Soft Conductive Rubber Composites for Dielectric Elastomer Electrodes

Lisa Rae Zoldos, Daniel Muffoletto, and Dr. Jennifer Zirnheld

Energy Systems Institute - University at Buffalo - School of Engineering and Applied Sciences

Introduction

Dielectric elastomer actuators, or DEAs, are compliant capacitors in which an elastomeric film is inserted between electrodes. When a voltage is applied, the film expands, and then moves back to the same position after being short circuited. The electrodes have to be able to adjust to the deformations of the film. Electrodes can be composed of: a dusted carbon powder, a conductive grease coating, thin metal films, an ion implanted layer, or a thin sheet of conductive rubber. Graphite and graphene are two carbon fillers that are considered here to tailor the electrical conductivity of the DEA electrode film.

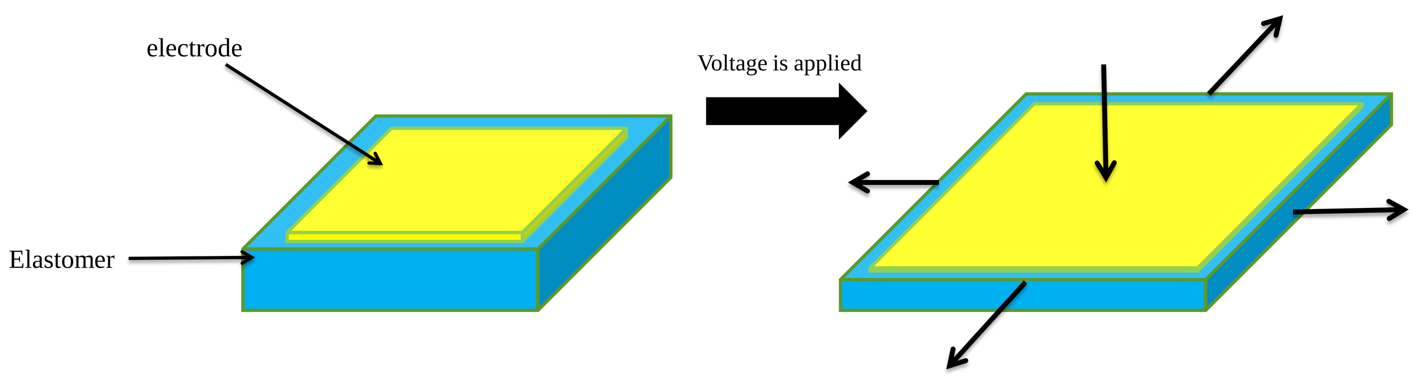


Fig. 1. A model of the dielectric elastomer actuator. When a voltage is applied, the elastomer expands.

Styrene Butadiene Rubber (SBR)

Four rubber materials were considered for use in the electrode system:

- Goodyear Pliogum 1028
- Goodyear Pliogum 1027
- Goodyear Plioflex 1502
- Aqueous Latex

Both the Pliogum 1027 and 1028 are food-grade polymers used in chewing gum in which the 1028 is firmer than the 1027 [1]. The Plioflex 1502 is a stickier, more pliable rubber than the other two. It dissolves at a higher rate than the other two, in a shorter amount of time. Composites made using aqueous latex on the other hand had no conductivity.

Fig. 1. The Pliogum has been soaked in toluene for a period of time in the mortar.

Fig. 2. A sample of graphene is mixed in a beaker with toluene

Carbon

There are many different allotropes of carbon, including graphite and graphene. Graphite is one of the most commonly noted allotrope, with its amorphous form being a fine powder. The atomic structure consists of multiple layers of covalently bonded carbon atoms as shown in figure 3. Graphene is a monolayer of carbon atoms in a honeycomb lattice [2]. The following two carbons were used:

- Angstron N006-P Graphene Powder (50 nm -100 nm thick)
- Southwestern Graphite Extra fine Powder

