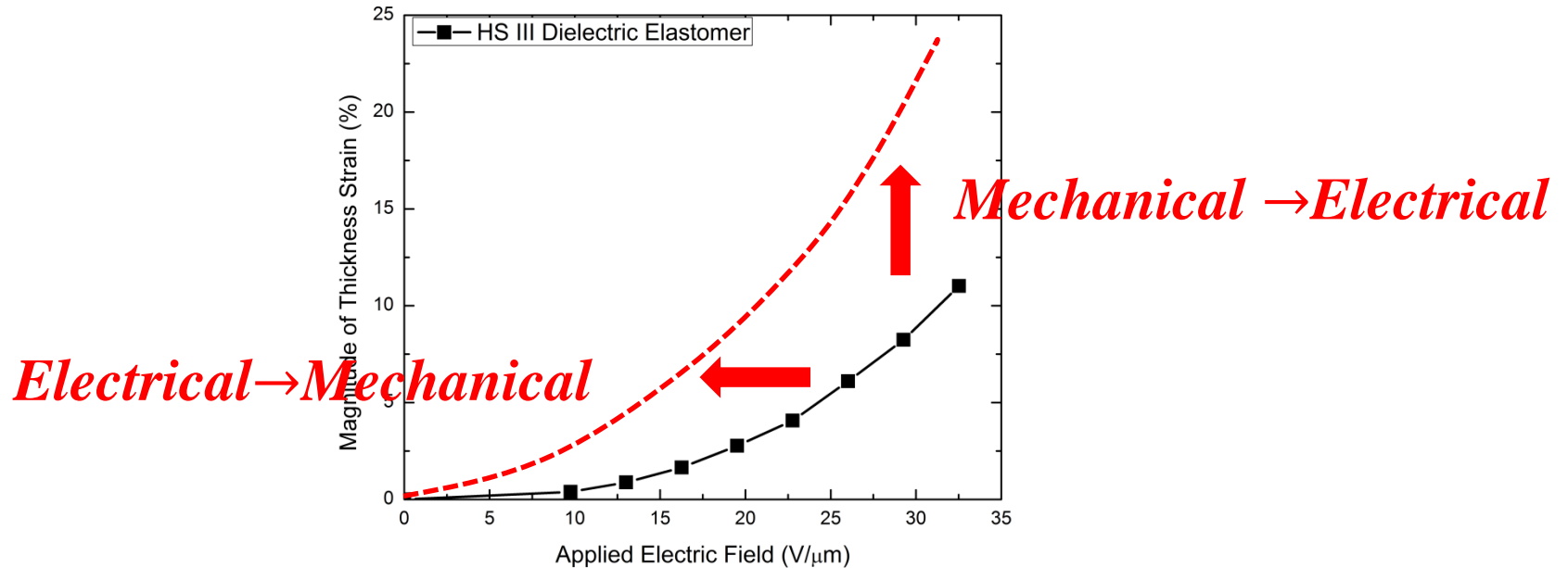


Electrical ↔ Mechanical

Advantages and Disadvantages

- Large deformation
- Fast response speed
- Good efficiency
- Low cost
- Lightweight
- Highly inert
- But, it requires extremely high voltage to actuate DE materials...

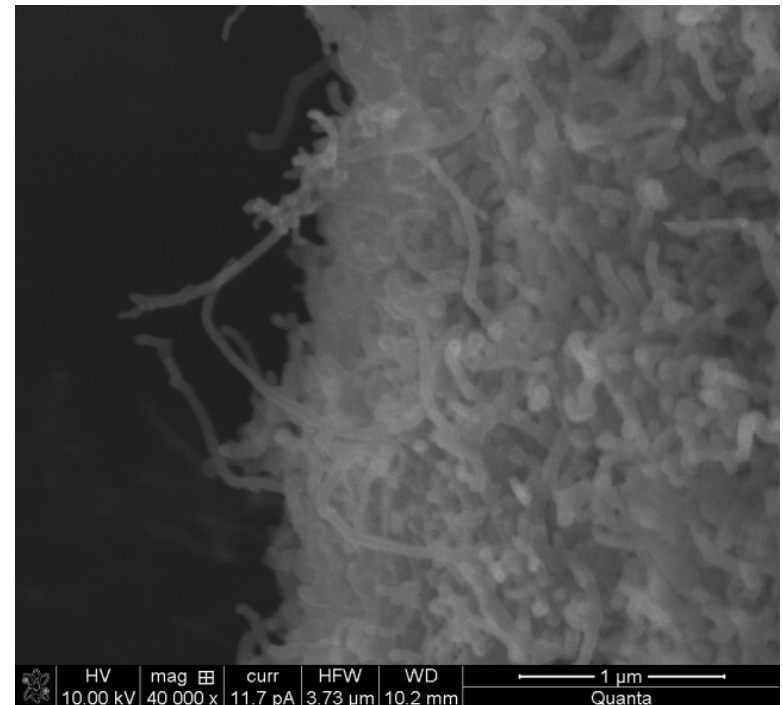
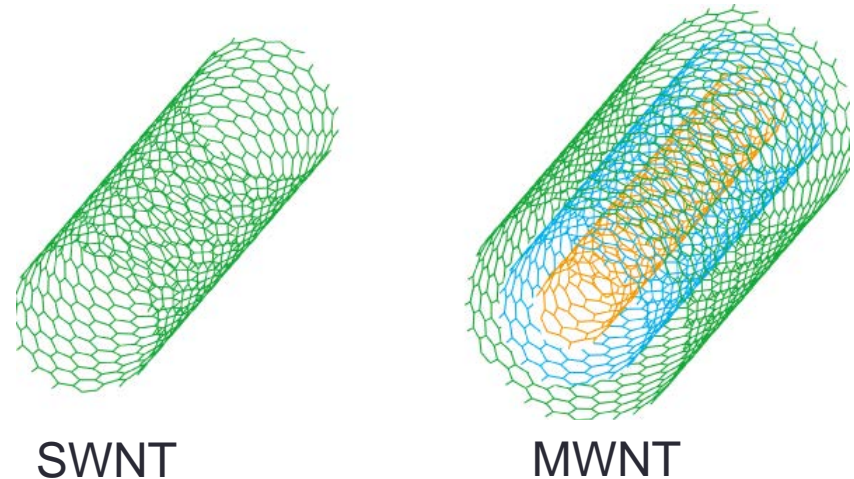
Primary Challenge



Carbon Nanotubes

- High aspect ratio
- High electrical and thermal conductivity
- High strength

Introduction of MWNTs to DEs is one of the first attempts.

