Sandia National Laboratories

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DC Breakdown of Glass Microballoon Filled Epoxy

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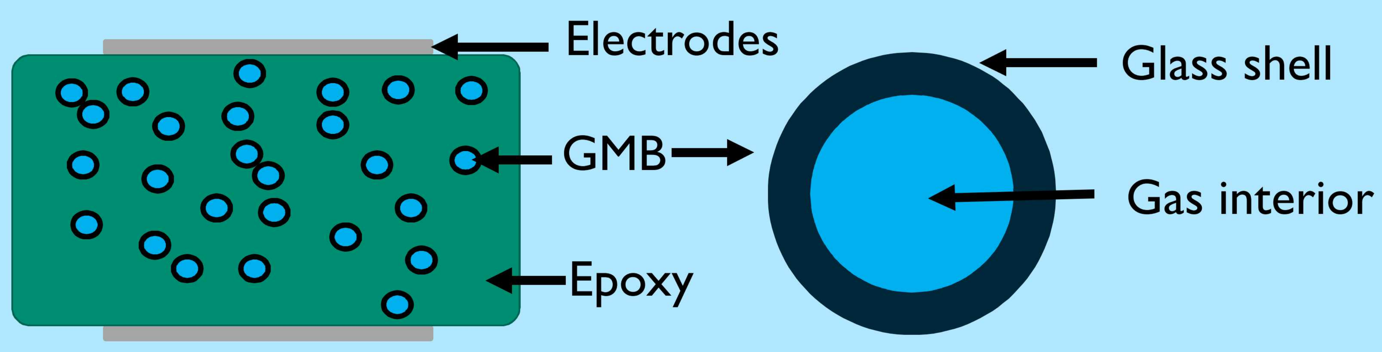
Background

Epoxies are used as high voltage insulation because they have high dielectric strength (17.5 MV/m) and long lifetimes. One way to increase the lifetime of epoxies is to add glass microballoons (GMBs), which increases thermal conduction to mitigate thermal breakdown. However, adding GMBs to epoxy results in localized field enhancements in the air inside of their glass shell. We hypothesize that the air in the GMBs will experience many partial discharges, but the glass shell will protect the surrounding epoxy from damage. We also hypothesize that there is an optimal fill fraction of GMBs to balance the need for better conduction without sacrificing electrical strength.

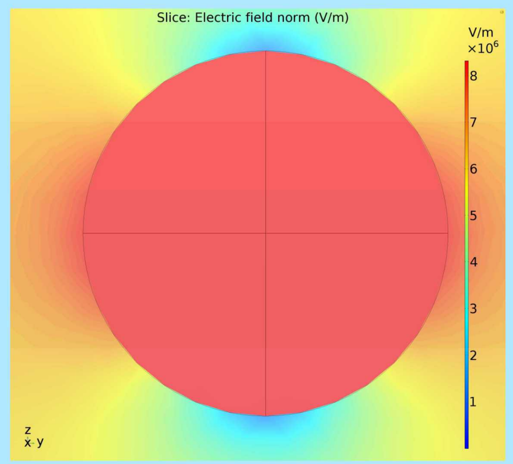
Research Questions

1. How does the performance of GMB filled epoxy compare to neat epoxy?
2. What is the optimal fill fraction of GMBs to epoxy to improve electrical strength?
3. How does a multilayer filler effect the electrical field and breakdown of the encapsulate?

Voids and GMBs cause electrical field enhancements

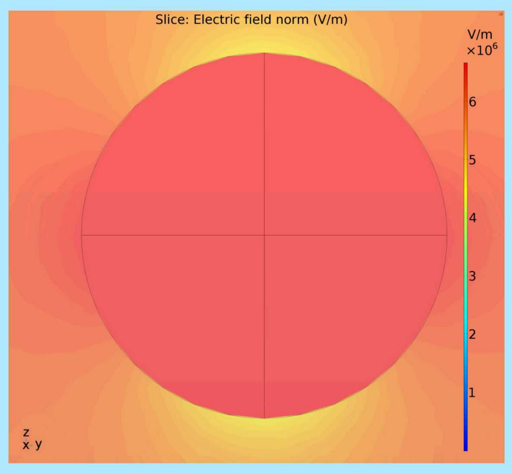


The voids impact the electric field in two ways; by concentrating the field within the void, and distorting the field around the void. The impact of the gas void is greater than the glass. We can see a compound effect on the GMB, one part from the epoxy and one from the shell.



