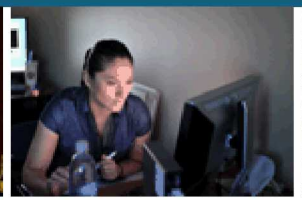
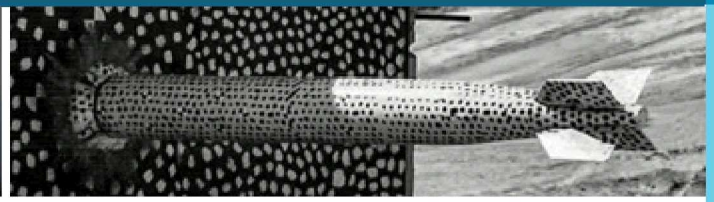
SAND2018-11436C

# Gel Capacitor Edge Margin Reduction Using Robust Dielectric Materials





*PRESENTED BY*

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ACKNOWLEDGMENTS

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# Acknowledgments

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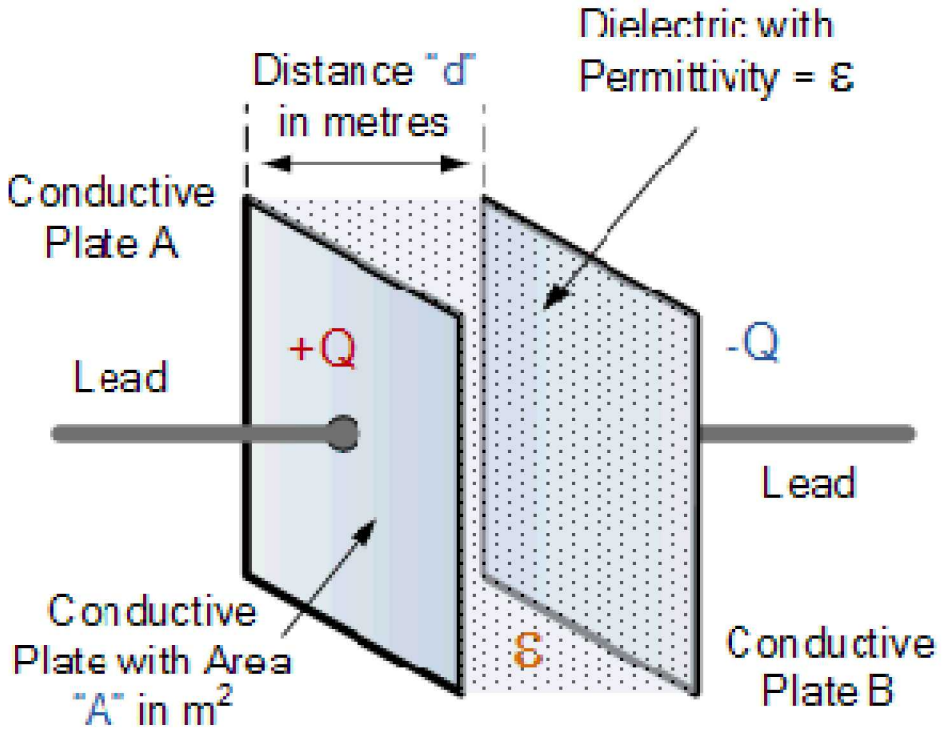
# Overview

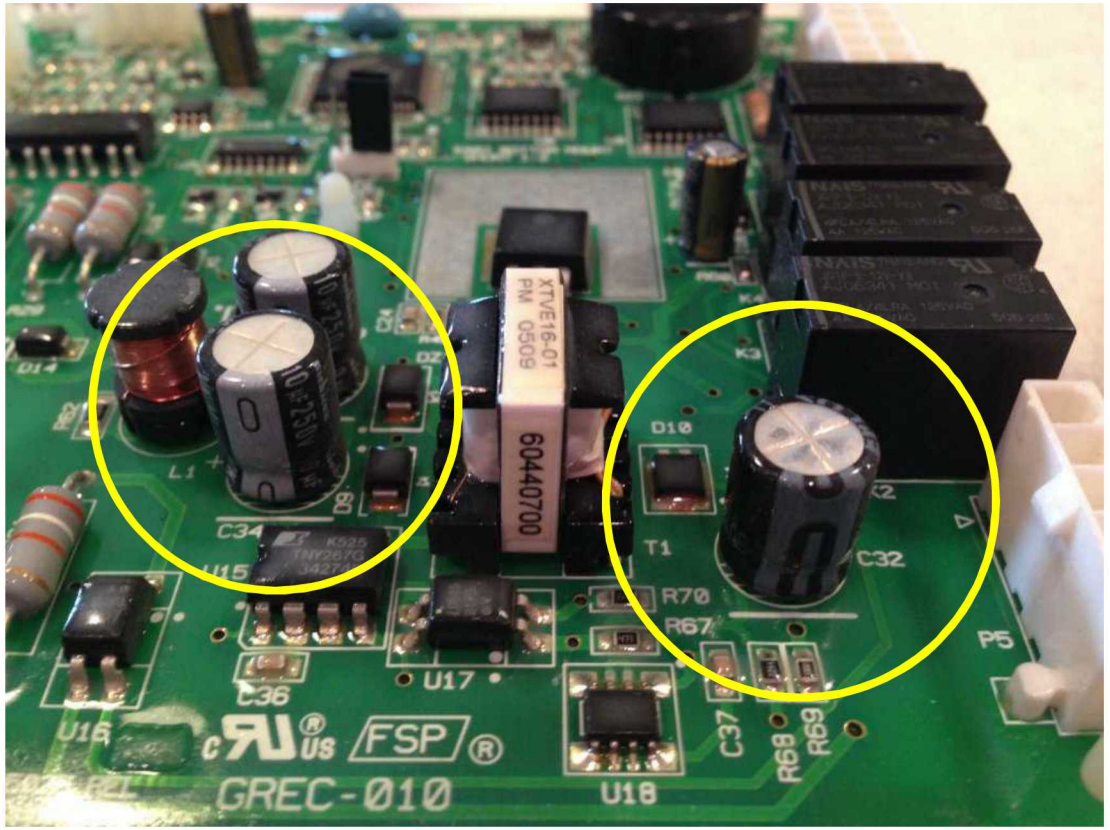
- Introduction to Capacitors
- Gel Capacitors
- Motivation
- Goals
- Material selection
- Fabrication Methods
  - Mayer Rod Coating
  - Lamination
- Results
- Future work

