Voltage Derating Behavior of High Temperature Capacitors for DC-Link Applications

Dr. Adel Bastawros
Chief Scientist
SABIC SPECIALTY

WHO ARE WE?

1976
Company established

29,000
Employees around the world

38
US$ bn
Net Sales

Top 2
Chemical Brand Value*

≈ 150
New products each year

11,070
Global patent filings

63
World-class plants worldwide

1950
Company established

Leader
Film capacitors
Energy Storage

5,400
Employees around the world

200
JPY bn
Net Sale

Innovative products
Vehicle electrification

R&D
Aggressive investments

28
Group companies

ULTRA THIN DIELECTRIC FILMS FOR HIGH HEAT CAPACITORS

INDUSTRY CHALLENGE

- For increased EV performance, OEMs require powertrain and capacitors to operate at higher heat and power levels
- Incumbent film capacitors, without active cooling, can operate only up to 105°C; other higher temperature films may reach 125°C. Both suffer from significant "derating" of operating voltage as temperature increases.
- Novel, thin dielectric films, capable of operating at higher temperatures at highest operating voltage.

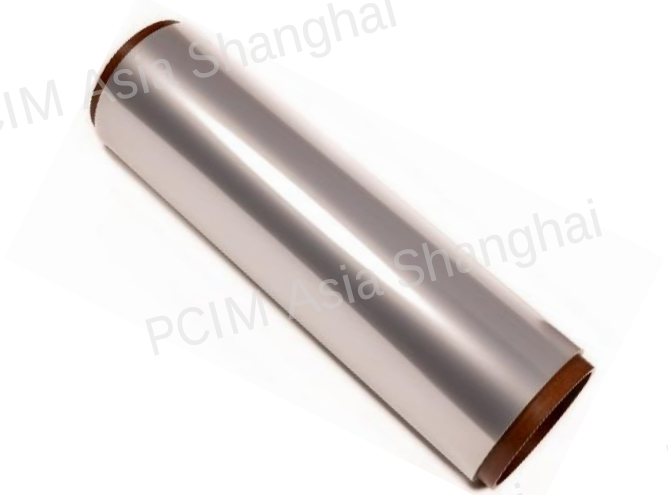
SOLUTION:

SABIC:

- New high heat film for DC-link capacitors: ELCRES™ HTV150
- High heat materials for stable superior performing xEVs

Nichicon:

- Film capacitors that can perform at temperatures up to 150°C
- Higher power density and voltage of EV traction inverters



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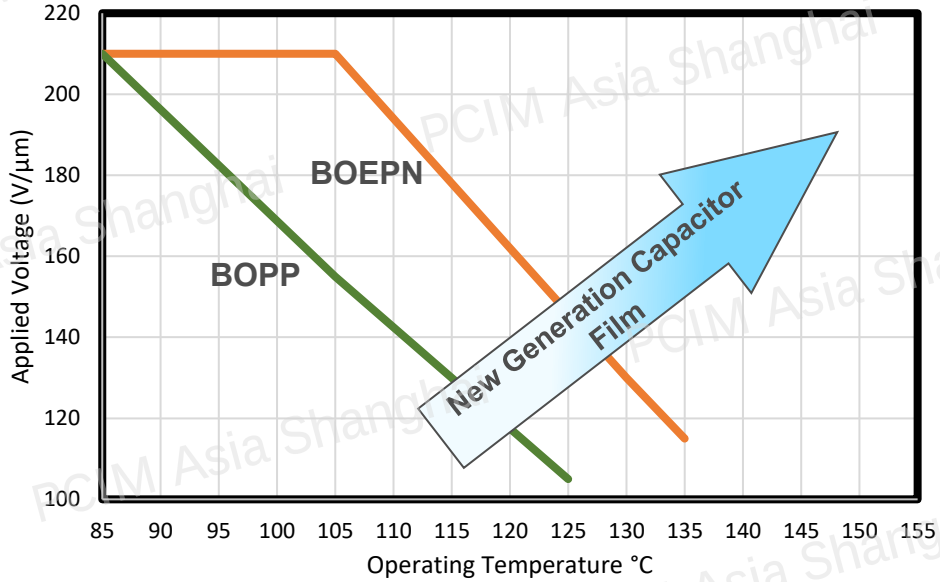
WHAT IS "DERATING" OF OPERATING VOLTAGE?