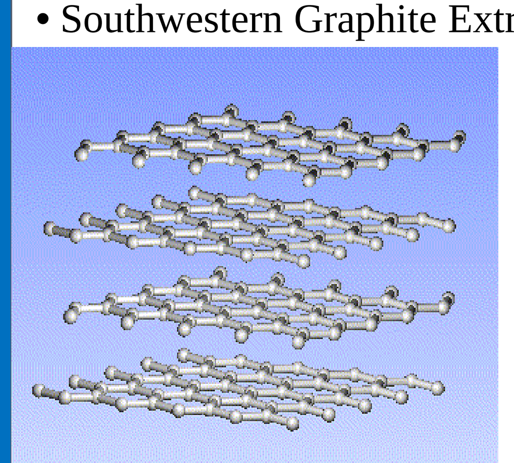


Fig. 3. The atomic structure of graphite [3]

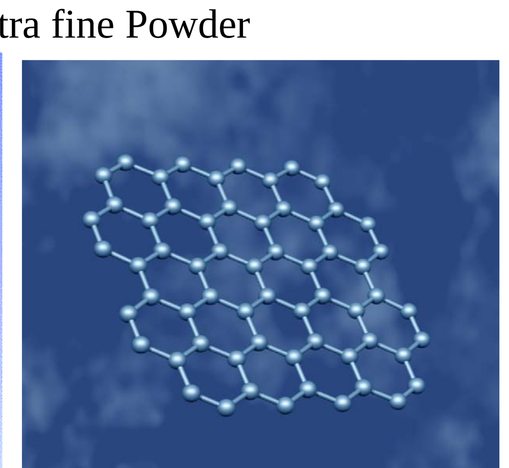


Fig. 4. The atomic structure of graphene [4]

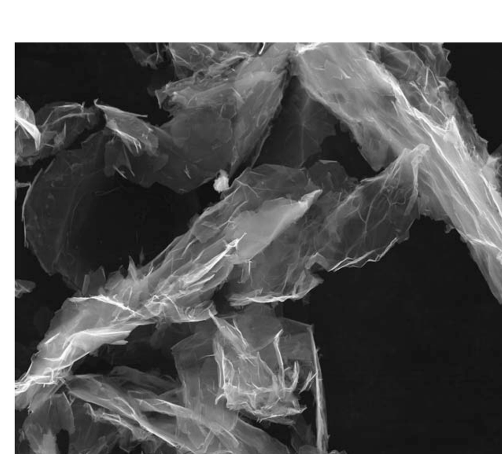


Fig. 5. The graphene in nanoplatelet form. [5]

Experimental Method

- Toluene
  - An SBR is soaked for in toluene for at least 24 hours.
  - The carbon filler is wetted with a small amount of toluene.
- Mortar and pestle
  - The SBR/toluene mixture is mashed with the pestle until a honey-like consistency is achieved.
  - The carbon/toluene mixture is then mixed into the SBR/toluene mixture.
- Mylar Sheet
  - The Mylar is not dissolved by the toluene.
  - The rubber/carbon composite is poured onto the sheet.
  - The composite is spread as thinly and evenly as possible.
  - The sheet is set to dry for a few hours.
- Measuring
  - A 1 cm x 5 cm portion is cut out.
  - Measured in resistance, thickness, and resistivity