# Brief Introduction to Capacitors

- Capacitors contain an insulating dielectric between oppositely charged conductive plates
- Energy stored in electric field can be quickly discharged (ex. Camera Flash)
- Commonly produced as rolled capacitors




https://www.electronics-tutorials.ws/capacitor/cap_1.html

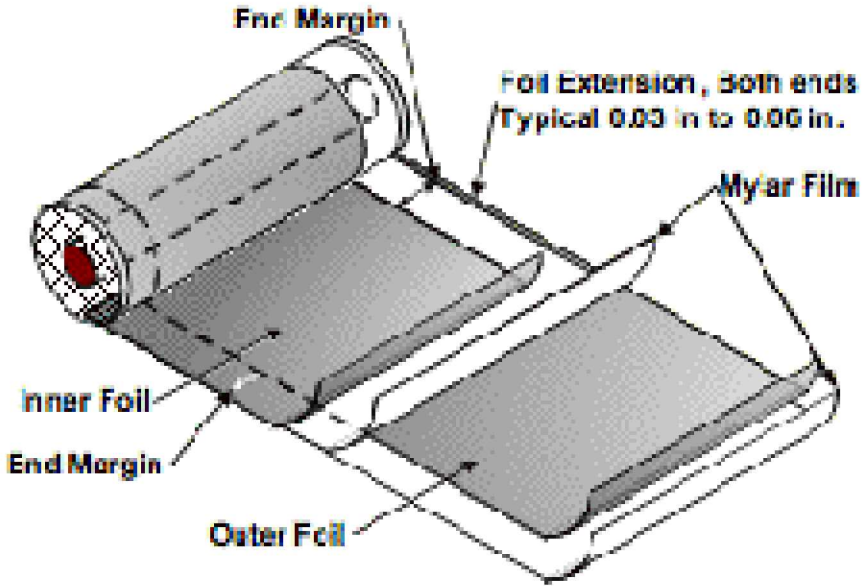


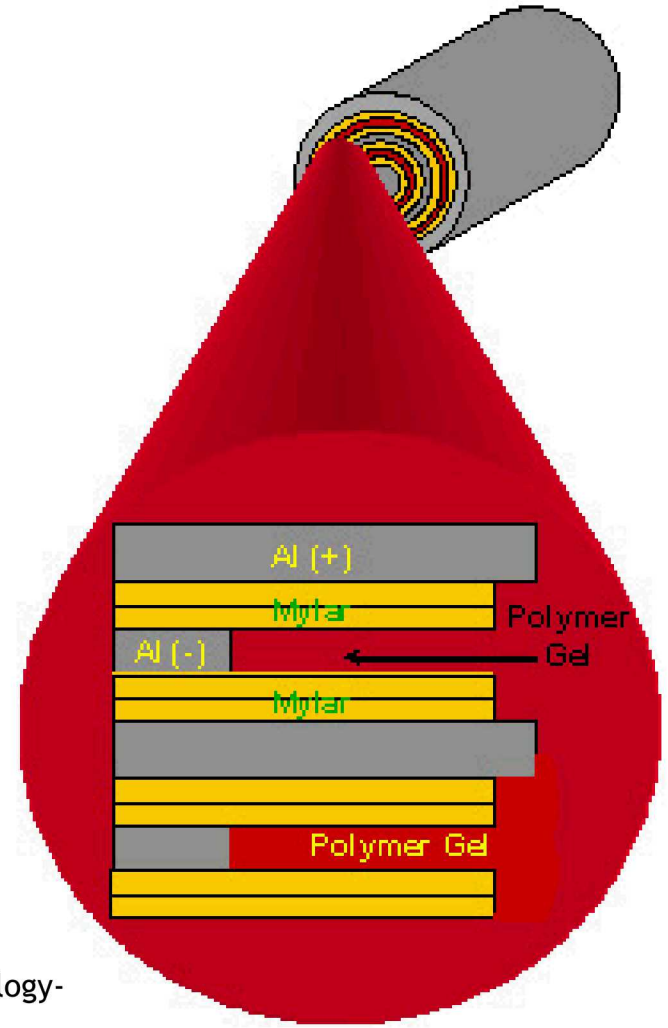

https://www.stevejenkins.com/blog/2014/03/how-to-fix-a-whirlpool-kitchenaid-w10219463-2307028-control-board-for-6/

# Gel Capacitors

The current gel capacitor design incorporates wound Mylar or doped Mylar that is impregnated with a gel dielectric and rolled. This design offers:

- High voltage and high current (fast discharge)
- Small weight
- Low physical volume
- System weak link(Mylar)