- Derating: reduction of operating voltage of polymer film capacitors at higher operating temperatures.
- For most polymers, the voltage withstanding ability decreases as temperature increases.
- Compensating for lower voltage withstanding at higher temperatures:
  - Active cooling to keep capacitor temperature low (added weight, larger volume, power consumption).
  - Rate the capacitor at lower voltage (derating).
  - Increase dielectric film thickness (overdesign) to maintain higher voltage rating.
  - Use dielectric film with stable performance over the temperature range.

- Examples*:
  - Series of elaborate reliability life tests at Temperature under DC Voltage for thousands of hours (e.g., 2000 hours).
  - 50% V-derating, caps with BOPP film, Temp 85 → 125 °C
  - 45% V-derating, caps with BOEPN film, Temp 105 → 135 °C
  - Derating is also impacted by capacitor design and processing



U. Wahner, and C. Alba, "Polymers in Film Capacitors – The Next Generation Material is available!", PCIM Europe 2023, pp. 144-149, 2023

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NEW GENERATION HIGH TEMPERATURE HIGH VOLTAGE CAPACITOR FILM

ELCRES™ HTV150

2021 R&D 100 WINNER

ELECTRICAL CHARACTERISTICS

- Stable high D_k and low D_f up to 150°C and 100 kHz
- High breakdown strength from -40°C to 150°C
- Good self-healing
- Stable capacitance, IR, and D_f at 150°C over 2000hrs of life-testing

POTENTIAL BENEFITS

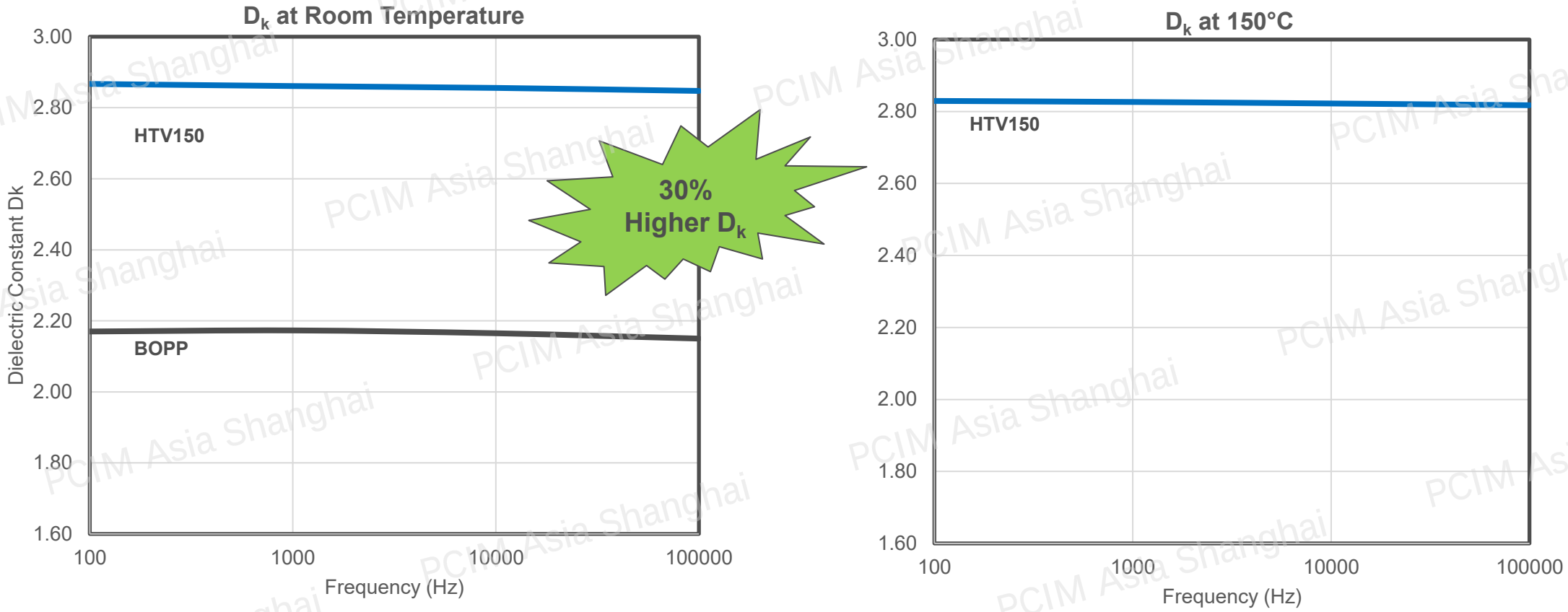
- Supports more reliable operation at elevated temperatures
- Co-location within power train improving efficiency
- Enabling the advantages of WBG chips to be fully utilized
- Downsizing or elimination of active cooling systems

