The Influence of Inter-layer Pressure on Performance of High Energy Density Metallized Film Capacitor

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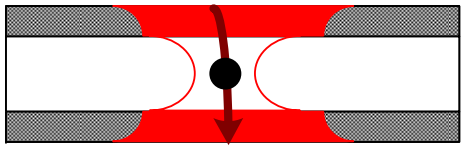
Outline

- Introduction
- Capacitance Loss Law
- Pressure Effect Experiment
- Calculation
- Conclusions

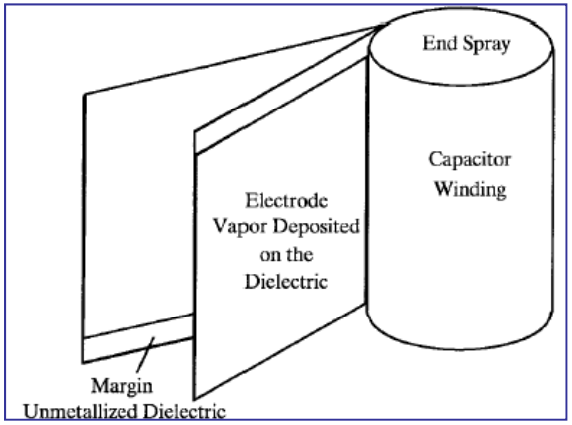
Introduction

- **Metallized capacitor**
  - **prevent capacitor failure due to local breakdown;**
  - **increase capacitor lifetime and reliability;**
  - **increase volume efficiency.**

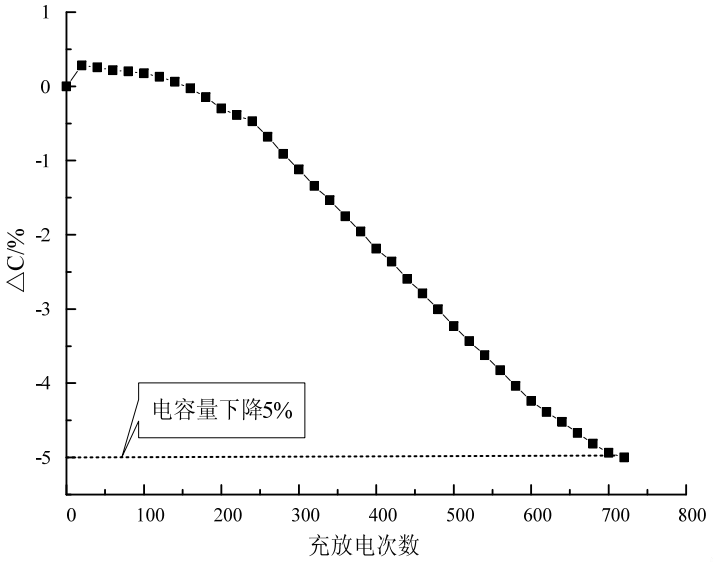


Metallized electrode
Dielectric film

Self Healing



Metallized capacitor construction



Microscope view of self-healing spot

Clearing energy

$$W_{sh} \propto C t_c^{\,a} U_n^{\,b}$$

a: 1~2
b: 2~5

- Small energy self-healing process needed
  - ✓Reduce capacitance
  - ✓Increase surface resistance of electrode
  - ✓Inter-layer pressure