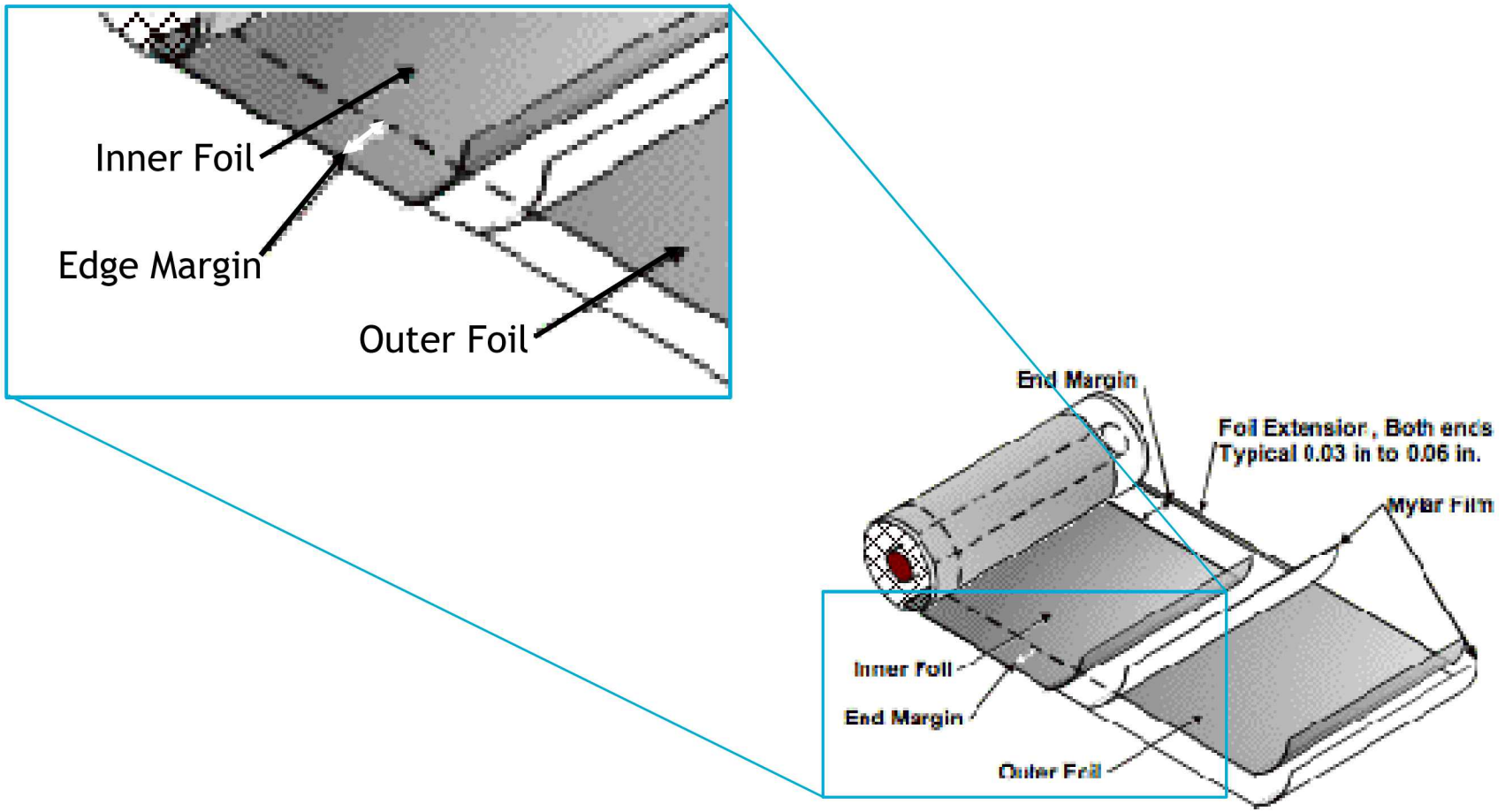




https://info.sandia.gov/capacitors/html/Technologies/technology-gelMylarCap.htm

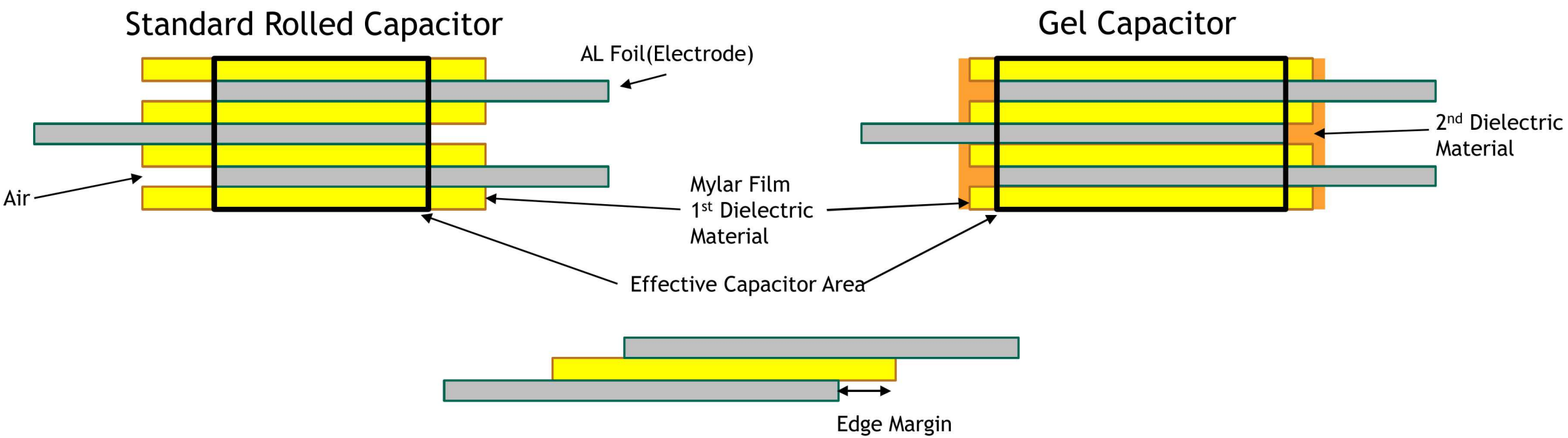
# Motivation

The edge margin prevents discharge around the Mylar through the air. Reducing the edge margin will:

- Reduce manufacturing cost
- Reduce weight
- Decrease size
- Increase reliability



# Edge Margin




Edge margin is the gap between one foil and the end of another foil

- Reduction in edge margin requires strong dielectric
- Strong dielectrics resist breakdown at higher voltages

For example:

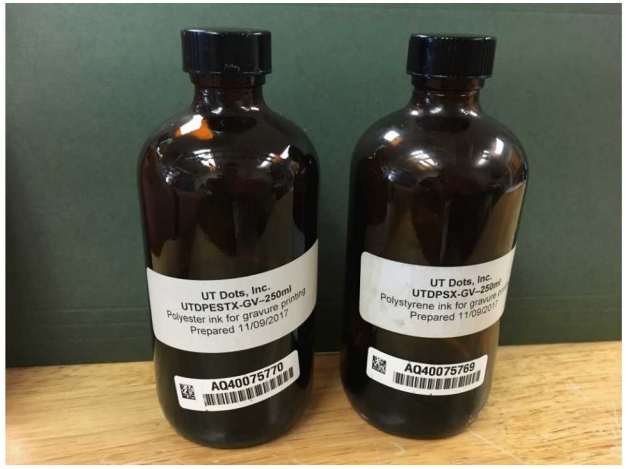
- To support 30kV requires 10mm spacing of air
- To support 30kV with polystyrene 1mm spacing is required