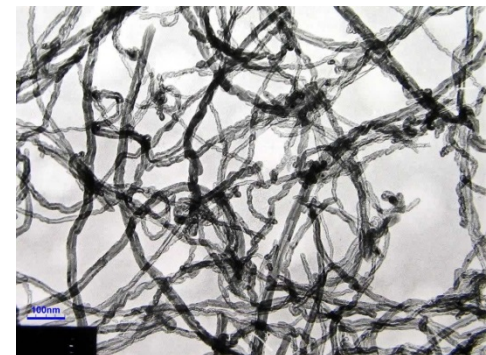


Materials

- **HS III RTV High Strength**
- **Mold-making Silicone Rubber (Alumilite)**
- **MWNTs (CheapTubes, Inc.)**
- **Conductive Carbon Grease (MG chemicals)**
- **RTV 60-CON Adhesive Sealant (Stockwell Elastomerics, Inc.)**



http://www.amazon.com/Alumilite-High-Strength-Making-Rubber/dp/B007RGE0B6/ref=pd_sim_ac_4?ie=UTF8&refRID=1J2A514KXBRQD4F47MVY

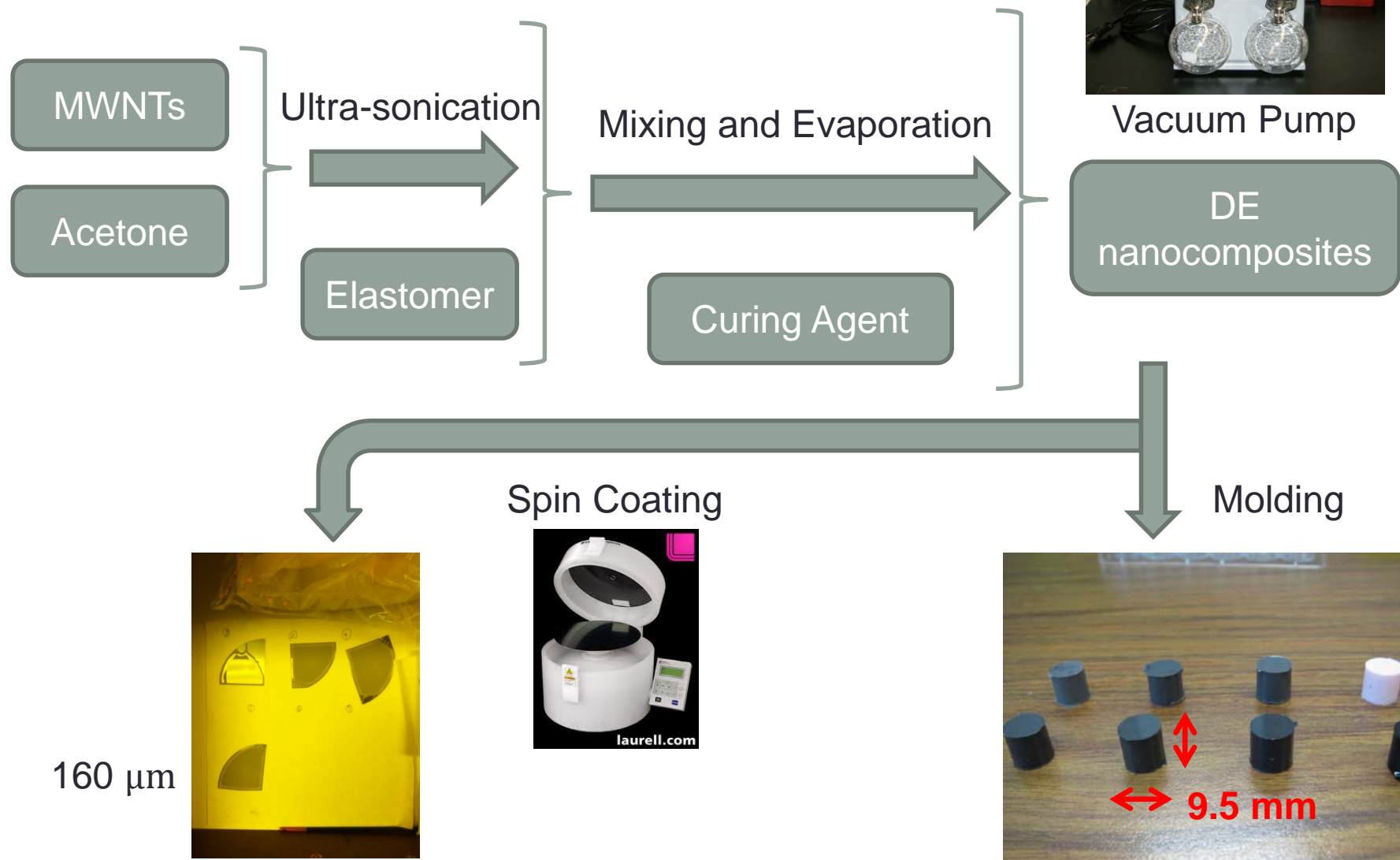


http://www.cheaptubes.com/MWNTs.htm#multi_walled_nanotubes-mwnts-20-30nm_specifications



<http://www.digikey.com/product-detail/en/846-80G/473-1121-ND/2233038>

Materials Fabrication



Compliant Electrodes

- The mixture of carbon grease and RTV 60-CON Adhesive sealant was air sprayed on the surface of the dielectric elastomer film.
- The electrode thickness was controlled to be about 20 μ m.



