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High Temperature Polymer Dielectric Material Development

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Motivation

Problem:

Our objective is to develop and engineer novel polymeric material systems for use as next generation polymer dielectric materials that can be used as a replacement technology for DC bus capacitors in hybrid electric vehicles (HEV) and fuel cell vehicles. The DC bus capacitors are currently the largest and the least reliable component of fuel cell and electric hybrid vehicle inverters. Capacitors represent up to 23% of both inverter weight and inverter cost.

Superior Polymer Dielectric Materials Needs:

- Soft Failure Mode
- Inexpensive
- High Dielectric Constant
- Dissipation Factor (<0.01)
- High Temperature Operation
- Low Weight
- Capable of Forming Thin Films (<5 um)

Current Status of Polymer Dielectrics

Two Types of Polymers:

Biaxial Stretched Polyethylene (AVX), Polyethylene teraphthalate, and Polypropylene

Similar dielectric properties (K = 2.2 to 2.5)

Operating temperature: 105°C (Prius, AVX); < 150°C

Polyphenylene Sulfide (PPS)

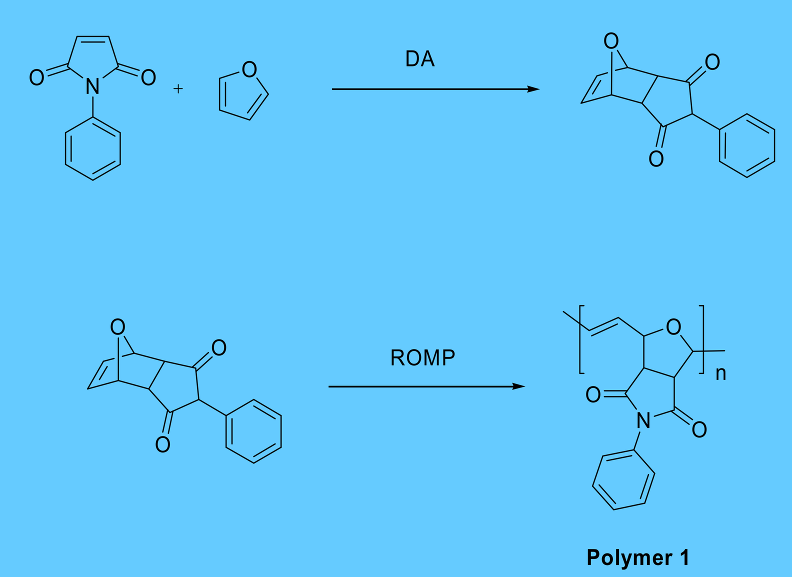
Best of all commercial polymer dielectric films that can operate at 150°C

Does not meet FreedomCAR volume requirements because of insufficient energy density

K = 3.1; 150°C operating temperature; ED = 0.55 J/cm3

Our Approach

Develop an inexpensive polymer with a very high dielectric constant and a low dissipation factor



Polymer 1

Polymer needs:

- Heteroatom content
- Aromatic character
- Degree of conjugation

Initial Polymer

Polymer Film Formation – Polymer 1

Polymers are solvent cast on to Al coated Silicon wafers for initial electrical characterization

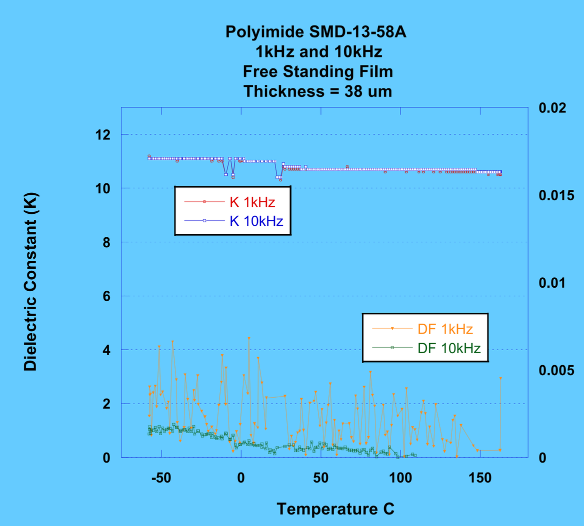
Polymer solutions are then cast from solution onto Mylar and removed to form a free standing polymer film before electrical evaluation

Both of the above techniques are not suitable for large scale polymer film formation which will be required in order to make capacitors.

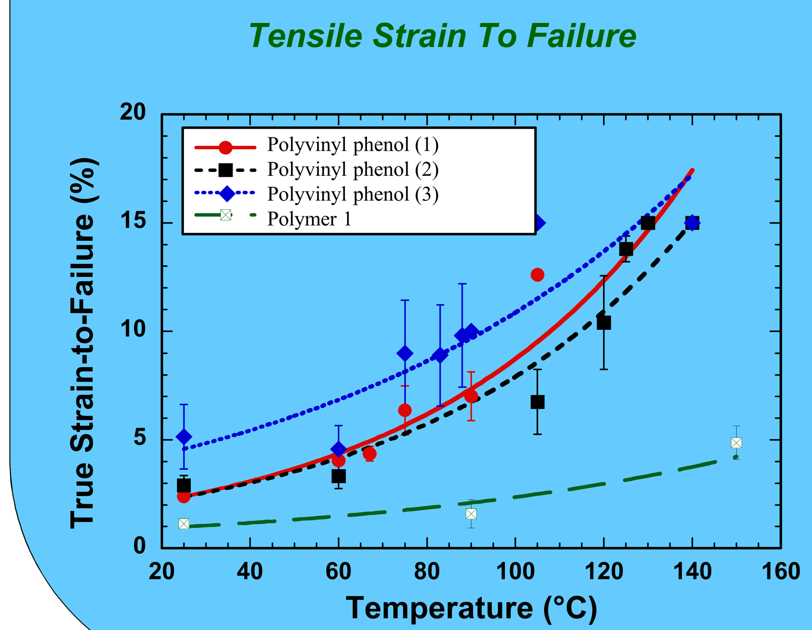
Electrical Characterization(Temperature)