Focused on :Dry type, PP film

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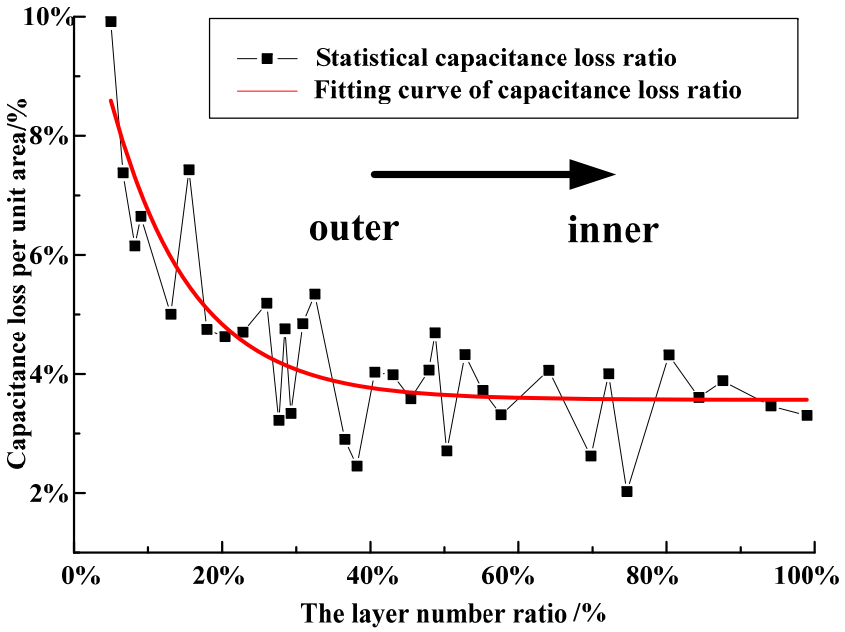
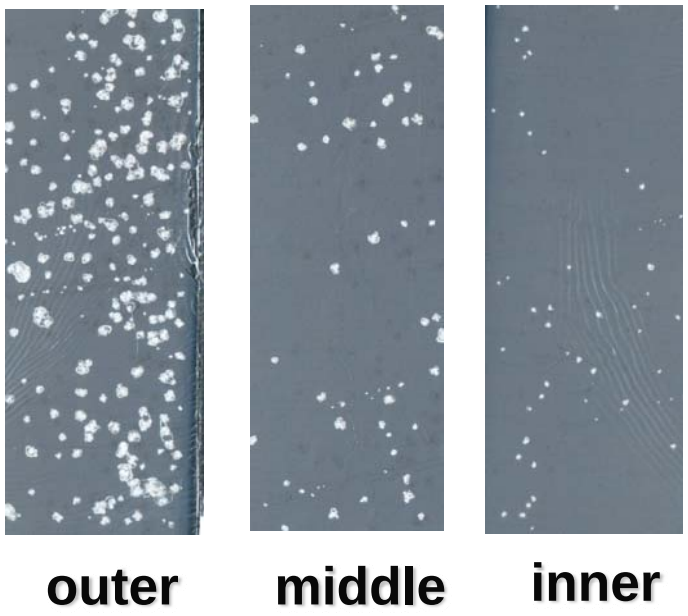
Capacitance Loss Law





Statistical capacitance loss ratio from the outer to inner layers

The elastic films add compressive radial force to every wound wrap, which made the inner layers have larger inter-layer pressure. The teardown analysis has shown that the capacitance loss decreased gradually from the outer layers to the inner layers.