- E-Mobility
  - Traction Inverter
  - On-Board Charger
  - Electrical Compressor
  - DC-DC Converter
- Renewable Energy
  - Inverter
- Industrial drives
  - Motor Drives and Controls
- Mass Transportation
  - Inverter

ELCRES™ HTV150 film is a candidate for applications requiring high temperature resistance during processing or operation

ELCRES™ HTV150 FILM CHARACTERISTICS

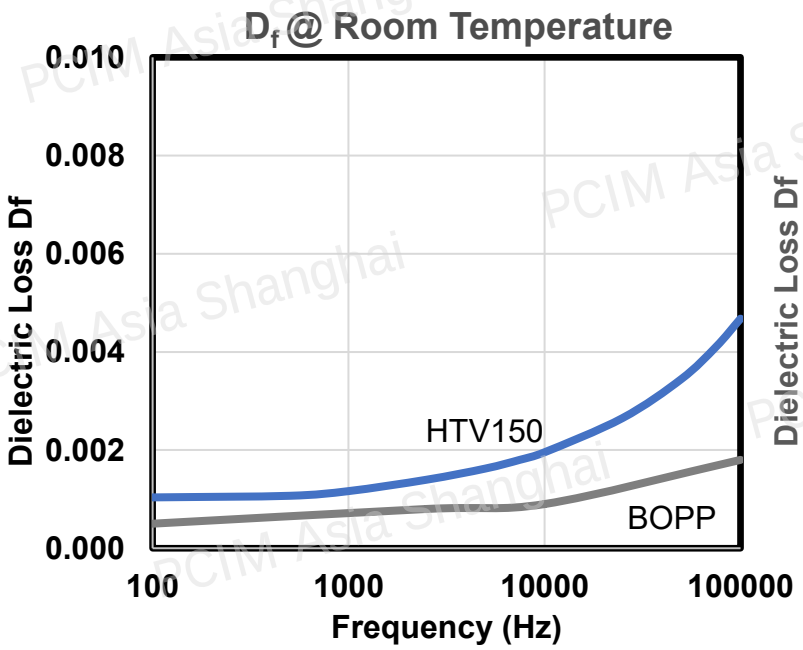
DIELECTRIC CONSTANT (D_k)