# Dielectric Material Selection

**Started with a list of over 25 dielectric materials, down-selected to 2 based off properties**

- Dielectric strength
- Dielectric constant
- Solution processability
- Price

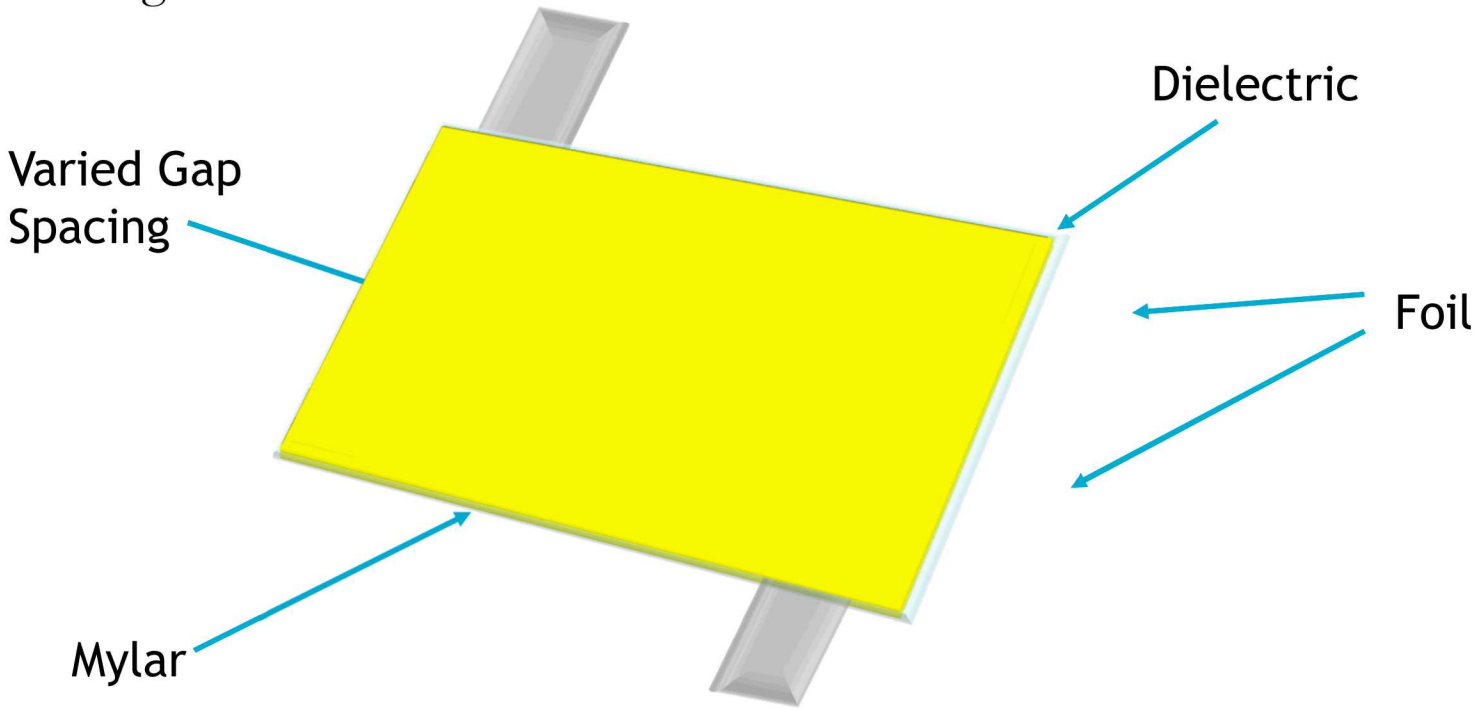
| | Polyester | Polystyrene |
|---|---|---|
| Viscosity (cPs) | 421 | 551 |
| Dielectric Strength (kV/mm) | 275 | 30 |
| Dielectric Constant | 3.2 | 2.56 |



# Planar Capacitor Design

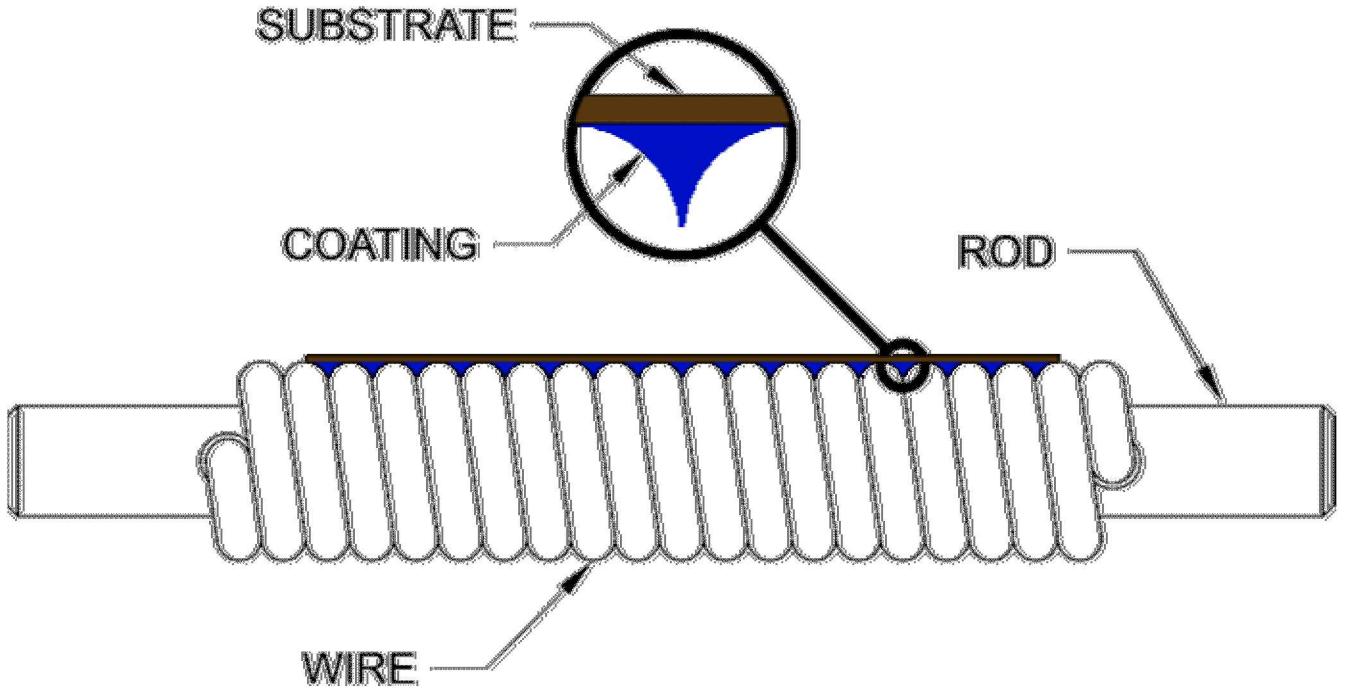
Production of rolled capacitors not practical, so a simplified version was conceived to test breakdown strength of dielectric materials. This consisted of

- Mylar bottom layer
- Foils with varied spacing of 1-5mm
- Dielectric material coating
- Mylar top layer



# RK Mayer Rod Coater

Mayer rod or metering rod coating uses a solid metal bar wound with wire. The gage of wire determines the thickness of film. The bar is pulled across the substrate leaving a uniform film with predictable thickness.