<http://www.tcpglobal.com/airbrushdepot/itemdetail.aspx?itemno=MAS+S622-L>

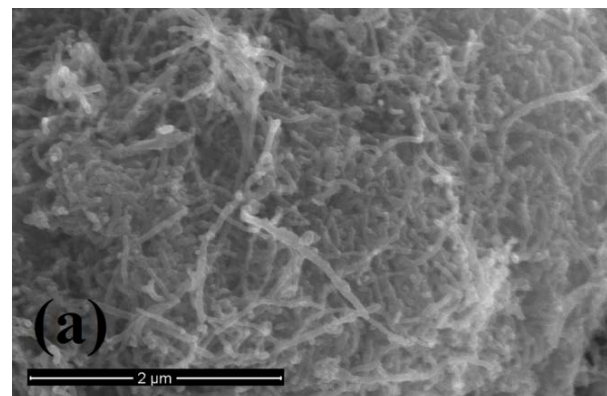


Dispersion of Carbon Nanotubes

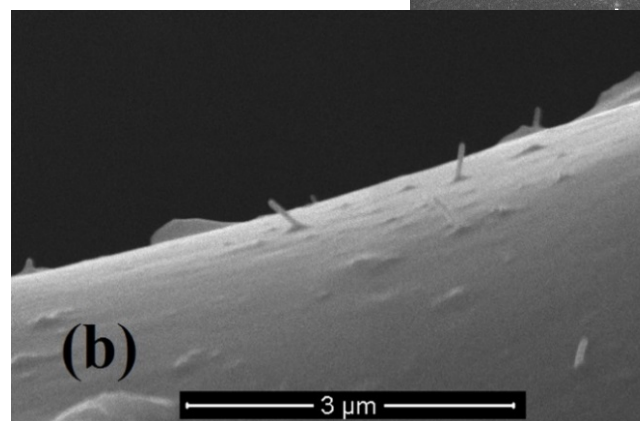
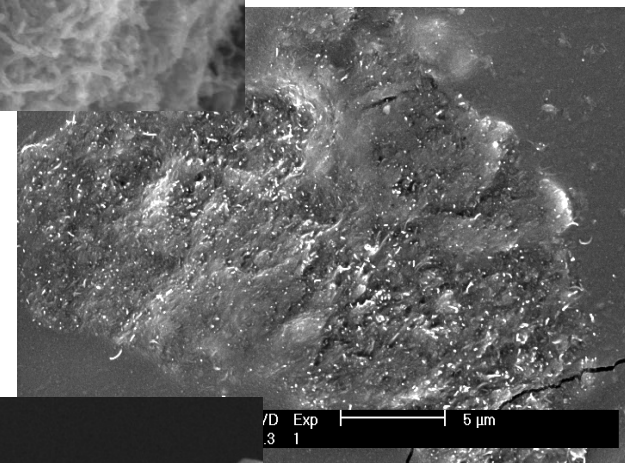
- To break van der Waals force, acetone and ultra-sonication are utilized.



Ultra-sonication device
20kHz, 130 W

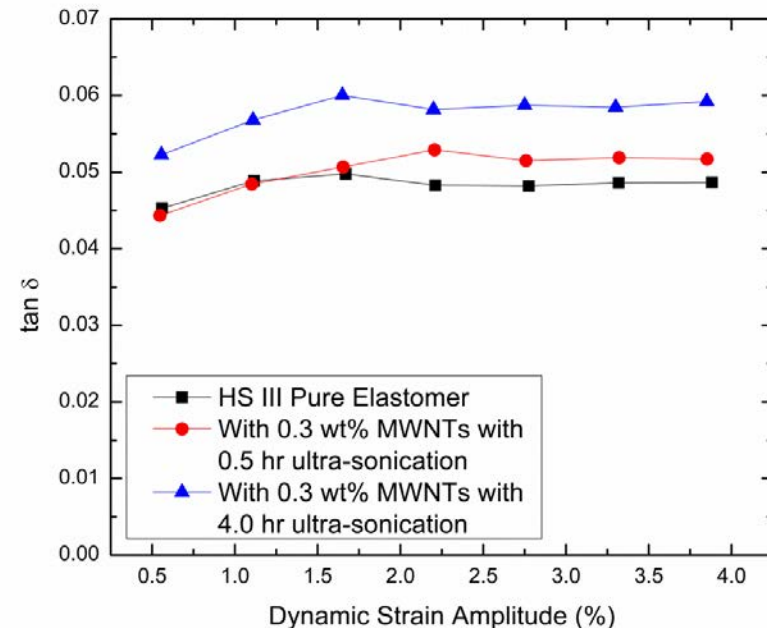
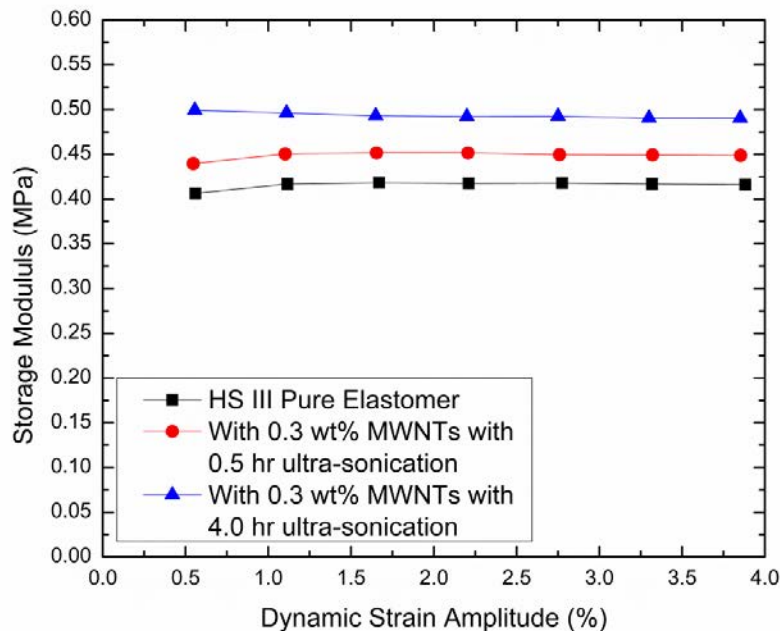