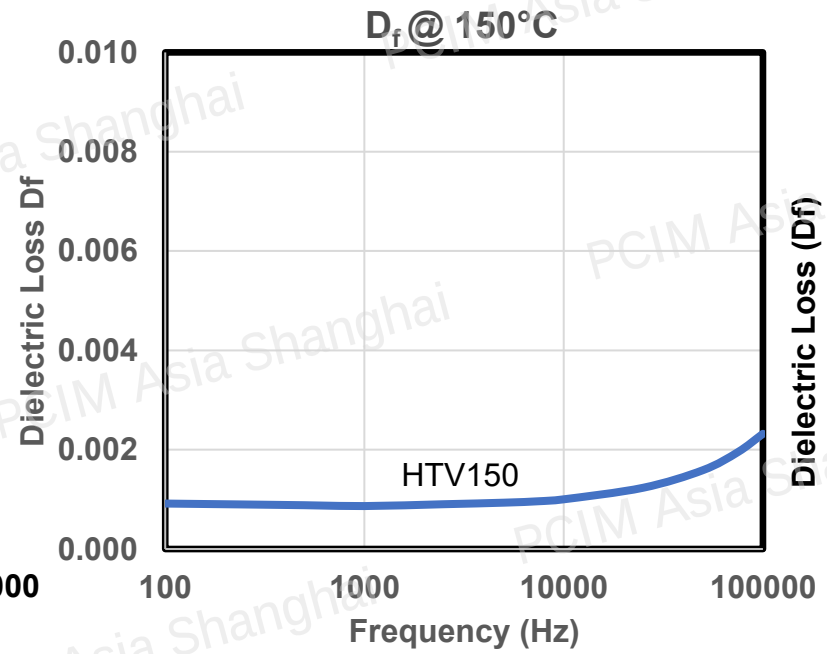


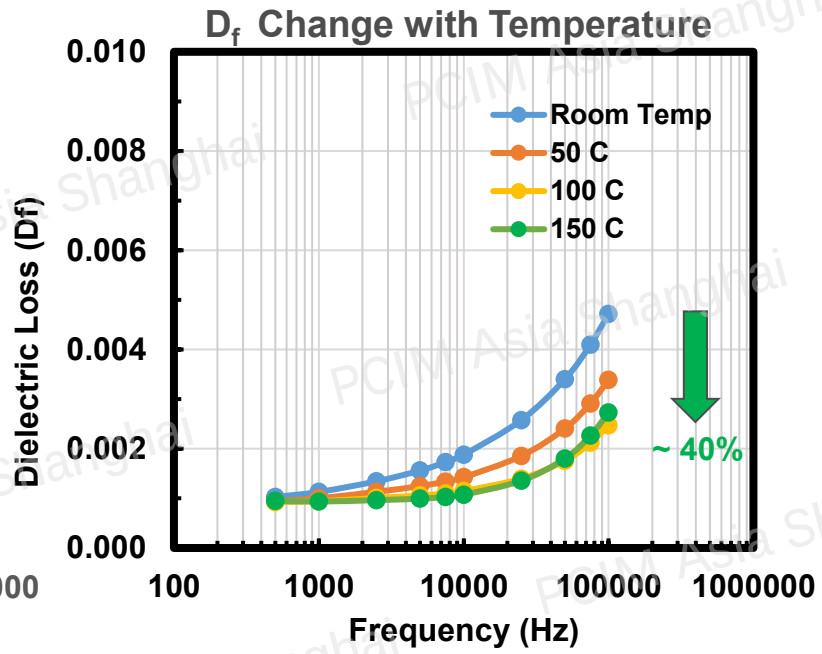
ELCRES™ HTV150 film maintains D_k performance at elevated temperatures and frequencies