Material was tested on the Al/Si substrate. The Au top contact was applied via evaporation

Tests of stand alone polymer films were difficult due to the brittle nature of **Polymer 1**



Mechanical Evaluation



Polymer 1 was tested using an Instron. The polymer is compared to polyvinyl phenol which was evaluated in the past as a low cost dielectric material

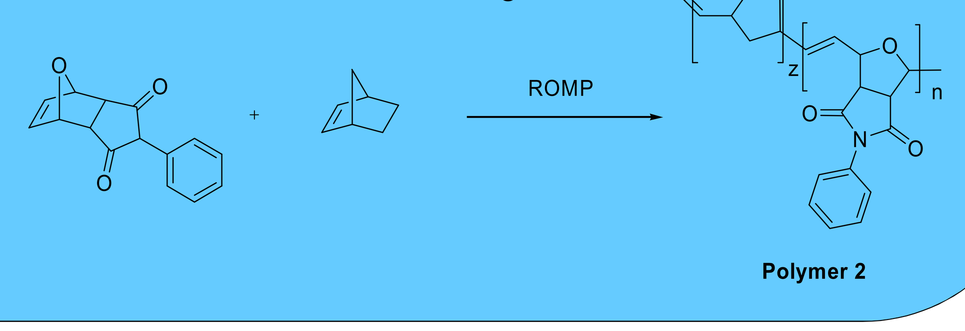
Polymer Modifications to Improve Properties

Two approaches have been taken to improve flexibility of polymer films

Add plasticizers

Examined several teraphthalates in varying weight percentages of 5-20%. The resulting films were still brittle

Copolymerization to lower T_g



Polymer 2

2nd Generation Polymer

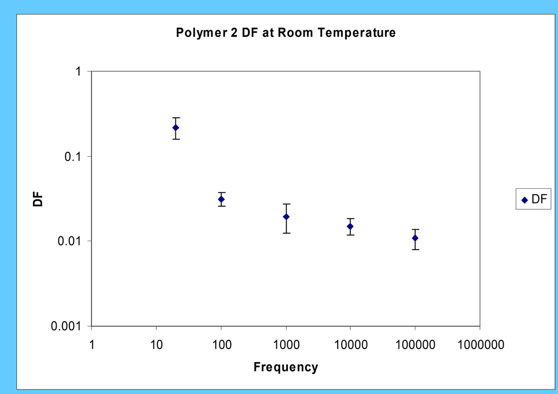
Polymer Film Formation – Polymer 2

Polymers films have been produced using a Gardco automatic drawdown machine

The film thickness is determined by with wire-wound metering rods

Films have been produced directly from the polymer synthesis solutions reducing polymer purification cost

Initial Electrical Characterization(Temperature)

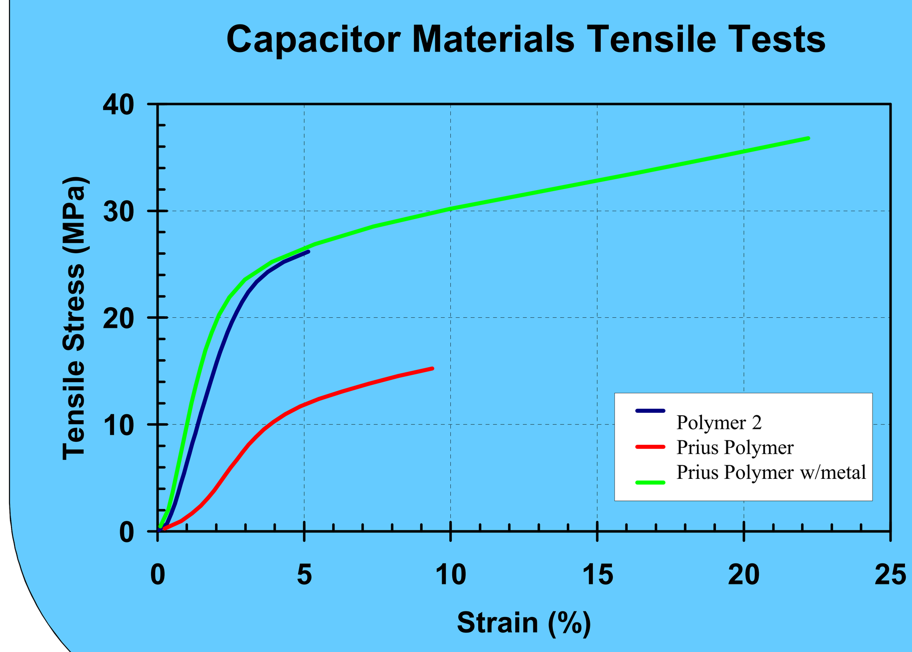


Room Temperature Measurement

Free standing polymer film evaluated after Au contact pads were evaporated

K = 5.13±0.48

Initial "Rough" Mechanical Evaluation



Tests were run in the TA DMA using the film grips with a loading rate of 3N/min. The samples were cut with edges that were not very parallel

Conclusions and Future Work

Developed a polymer system with very large dielectric constant and relatively low dissipation factor over a wide temperature range

The material properties of Polymer 2 are comparable to the Prius dielectric material

We are beginning to produce larger scale films for actual prototype capacitor fabrication

Putting in place NDAs with a major capacitor company and a chemical manufacturer to scale up the polymers and begin prototype capacitor fabrication

NNSA National Nuclear Security Administration

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