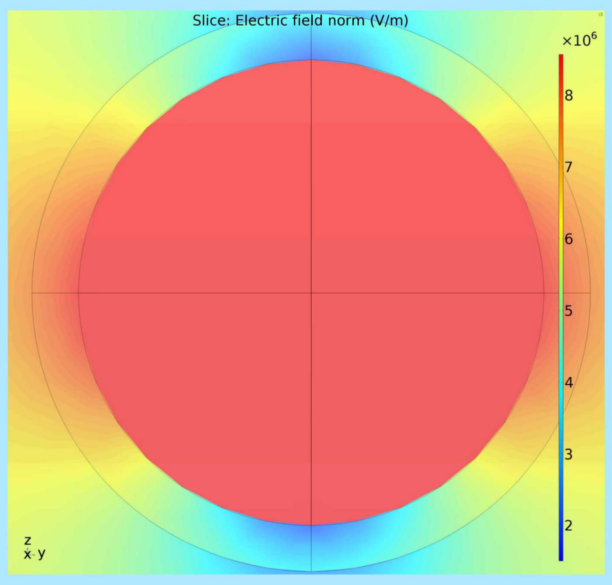
Gas single void

- Electric field in void: 8.28 MV/m
- Enhancement: 37.8 %



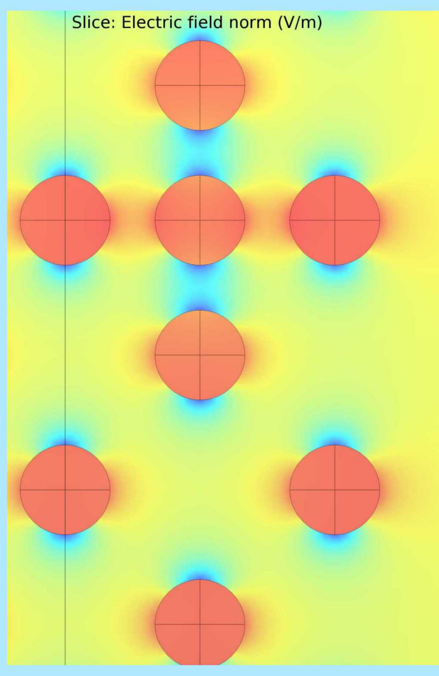
Glass single void

- Electric field in void: 6.66 MV/m
- Enhancement: 11 %



GMB

- Electric field in void: 8.57 MV/m
- Enhancement: 42.8 %
- Electric field enhancement in glass shell is not uniform



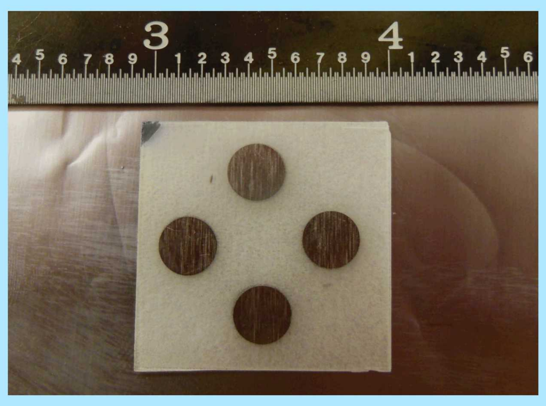
Array of gas voids

- The electric field of an individual void matches the case of a single void
- When close to another void the electric field is no longer uniform