ELCRES™ HTV150 FILM CHARACTERISTICS

FILM DIELECTRIC LOSS D_f



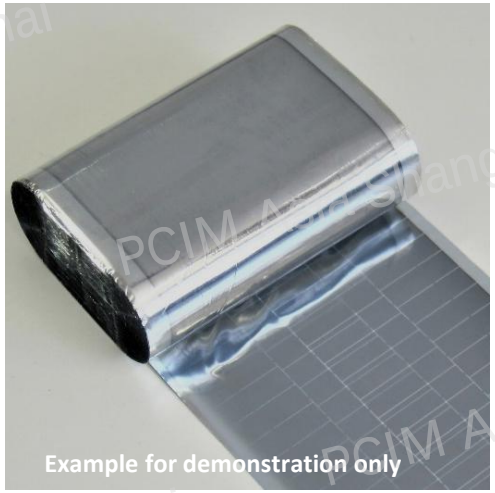




ELCRES™ HTV150 film offers lower dielectric losses at higher temperatures and frequencies

HIGH HEAT CAPACITOR BUILDS

- ELCRES™ HTV150 films: 5µm
- Advanced segmented metallization
- 20Ω/ 5Ω body/ heavy-edge resistivity
- 10 µF capacitors
- Flattened elements
- 6-10 capacitors per temperature condition
- Reliability life testing for 2000 hours at 105, 130, & 150 °C; under DC voltage.



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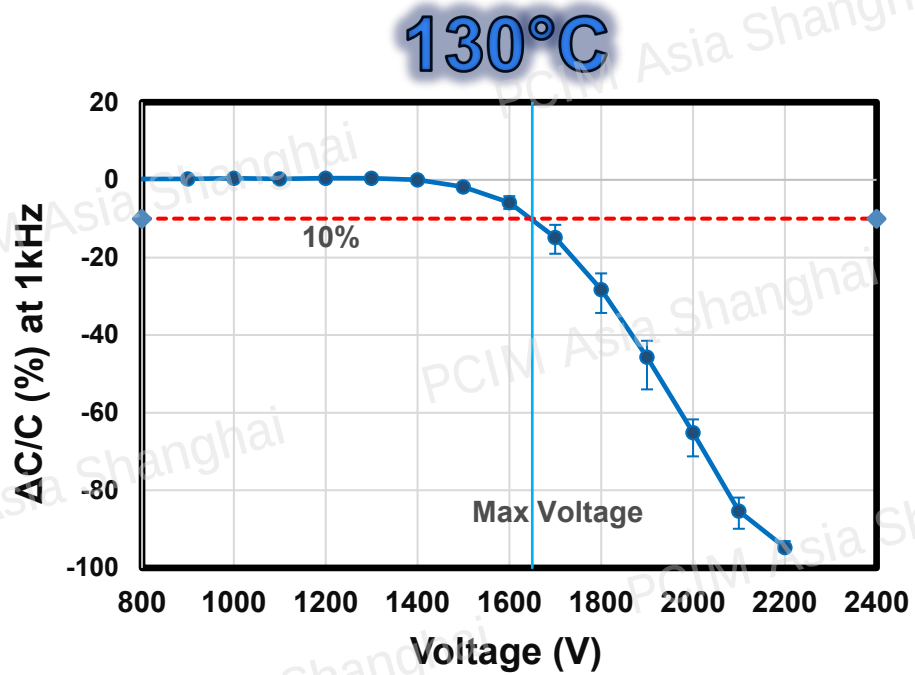
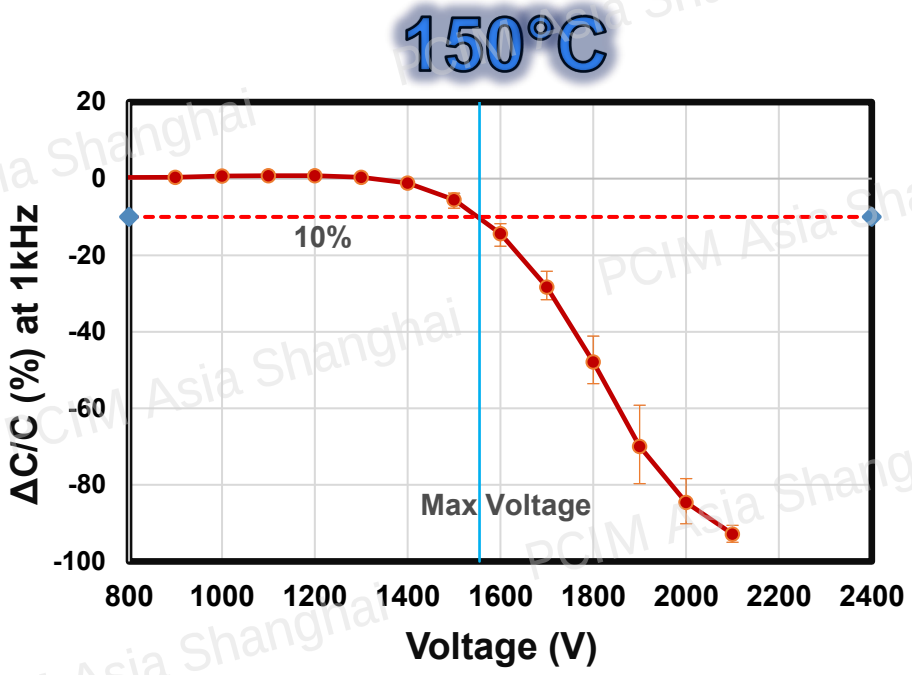
- Monitored:
  - Capacitance change ΔC%
  - Insulation Resistance IR
  - Dissipation loss Tan δ
  - Equivalent Series resistance ESR