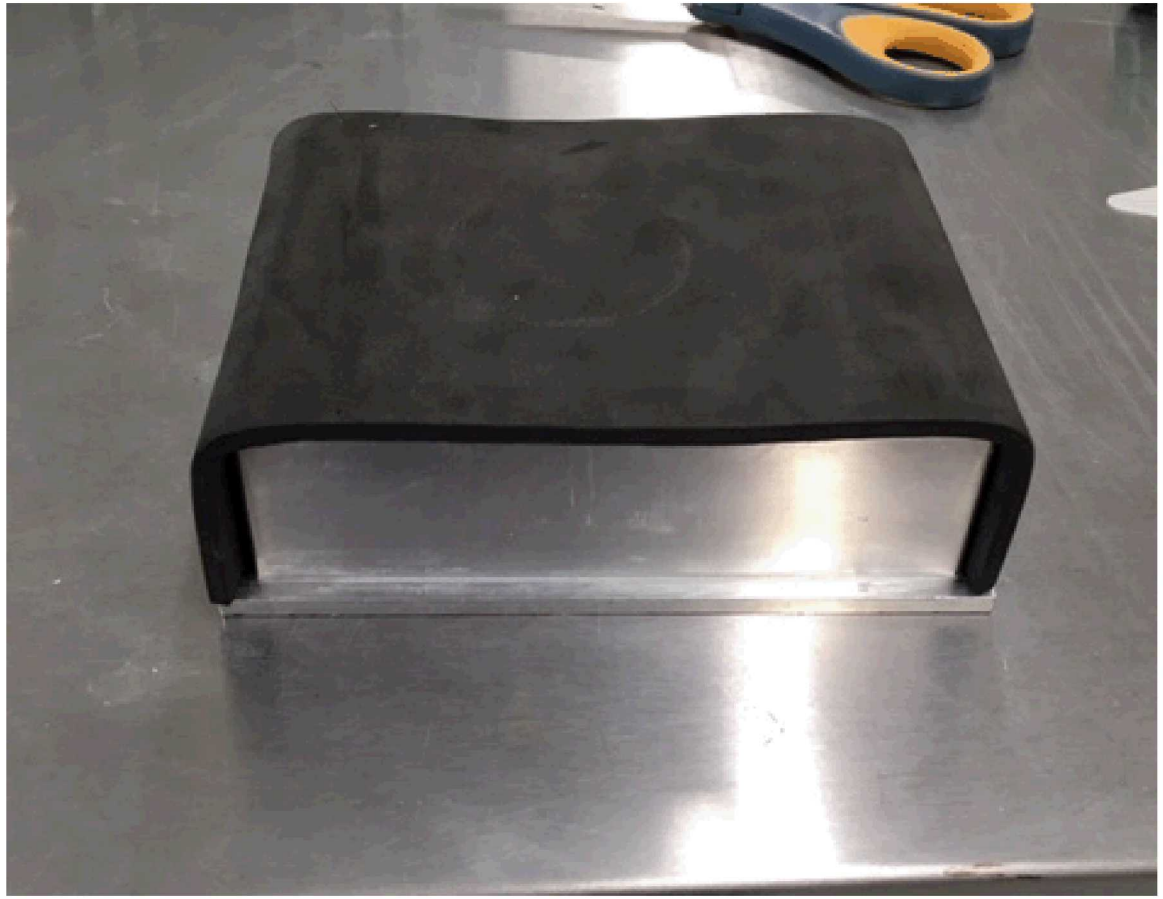




https://buschman.com/what-is-a-metering-rod-how-a-small-part-plays-a-big-role/

# Mayer Rod Coater process

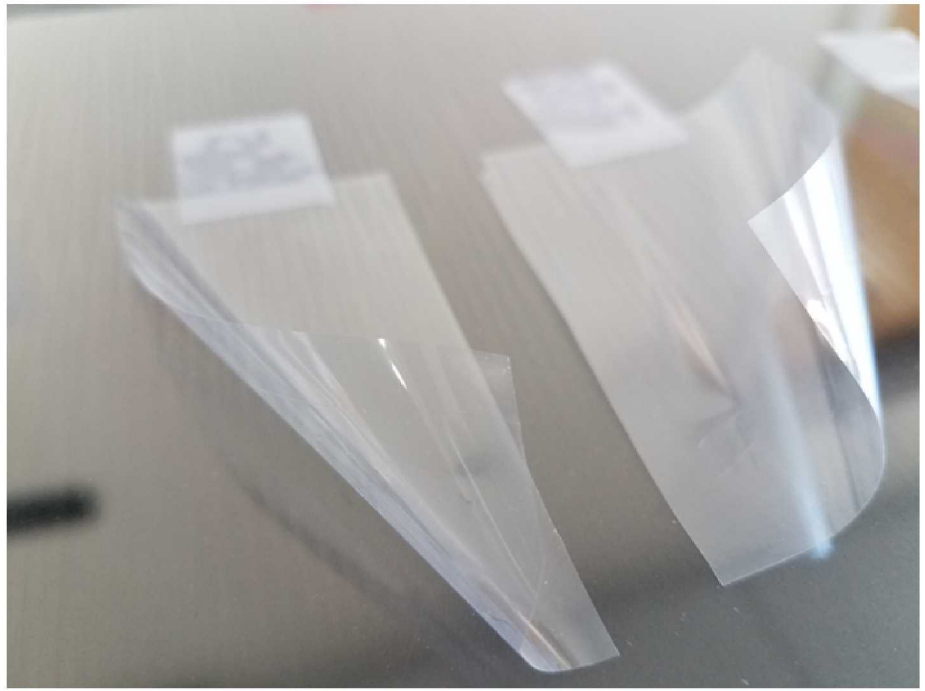
The RK coater gave predictable film thickness, however during use it was found that the film thickness was independent of speed and pressure which allowed for the process to be simplified.

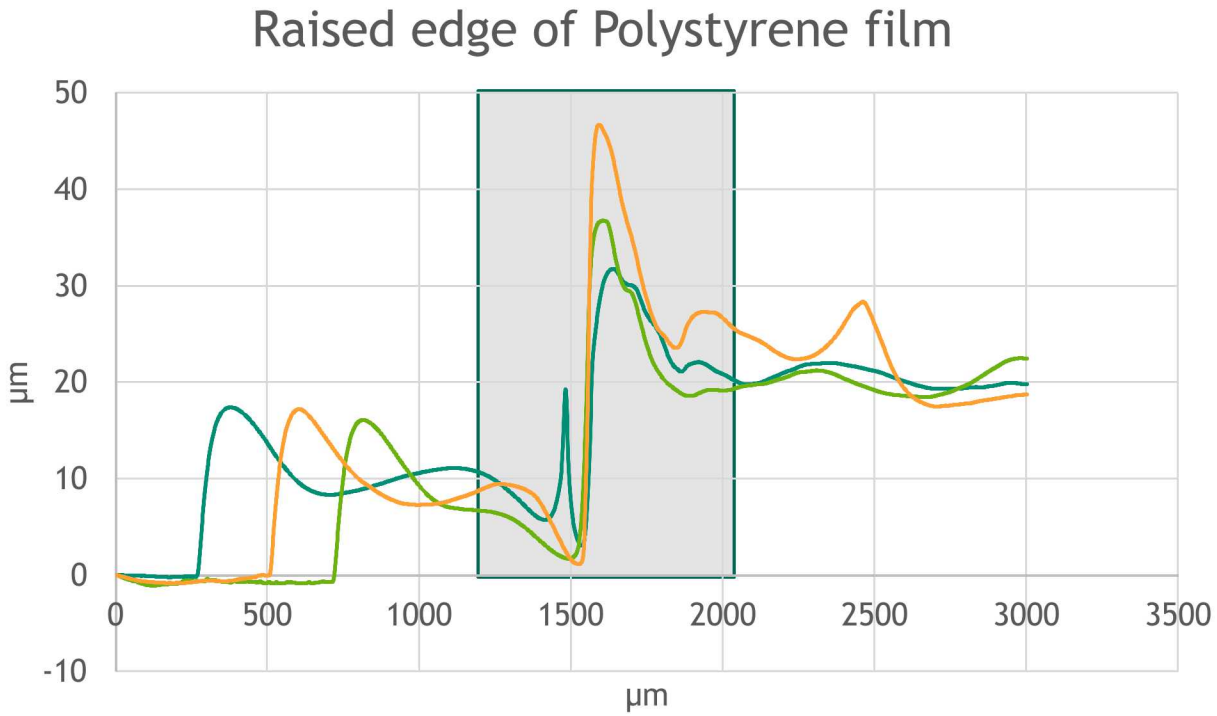
- The RK coater was replaced with an aluminum block and foam
- The same rods were used
- Results were identical with this process