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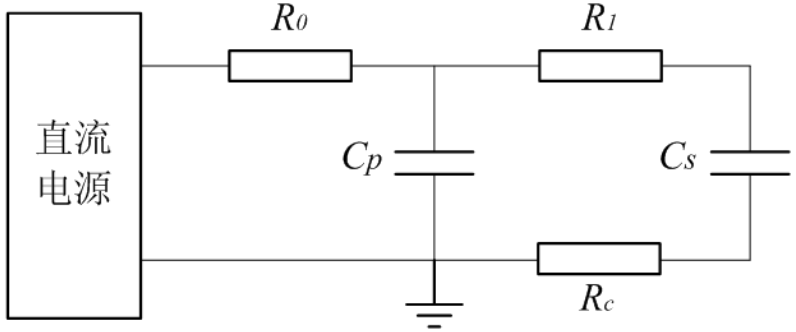
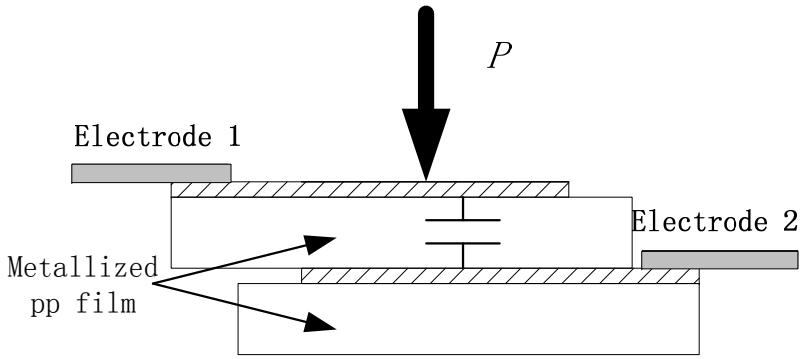
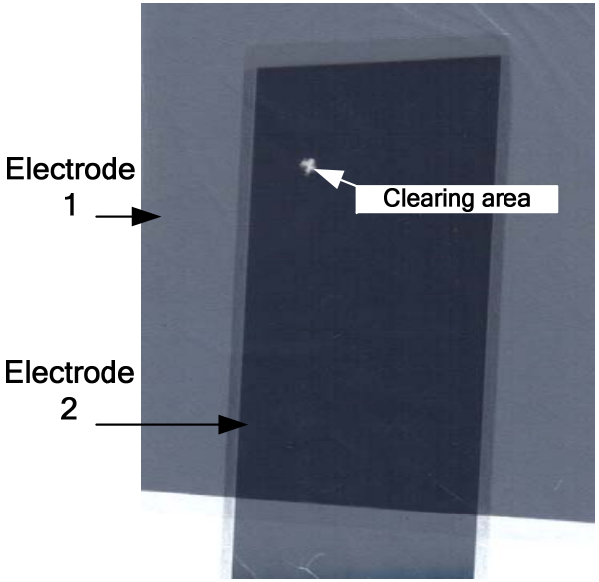
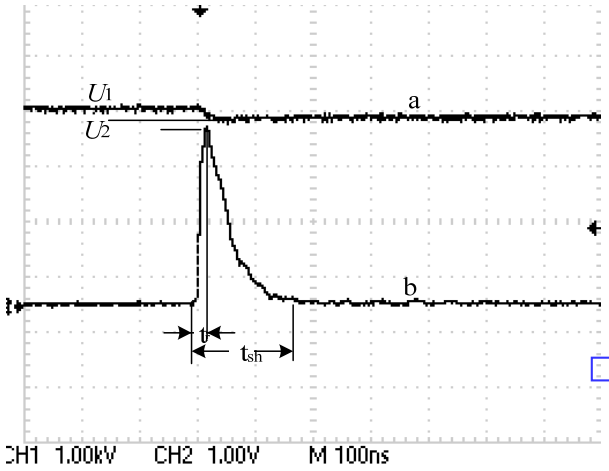
Pressure Effect Experiment