Processing



Dispersion of Carbon Nanotubes

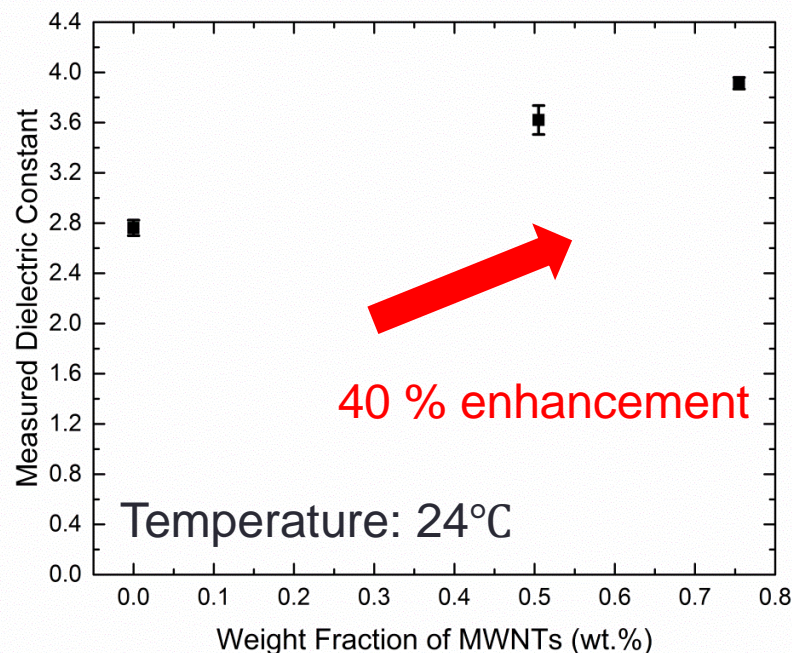
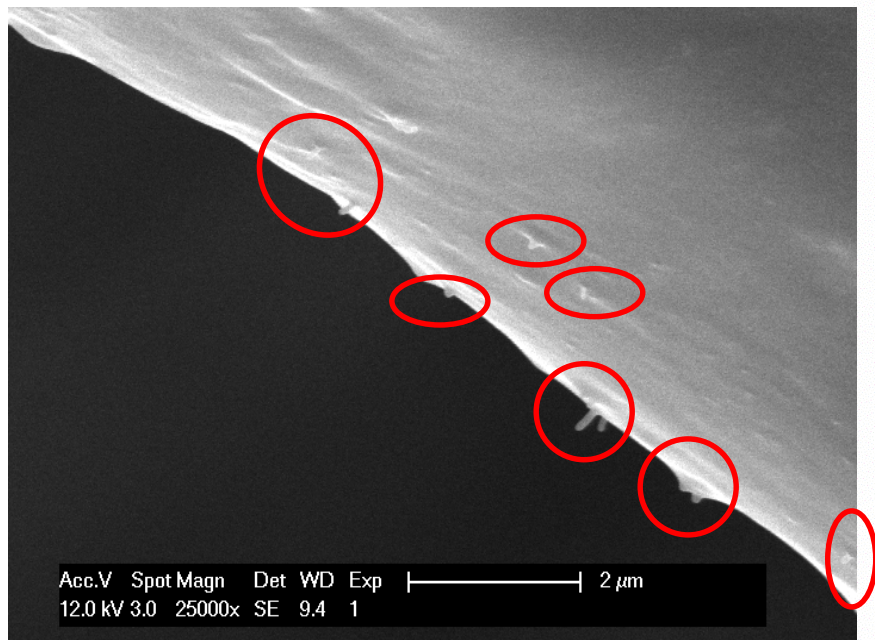
DE nanocomposites filled with MWNTs



Small amount of MWNTs greatly increases the stiffness and damping of DEs.

DE nanocomposites filled with MWNTs

Cross Section of a Fractured Surface
DE nanocomposites with 0.75 wt. % MWNTs

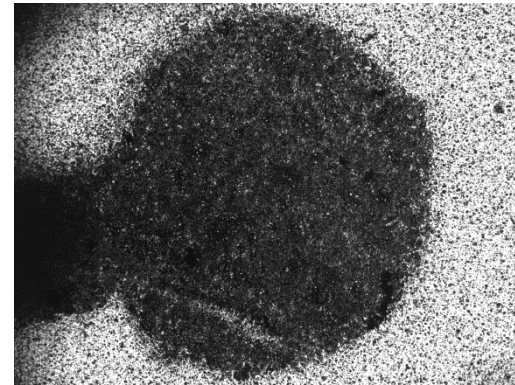


Small amount of MWNTs significantly increases the dielectric constant of DEs.

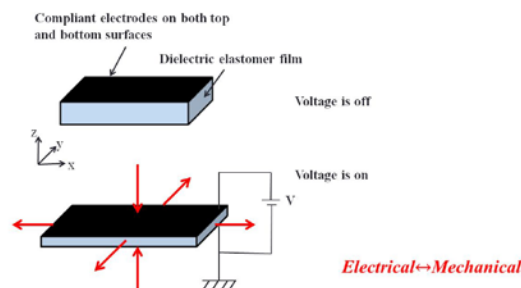
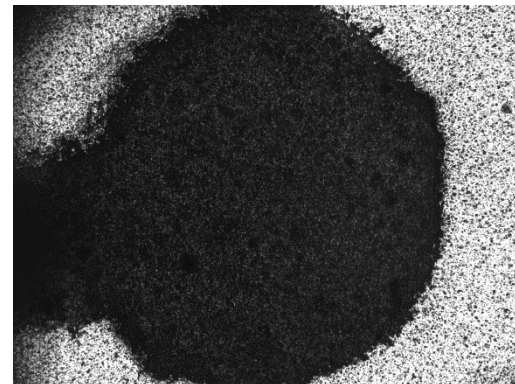
Conventional Electromechanical Measurements

-Video or CCD cameras were used to capture the area change. (e.g., Pelrine 2000, Yuan 2009)