Polymer samples and setup

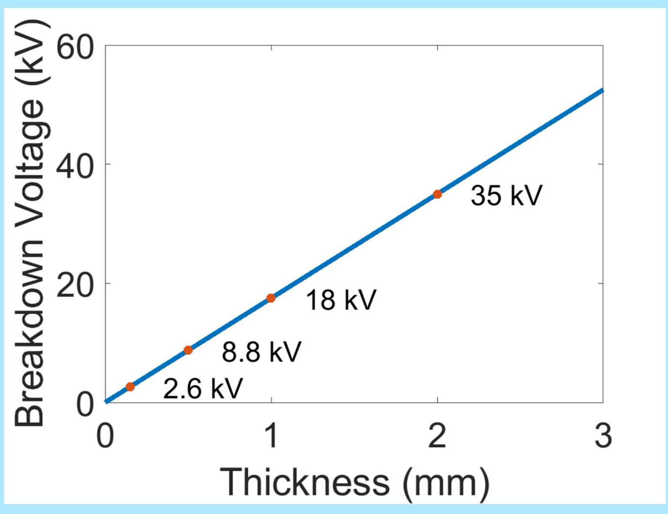
Making samples

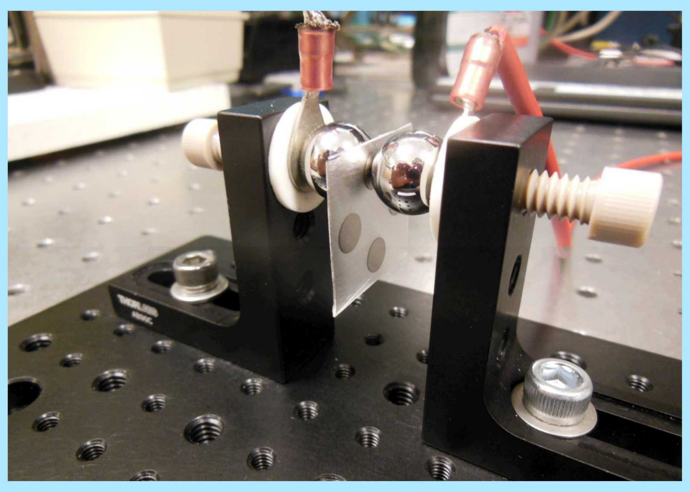
- Mix Epon 828 resin and Diethanolamine with different amounts of GMB filler to achieve different fill fractions
- Pour into molds
- Heat cure for 24 hours
- Sputter on platinum electrodes