ELCRES™ HTV150 films are compatible with existing downstream metallization, slitting and capacitor building technologies

CAPACITOR VOLTAGE STRESS TEST (5µm film)

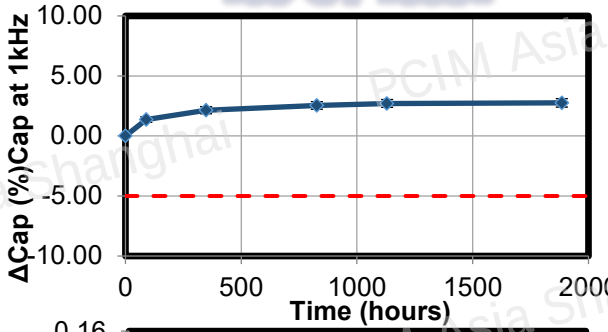
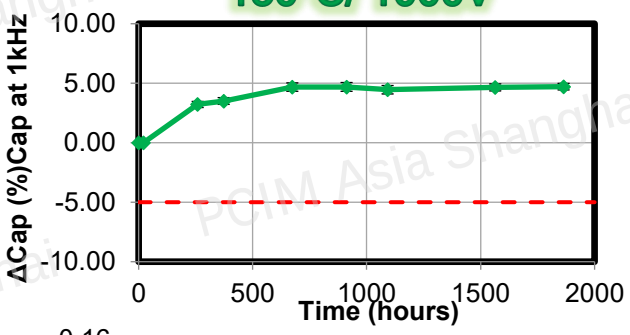
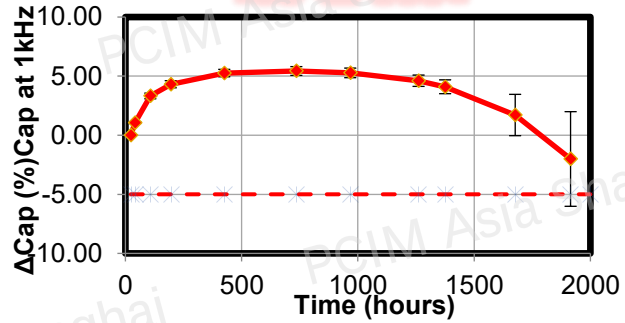