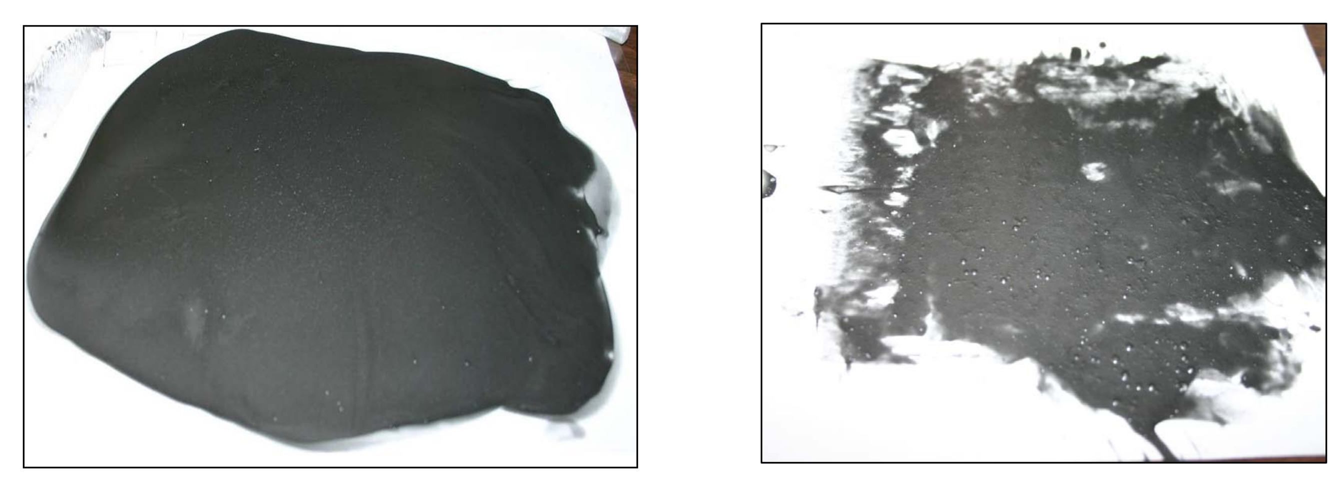


Fig. 6. On the left is a composite of Plioflex 1502 and graphene. On the right is Pliogum 1027 with graphene.

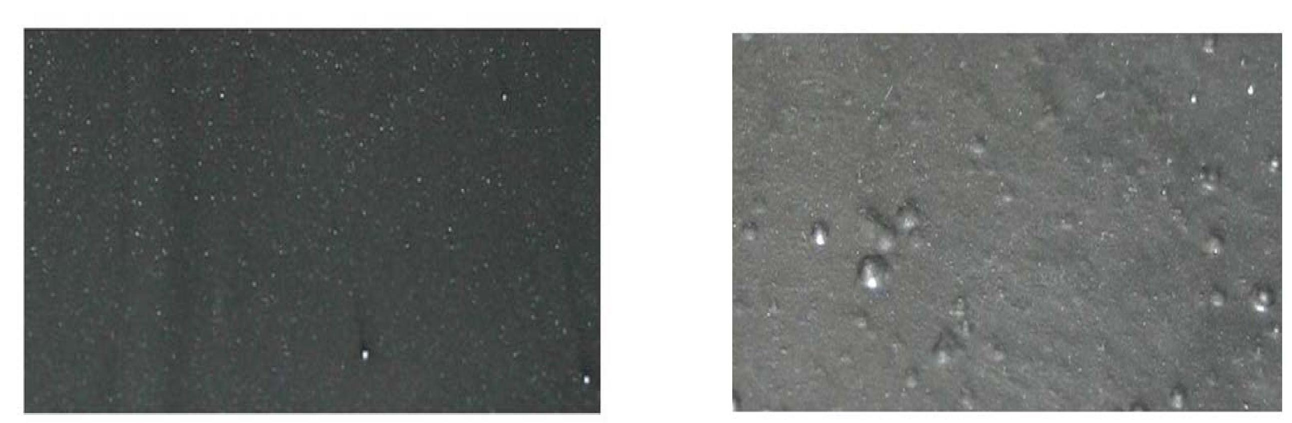
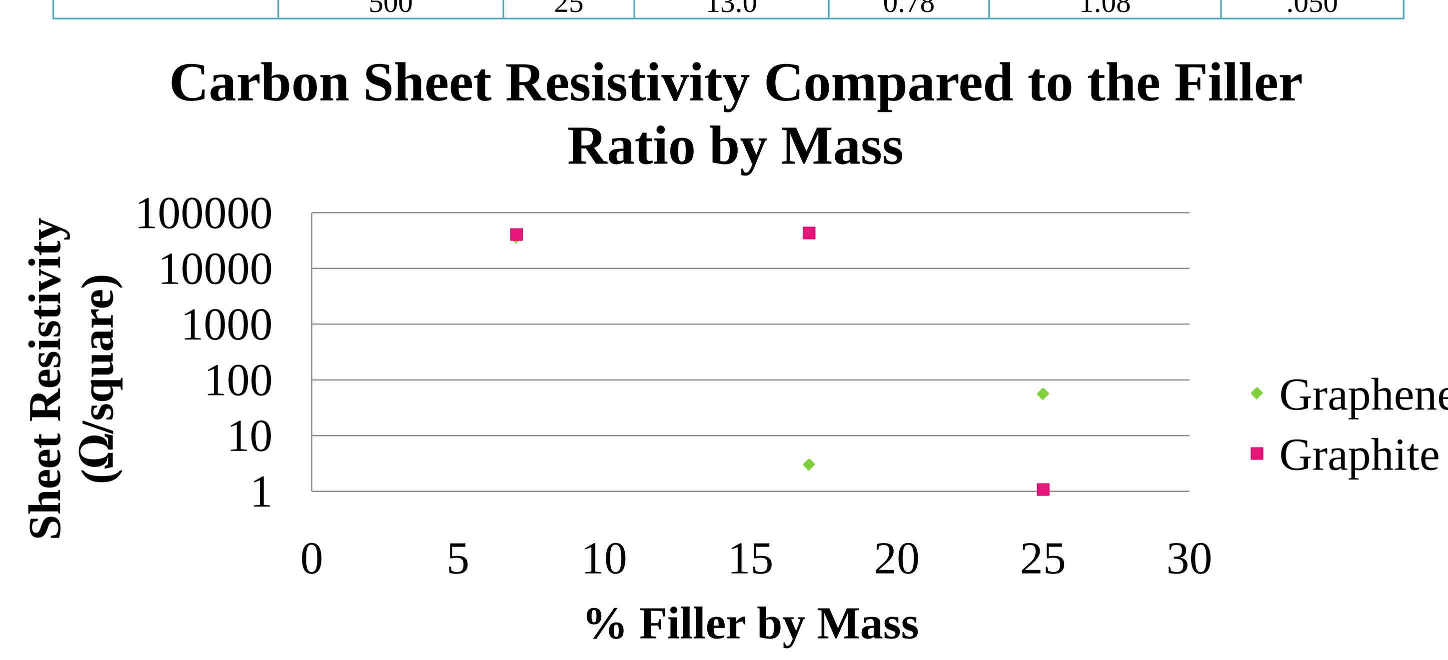