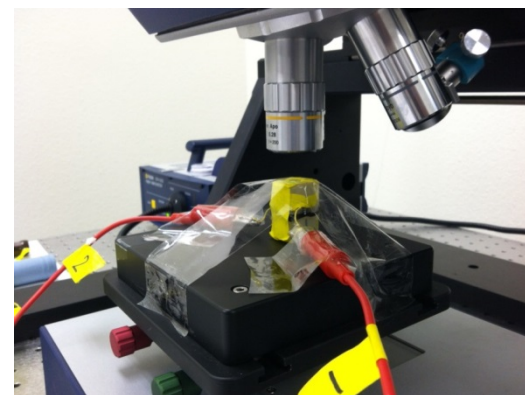
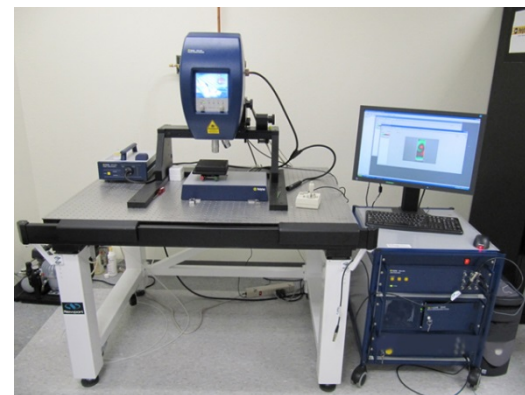
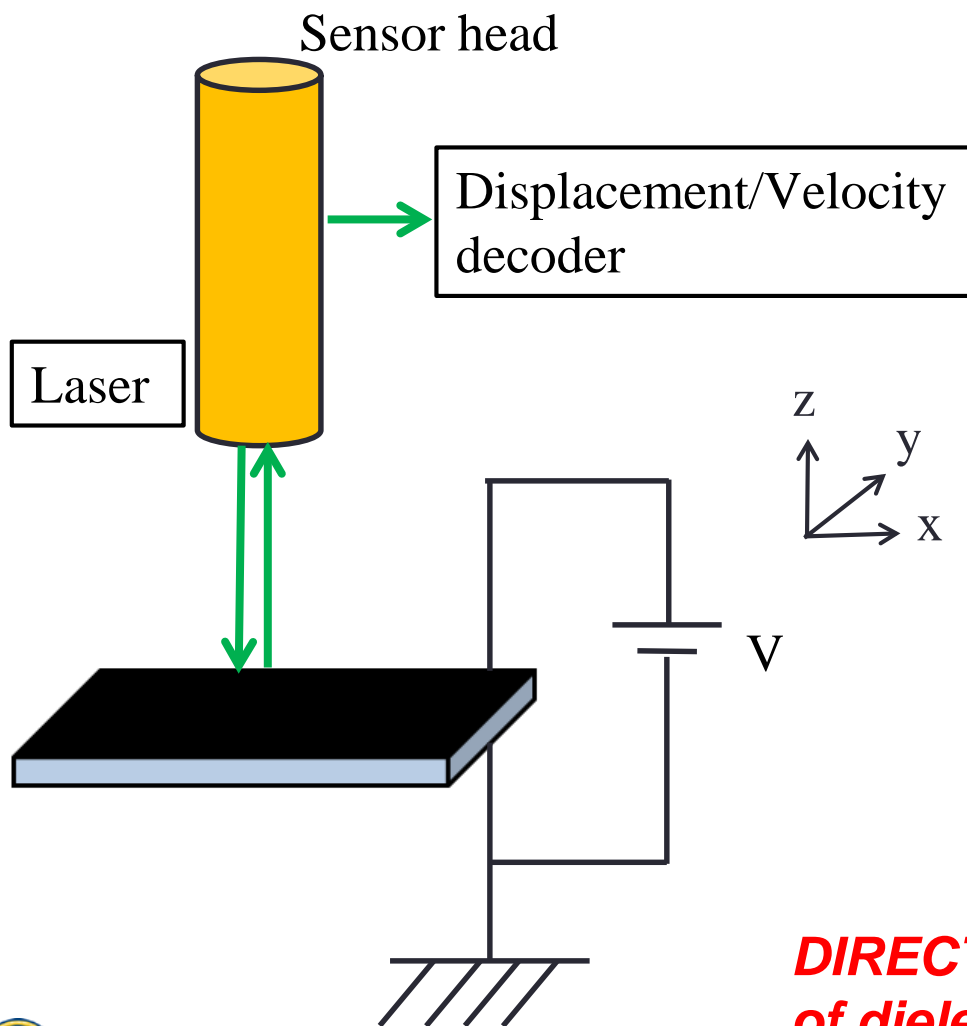
-Then area expansion was converted to thickness strain under the incompressibility assumption. (e.g., Pelrine 2000, Choi 2014)



Electric field is applied.