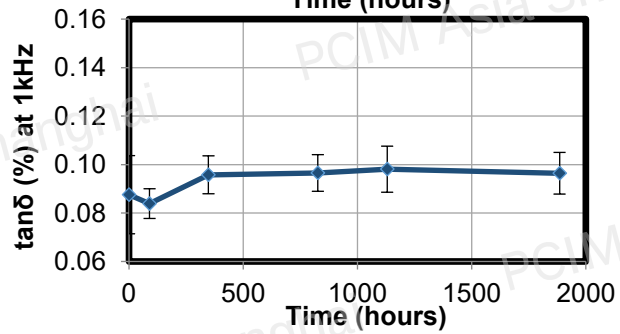
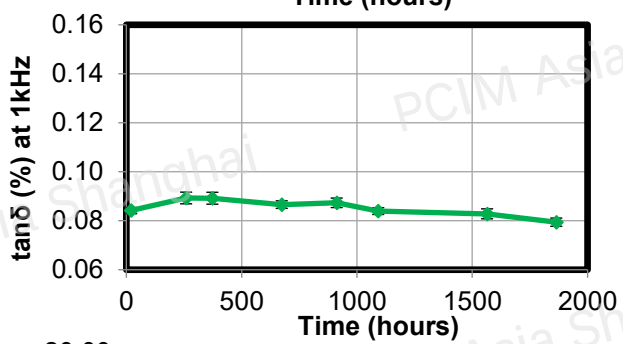
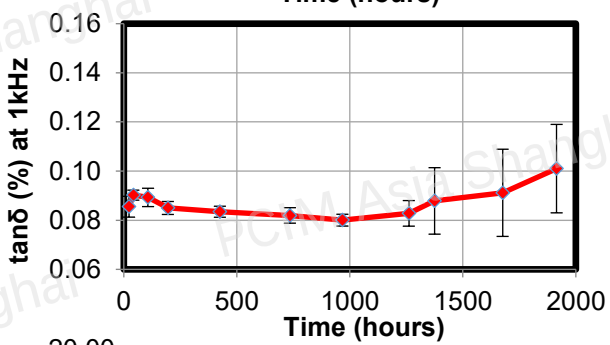
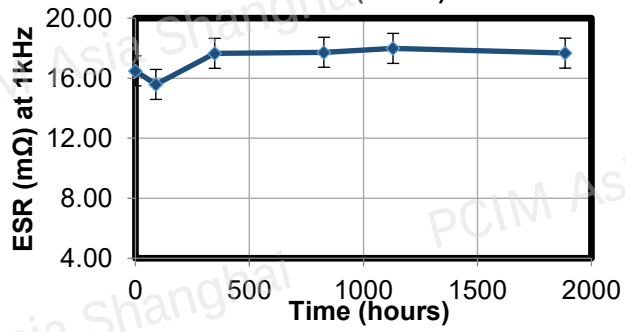
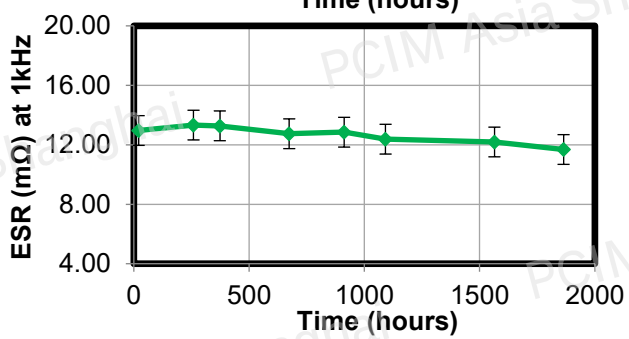
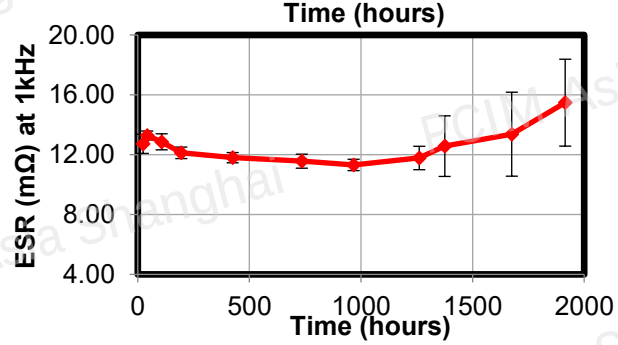