Fig. 7. A close up of both samples shows the composite on the right with more air bubbles and pieces of undissolved rubber.

Resistance and Sheet Resistivity

Carbon Type	Quantity (mg)	% Filler	Width (mm)	Resistance (kΩ)	Sheet Resistivity (Ω/square)	Thickness (mm)
Graphene	100	7	11.3	>30000	36000	.080
	300	17	11.4	2.5	3.0	.12
	500	25	12.3	43	56.0	.050
Graphite	100	7	12.8	>30000	41000	.040
	300	17	13.6	>30000	43000	.040
	500	25	13.0	0.78	1.08	.050



Results

- Time
  - The more time the rubber sits in toluene, the more it dissolves.
  - Ideal time: at least 24 hours
- Graphene versus graphite
  - Graphite is denser than graphene
  - When mixed with toluene and set for the same time, Graphite separated slightly faster.
- Rubber
  - Plioflex 1502 dissolved the fastest of the three rubbers used.
  - Pliogum 1028 was the least willing to spread on the Mylar sheet

Fig. 8. 150 mL beaker with 1.5 g of Plioflex 1502 in 40 mL of toluene.

Conclusion

Graphene has a higher aspect ratio than graphite and lower cost than carbon nanotubes, which is an appealing option as a conductive filler for rubber composites. Although graphite composites have a better conductivity at high filler concentrations, the graphene did not need as high of a filler ratio to reach a good conductivity. The Plioflex 1502 rubber gives the best consistency, with minimum bubbles and undissolved pieces of rubber.

Future Work

Next step is to experiment with silicone grease and dusted carbon as a type of compliant electrode for the DEAs. The silicone grease is commonly used but not well liked because of its messy application. It would be a good comparison of this viscous material to the solid electrodes studied here.

Also, research has started to emerge about the usage of carbon nanotubes. They have similar properties to that of graphene, but are in a cylindrical shape. Conducting tests and comparing them to the graphene and graphite would further help our understanding of these carbons.

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