# Challenges with RK coater

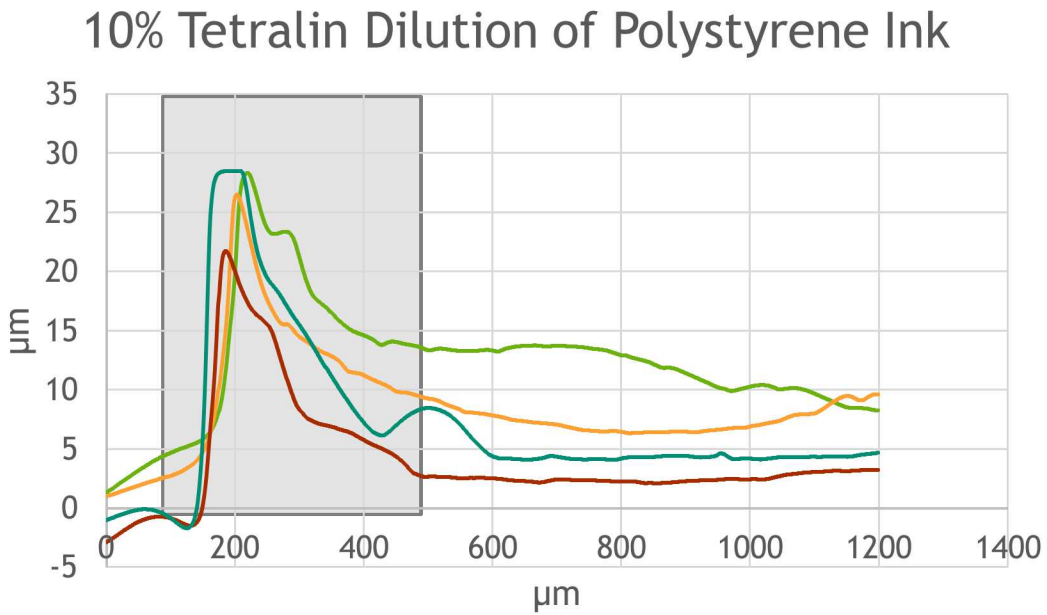
- Volume reduction caused curling of Mylar while drying
  - Resolved using an adhesive substrate below Mylar to hold flat
- Drying effects leave raised edge of film as seen by profilometry
- Efforts to address this were made by diluting the dielectric materials(PS)

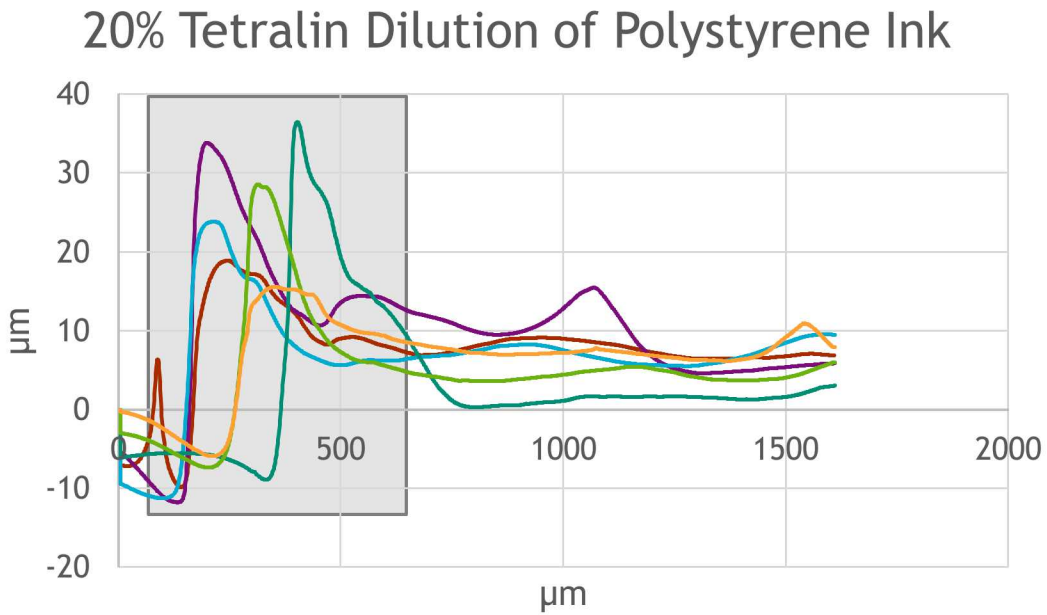




# Efforts to address raised edge

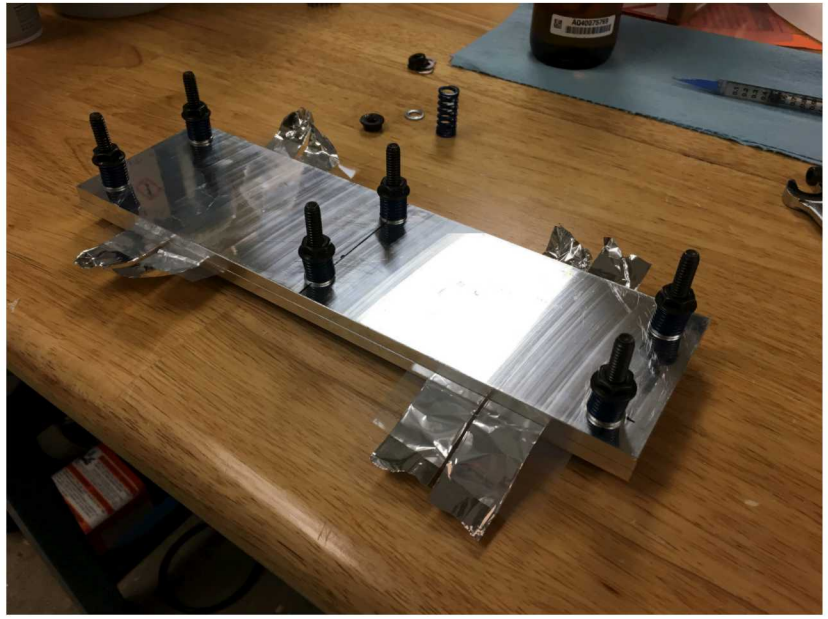
- Attempted to control drying effects by adding high-boiling co-solvent Tetralin
- Despite slower drying, raised edges still occurred
- Explored alternative techniques to Mayer rod coating due to the raised edge: Lamination