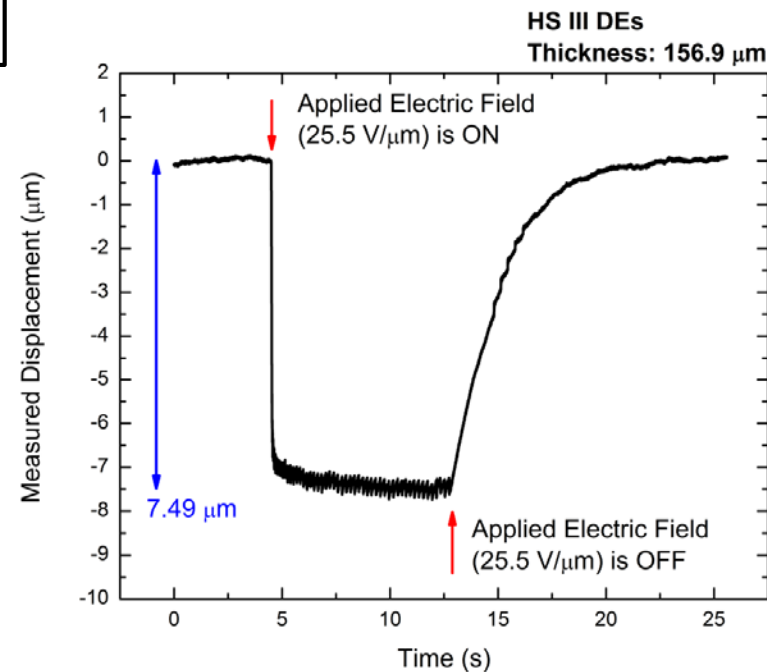
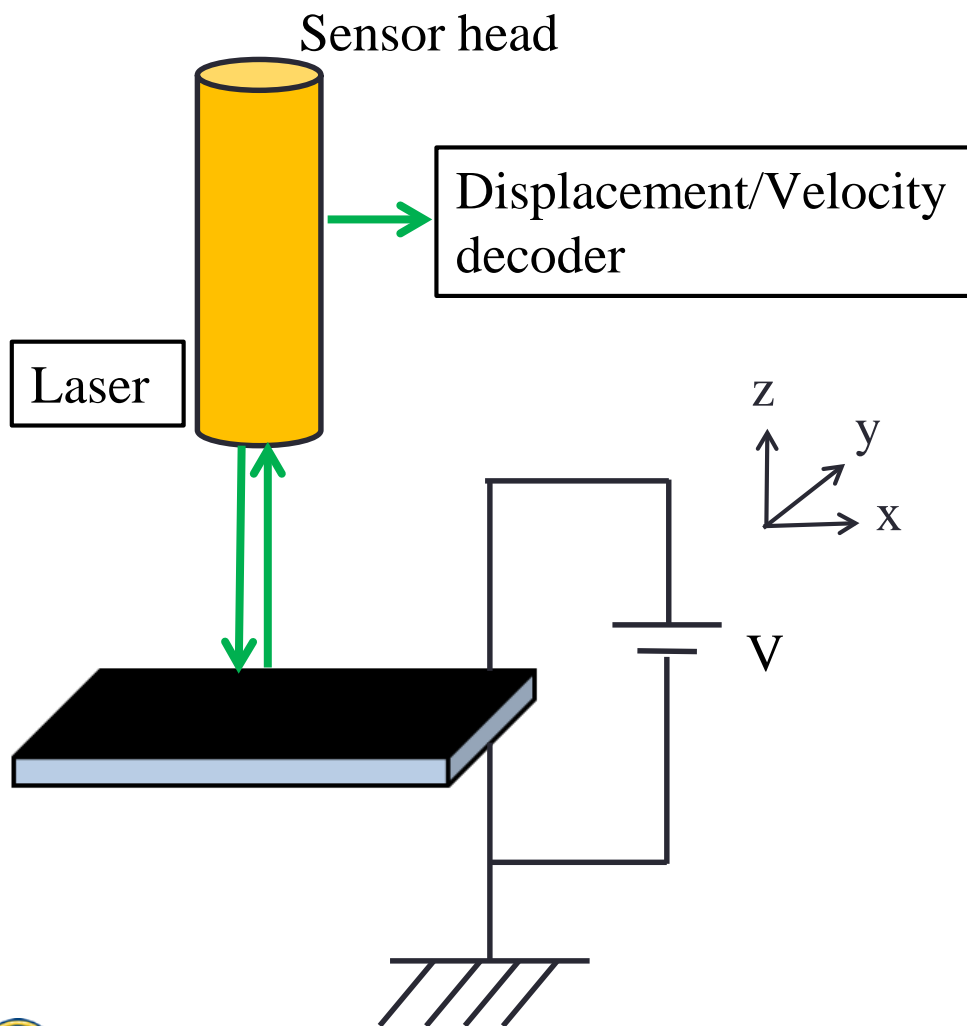
Laser Doppler Vibrometer



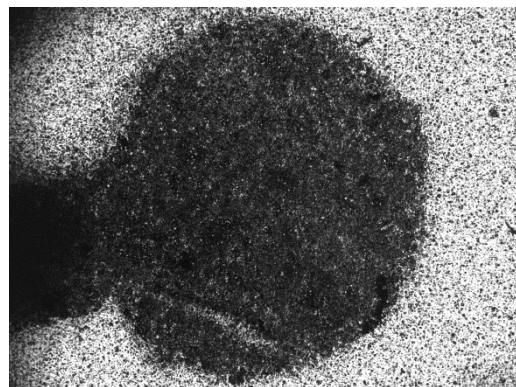
Temperature: 24°C

DIRECTLY detect the thickness strain of dielectric elastomers

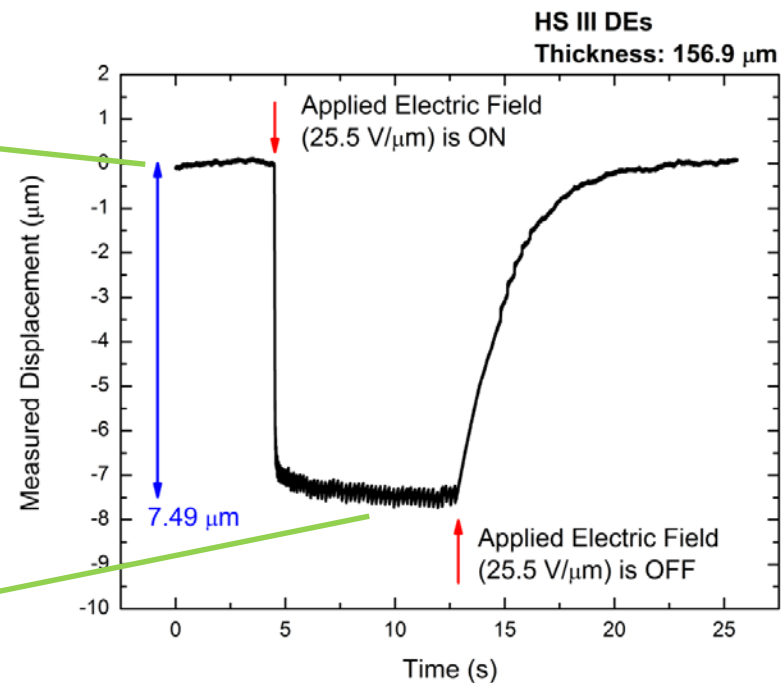
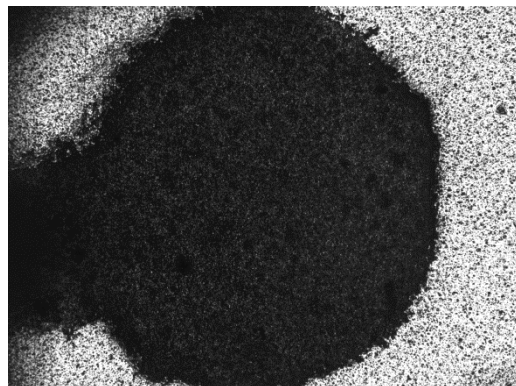
Laser Doppler Vibrometer Setup