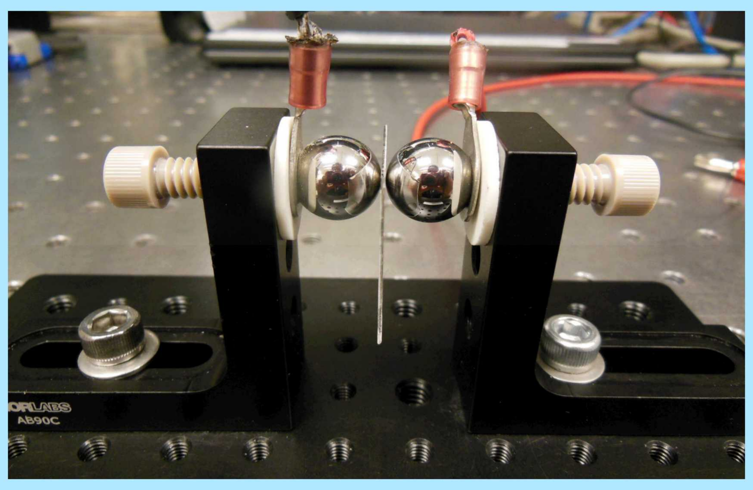


0.5 mm thickness

Expected Breakdown Field of Epoxy = 17.5 MV/m



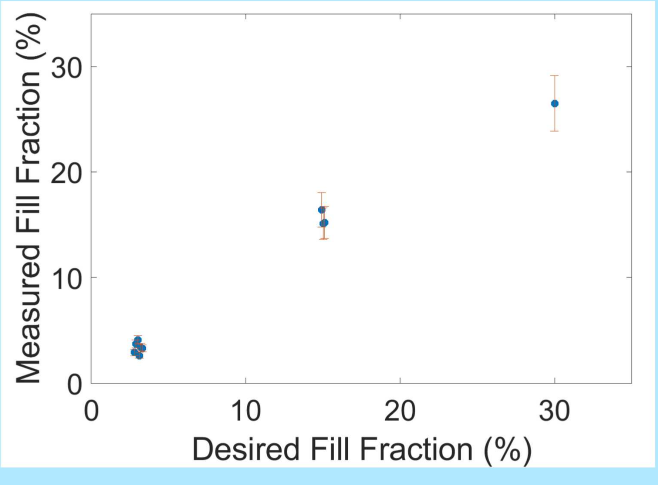


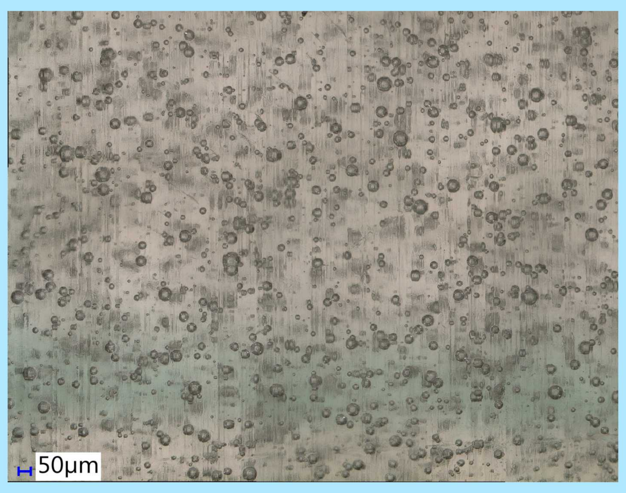


Setup is designed to allow easy adjustability and transfer of samples, with insulating washers and screws to isolate the setup from the electrodes

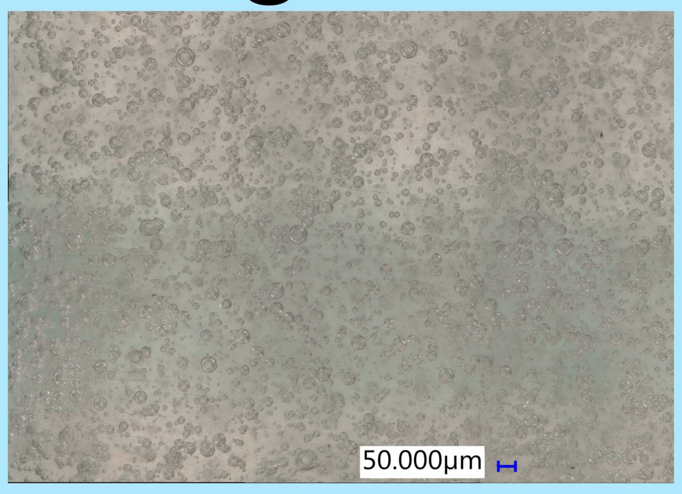
Measurements of fill fraction and thickness show target values achieved

- Samples are measured to be within 1 % of desired thickness
- There are a range of fill fractions
- Microscopic images show the distribution of GMB's are not uniform

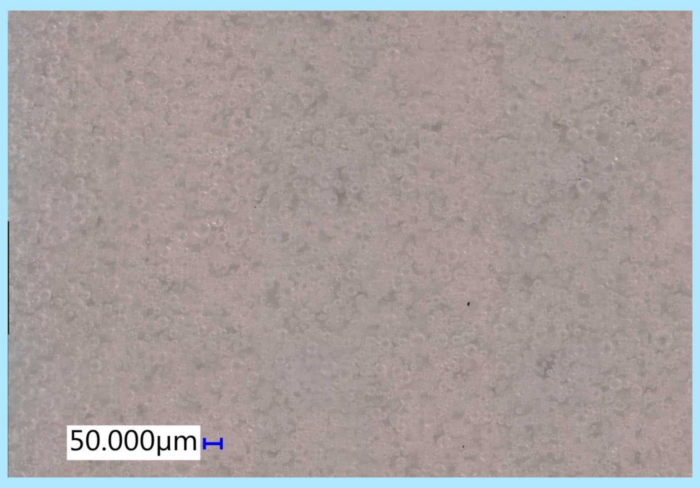




3% GMB fill by volume



15% GMB fill by volume



30% GMB fill by volume

Conclusion

- While the effect of GMB on electrical breakdown is not yet known, COMSOL modelling shows localized field enhancements susceptible to partial discharges
  - This enhancement is greater when voids are closer
- The fabrication methods used in our lab have produced samples with customized geometry and fill fractions, allowing for repeatable tests on nearly identical samples

Next steps

Impedance analysis of samples before and after electrical testing to determine material changes

Electrical Breakdown Testing

- Rapid rise – 500 V/s voltage ramp to achieve breakdown in 10 - 20 seconds
- Short term – increment voltage in 500 V/60 s steps to determine inception voltage
- Degradation tests – hour long tests at constant voltage (higher than inception voltage to cause partial discharges to occur)

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