# Lamination

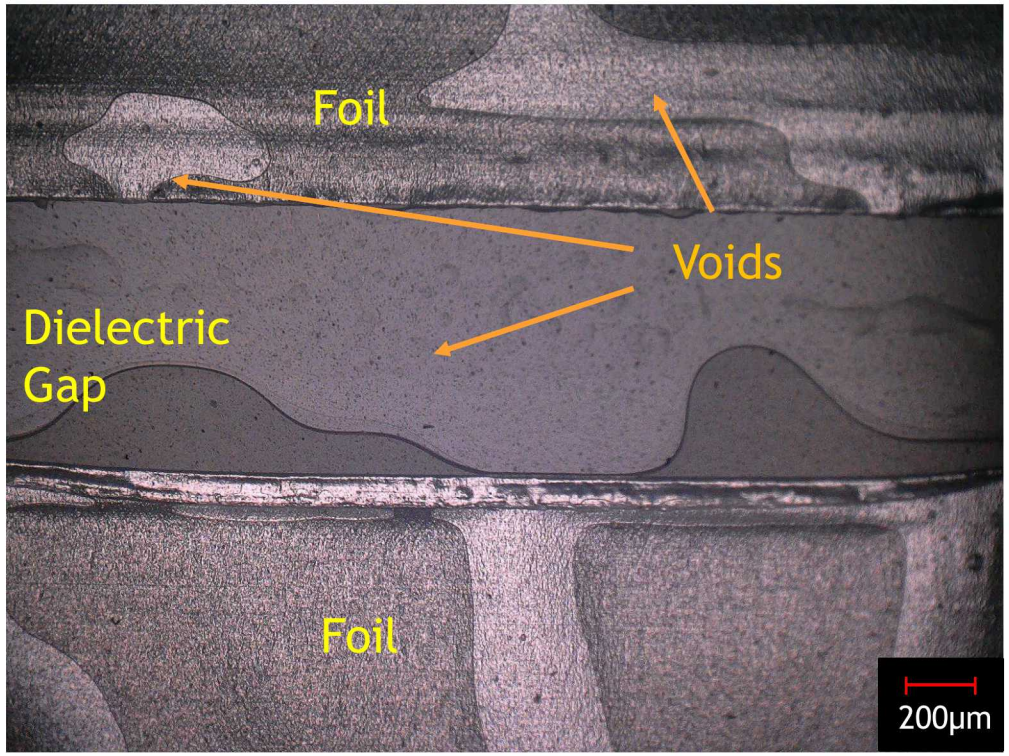
- Previous attempts left voids in the film, the lamination process would use the thermoplastic properties of the inks to alleviate voids.
- The planar capacitor was formed in stages
  1. Dielectric material applied to Mylar using a pipette (~20ml)
     - Air dry/ oven dried with top Mylar off
  2. Top Mylar layer applied and compressed using aluminum plates (total of 55lbF)
  3. The entire assembly was then dried in vacuum oven

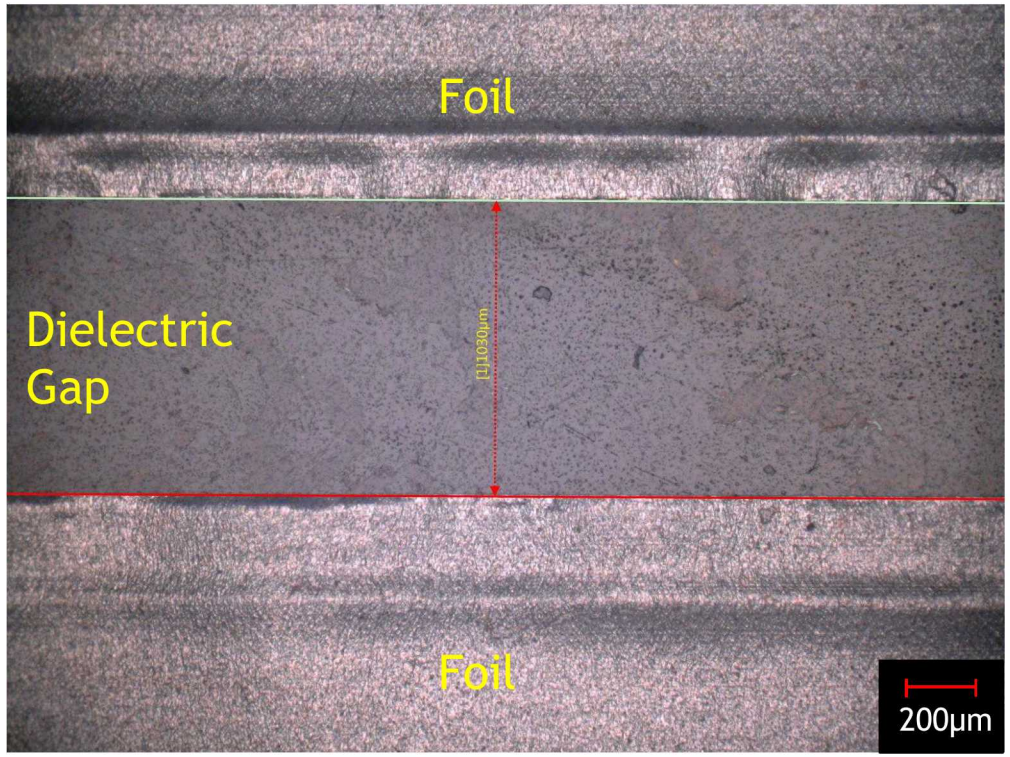


- Variables
  - Time (1-16 hours)
  - Temperature (90-140°C)
  - Compressive force (5.5-55lbF)
  - Vacuum (50-83kPa)