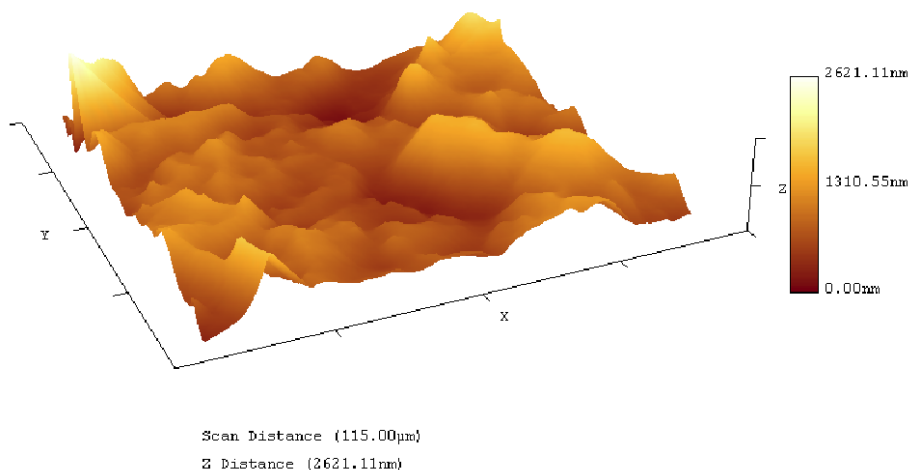
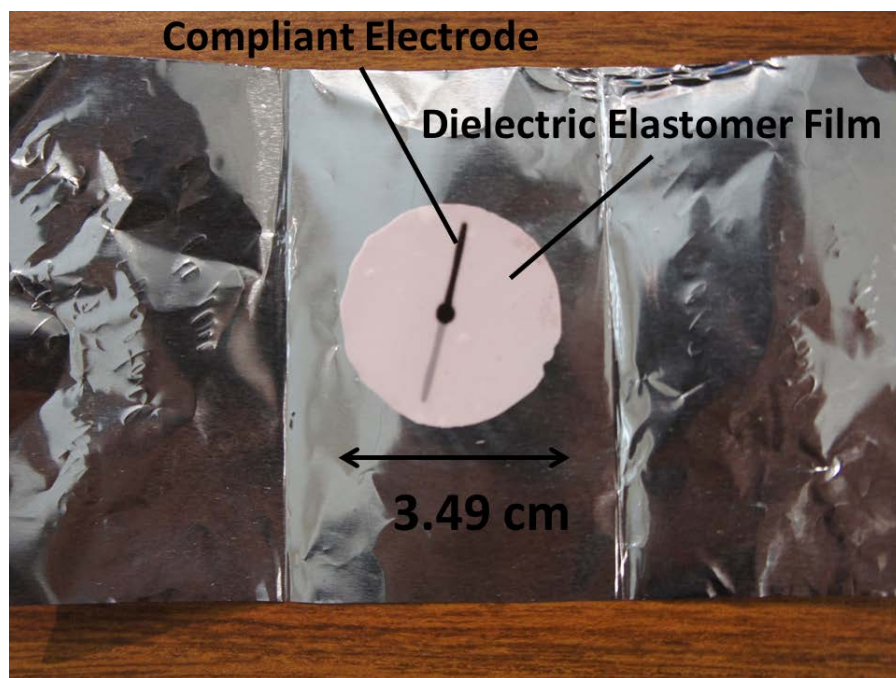
Surface Displacement Measurement



25.5 V/ μm
is applied.



Roughness of Compliant Electrodes

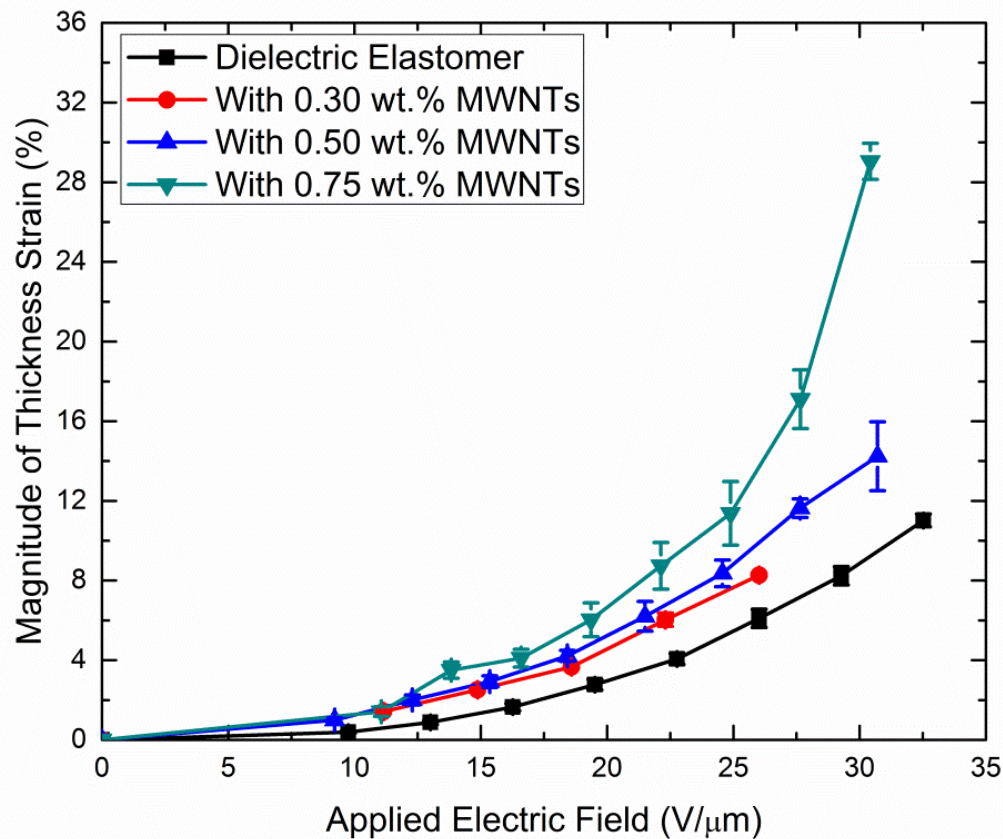


Roughness: $\pm 1.3\mu\text{m}$ at maximum
within $115\mu\text{m} \times 115\mu\text{m}$ area