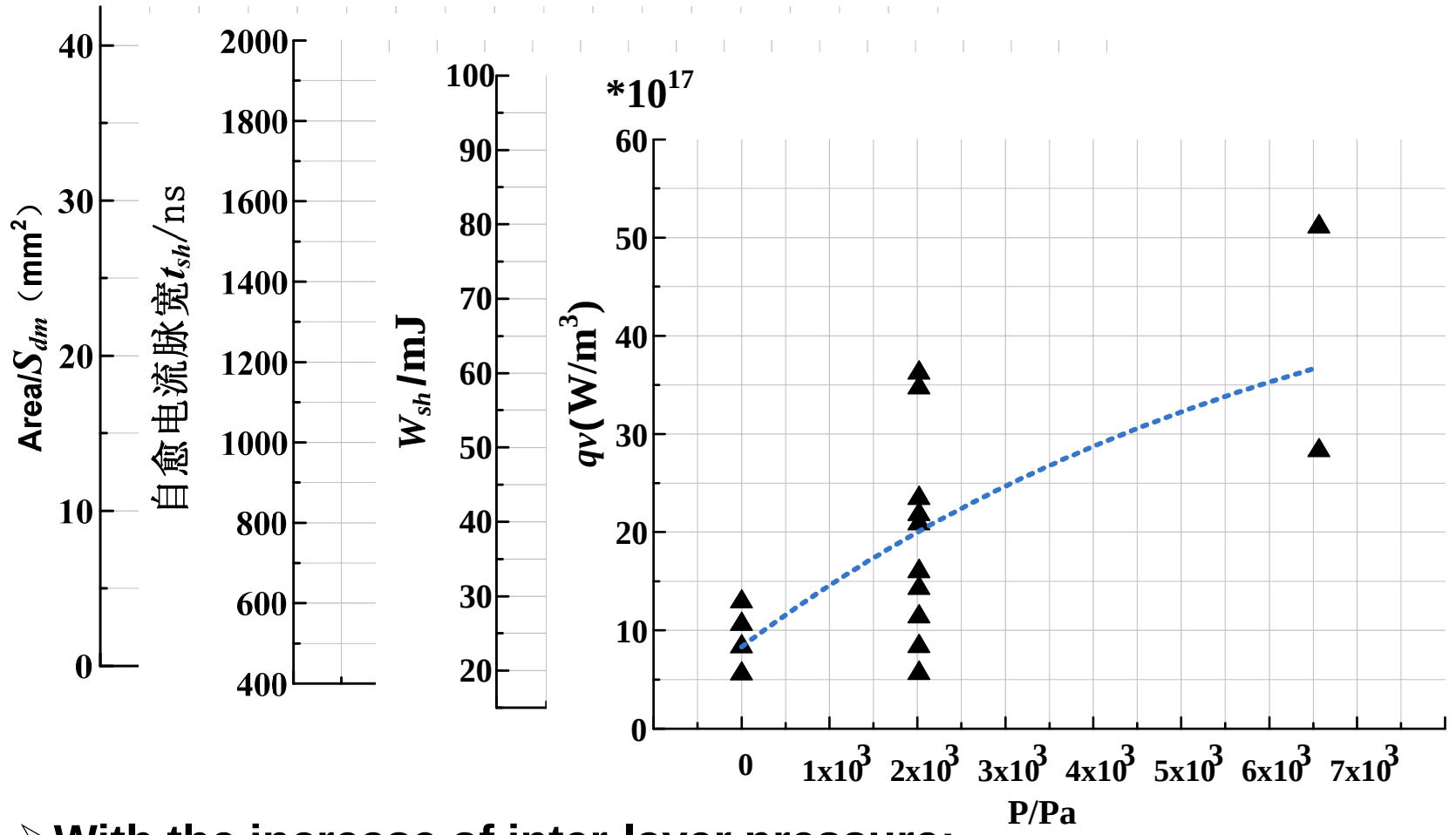
Test sample: 30cm^2-8.0μm-25Ω/□





$$W_{sh} = \frac{1}{2}CU_1^2 - \frac{1}{2}CU_2^2$$

$$q_v = \frac{W_{sh}}{t_{sh}V} = \frac{W_{sh}}{t_{sh}S_{dm}d}$$



- With the increase of inter-layer pressure:
  - ✓Clearing area, t_{sh}, clearing energy W_{sh} decrease while dissipated energy density (S_v) increases (concentrated arc)
  - ✓A saturation tendency

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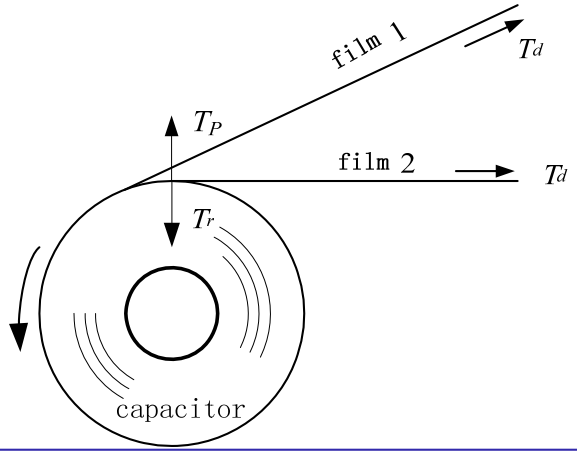
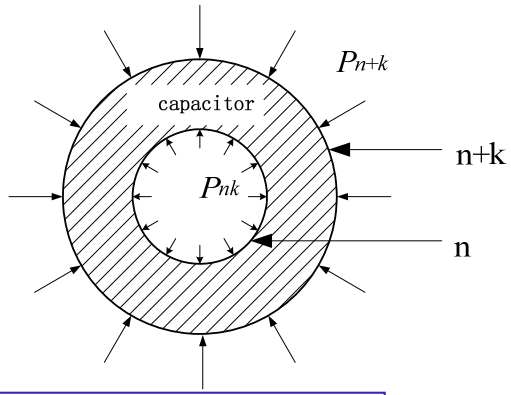
Inter-layer Pressure Calculation