# Lamination Process Results

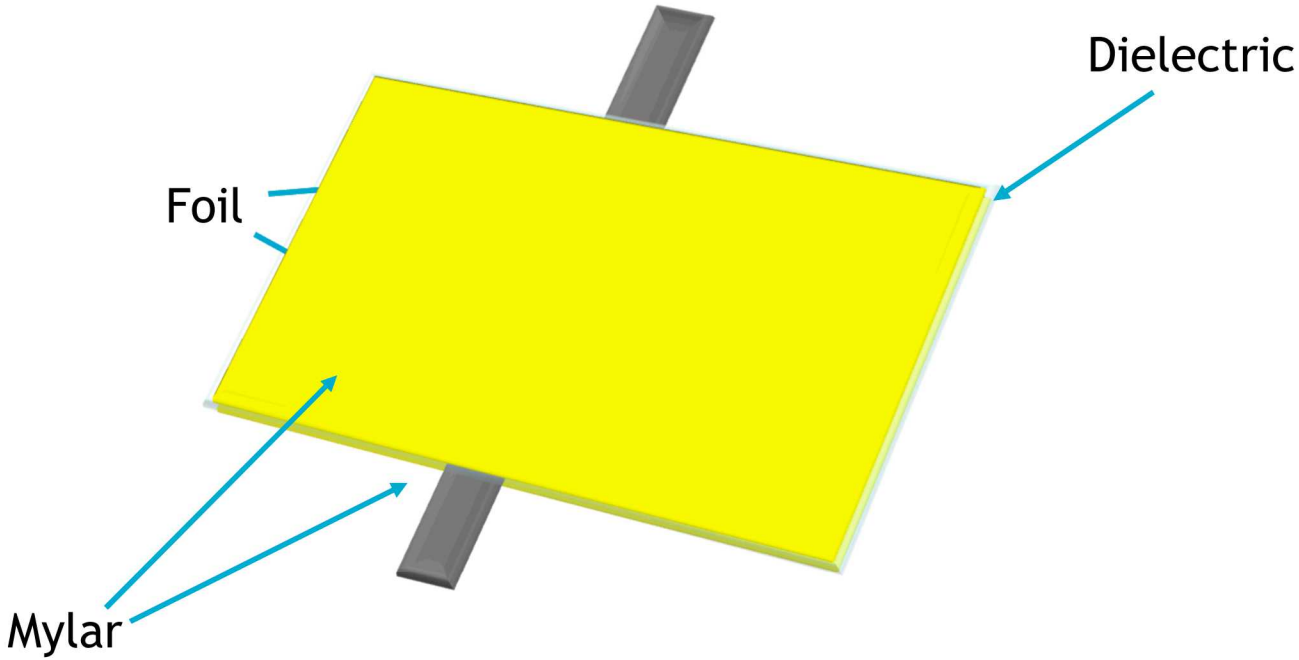
- Lamination was successful in achieving uniform film with no voids
- The samples were tested with a ramp up voltage up to 20kV
- The initial design failed due to high field concentrations at corners.



# Redesign

- Rounded corners to reduce high field concentrations
- Separation of probe foils reduce possibility of arcing
- Decrease size to 1 inch
- Polystyrene samples produced positive results with no breakdown at 20kV



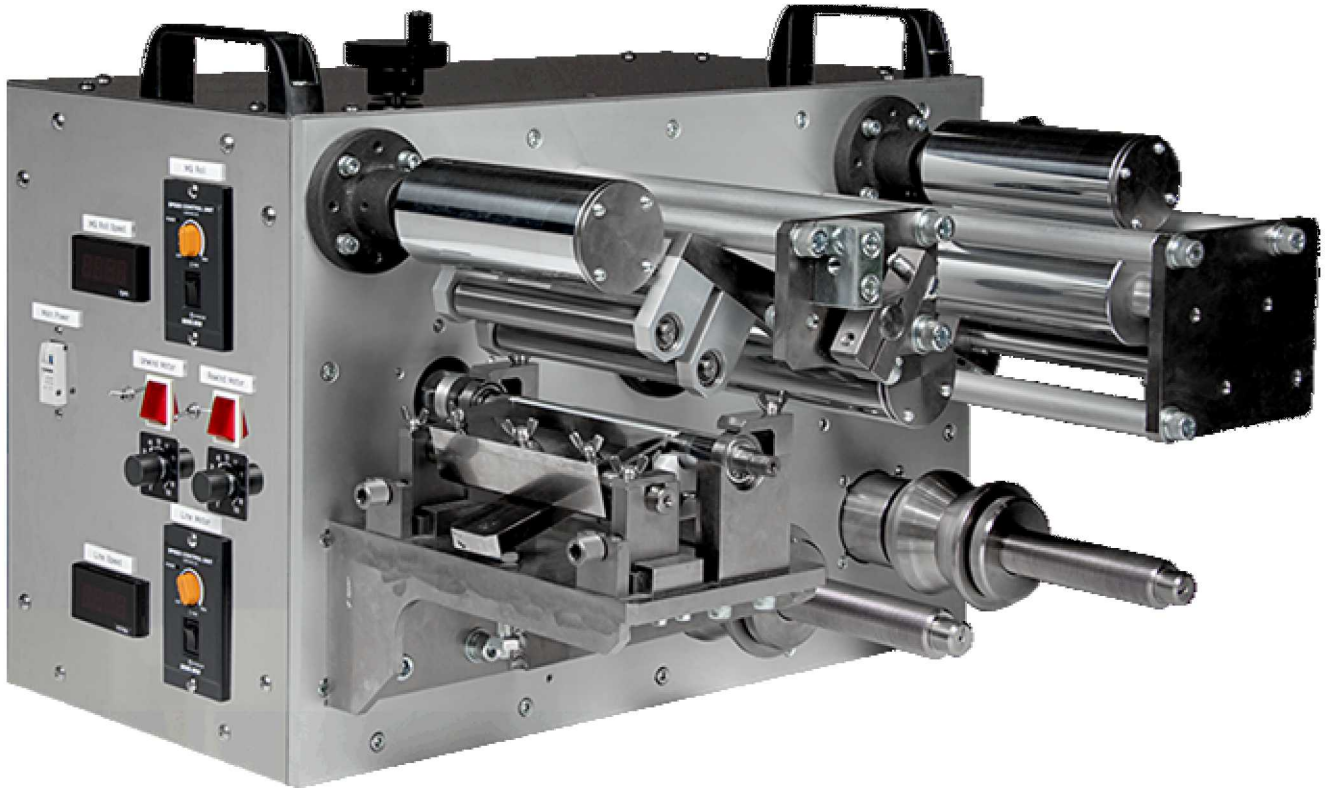
# Results

- Voltage Ramp Rate: 250V/s
- Temperature: Ambient
- Max Voltage: 20kV

| Serial Number | Dielectric Material | Gap Spacing (mm) | Breakdown Voltage (kV) |
|---|---|---|---|
| 2 | Polystyrene | 1.189 | 20 |
| 4 | Polystyrene | 1.722 | 20 |
| 10 | Polystyrene | 3.418 | 20 |
| 11 | Polystyrene | 4.114 | 20 |
| 12 | Polystyrene | 4.695 | 20 |
| 13 | Polyester | 1.534 | 20 |
| 14 | Polyester | 0.4 | 17.82 |
| 15 | Polyester | 1.819 | 20 |
| 18 | Polyester | 1.58 | 19.57 |
| 19 | Polyester | 1.662 | 20 |

# Future Work(Reel to Reel)

- Planar test structures indicate edge margin reduction to 0.7-4mm possible
- Future work will scale up process using reel-to-reel system for rolled capacitors
  - Microgravure coater for application of dielectric ink
  - Custom built laminator to assemble capacitors



# Summary

- Constructed planar capacitors with varied gap spacing to replicate edge margin
- Tested two different dielectric materials within the replicated edge margin
- Successfully demonstrated Polyester and Polystyrene as dielectric materials will reduce the edge margin
- Future work will use a Reel-to-Reel machine to produce rolled capacitors with Polyester and Polystyrene

Questions??