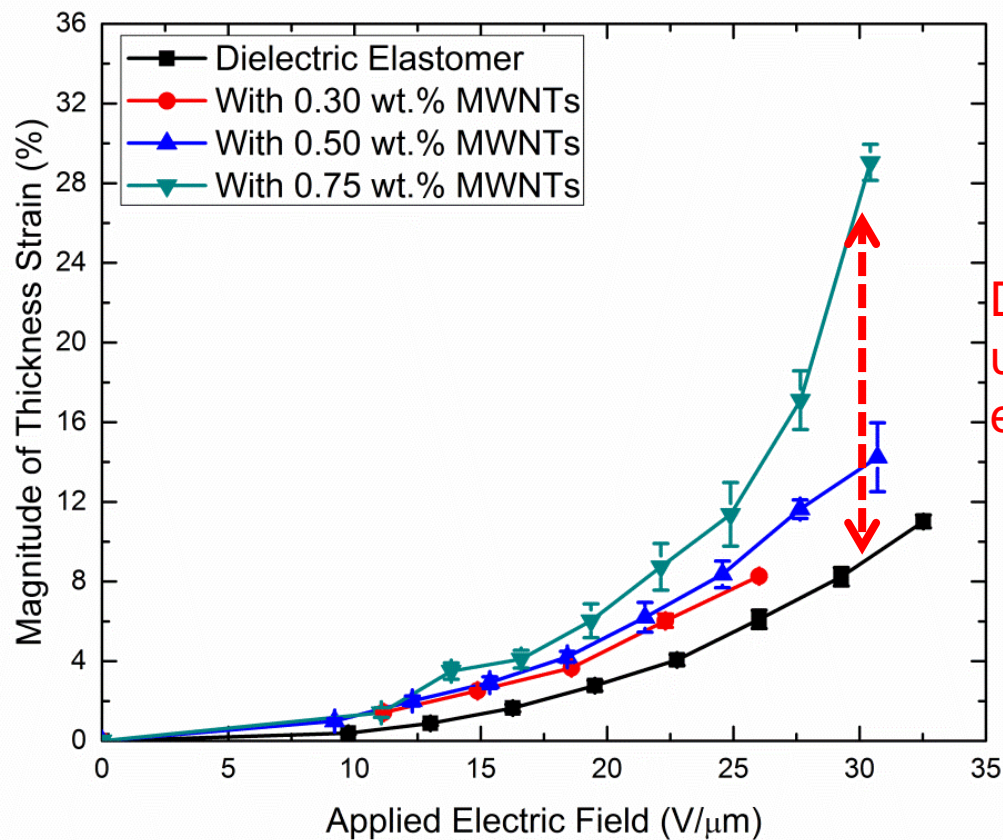
***Roughness of the electrodes does not
affect the displacement measurement.***

Experimental Results

The thickness strain does not depend on the boundary conditions in our setting.

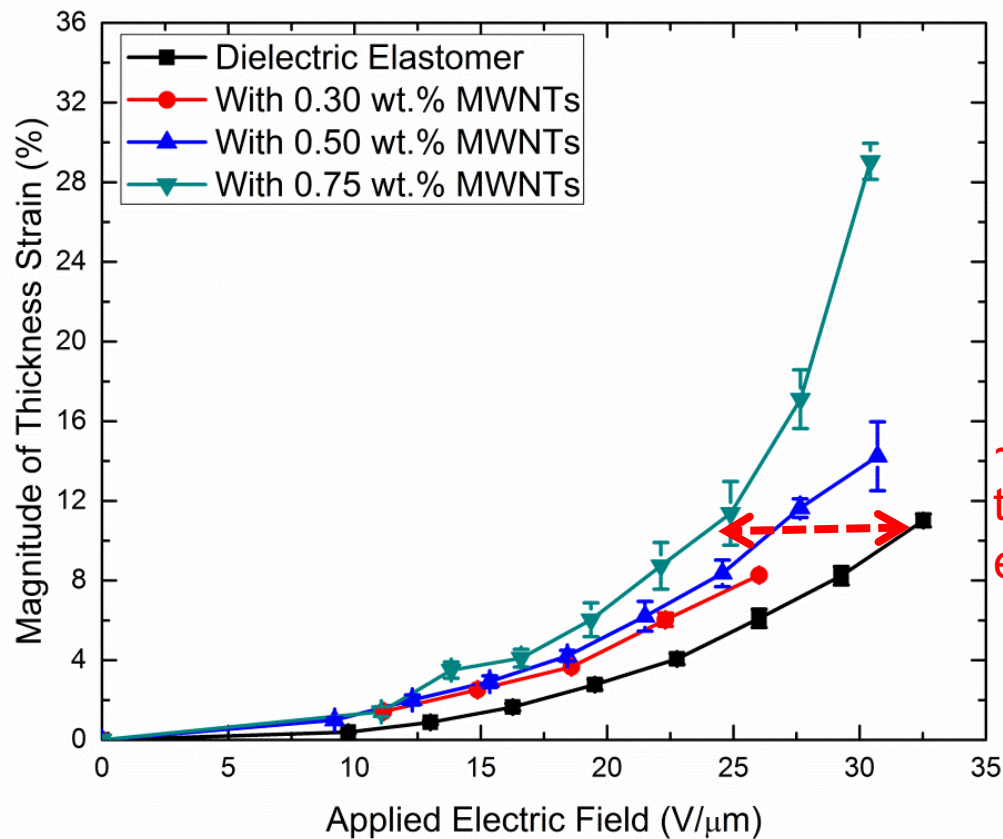


Experimental Results



Deformed about 300 %
under the same applied
electric field

Experimental Results



~30 % decrease in
the required applied
electric field

Conclusions

- DE nanocomposites filled with MWNTs are developed as smart materials for actuators and energy harvesting.
- MWNTs are demonstrated to be effective in improving the electromechanical properties of DE nanocomposites.