- **Calculation based on film theory*****





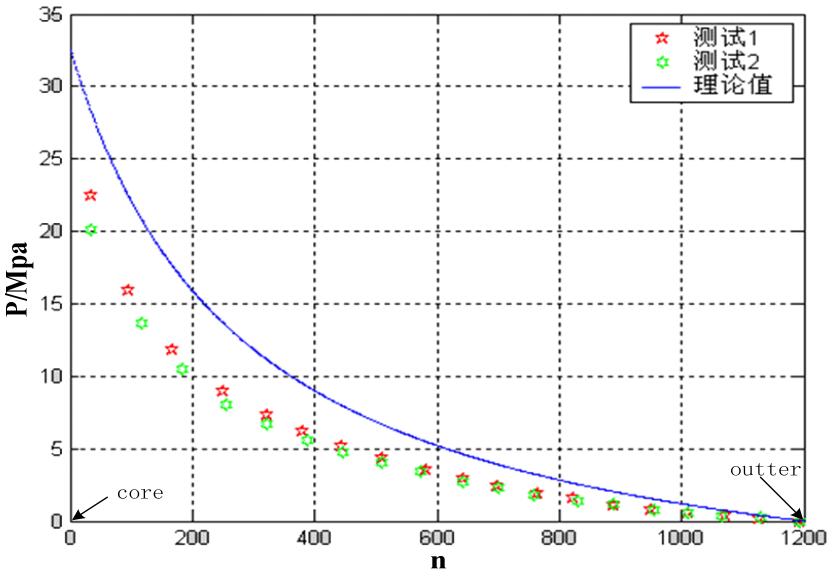
$$P_{nN} = 2(N-n)\frac{\sigma_1 d_0 b - T_d}{b\left[r_0 + (n-1)2d_0\right]} = 2\cdot(N-n)\frac{(\sigma_1-\sigma)d_0}{\left[r_0 + (n-1)2d_0\right]}$$

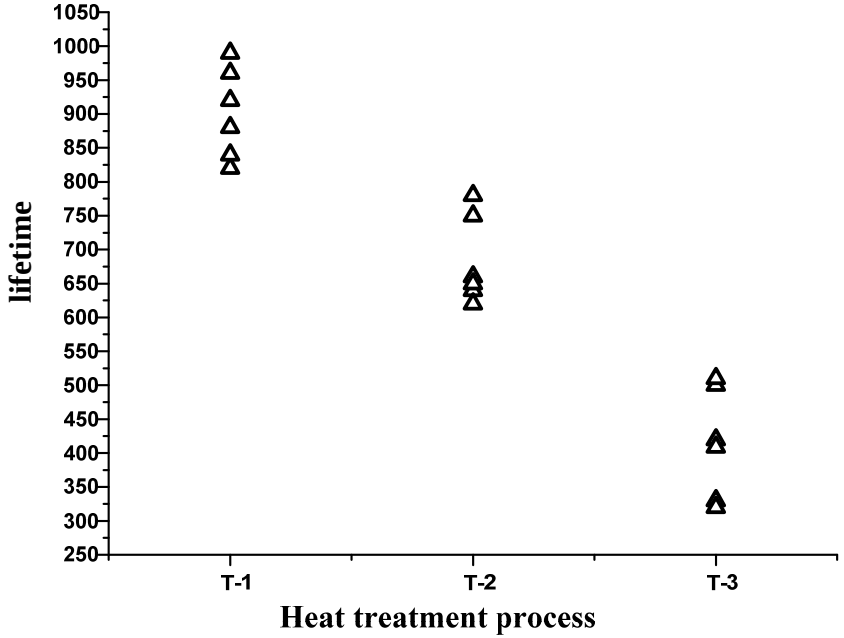
$$\Delta P_{nN} = \frac{\sigma_1 d_0 b - T_d}{T_d} = \frac{\sigma_1 d_0 b}{T_d} - 1$$

***Calculation based on"*Calculation and Measurement of Metallized Film Capacitor's Inner Pressure and Its Influence on the Self-healing Characteristics*[J]". IEEE Transactions on Dielectrics and Electrical Insulation, 2009

Capacitor film :

- **width=110mm, *d0*=8μm,Td=6.74N.**





- **A proper heat treatment process increase the inter-layer pressure**

✓**85℃， P increases to1.01 p.u.**
✓**100℃, P increases to 2.15p.u.**

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Conclusion

- In dry type metallized capacitor, the outer layers have the majority capacitance loss ratio;
- Larger inter-layer pressure helps to a small energy self-healing process; test results show that clearing energy and clearing area decrease with inter-layer pressure, and power density of self-healing increases with the pressure.
- The maximum value is close to the mandrel, it may be reach tens of MPa; A large increment of inter-layer pressure would be achieved by heat treatment process, and the working performance of dry type capacitor can be improved by proper heat setting process.

- **Thank you for your attention!**

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