For 10% Drop in C	Max Voltage	Operating Voltage
@ 130°C	1650V	**1000V**
@ 150°C	1550V	**900V**

@105 °C Operating Voltage of 1050V was selected for testing.

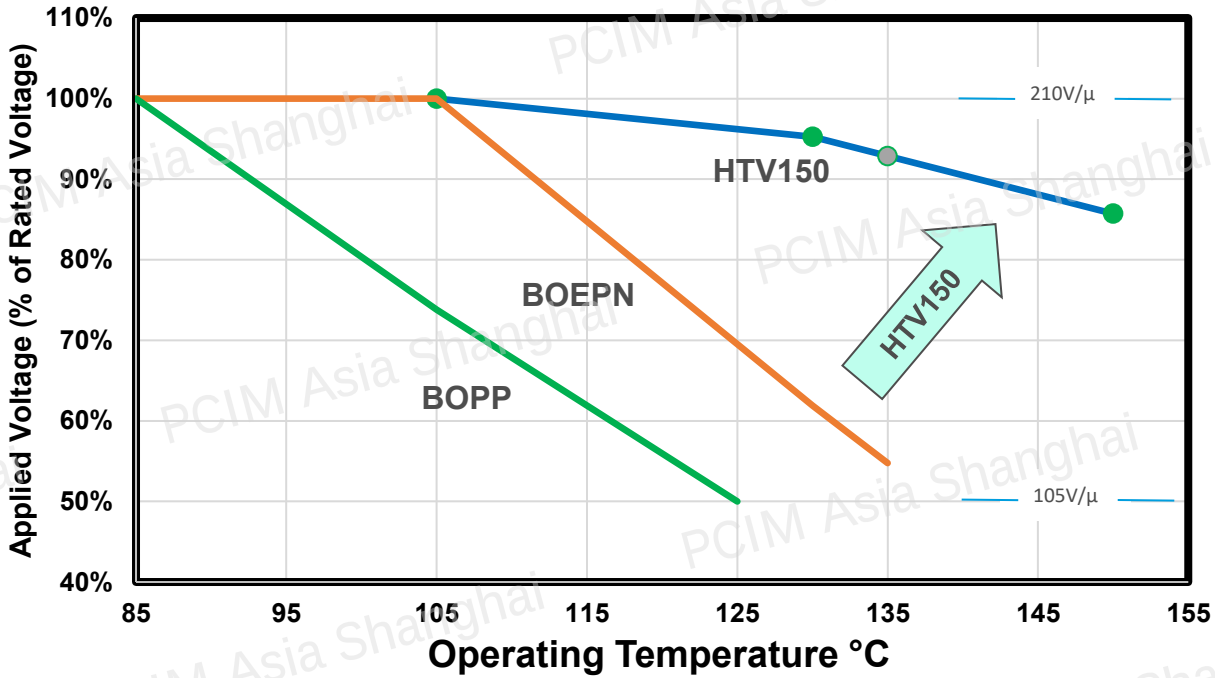
RELIABILITY LIFE TESTING OF HIGH HEAT CAPACITORS

	105°C / 1050V	130°C/ 1000V	150°C/ 900V
ΔC (%)			
tan δ			
ESR (mΩ)			

ΔC < 5%, tan δ < 2x the starting value, and IR & ESR remained stable for 2000 hours

DERATING PERFORMANCE OF CAPS BUILT WITH HTV150 FILM

- **Caps with BOPP*:**
  - **50%** Voltage Derating when Temp 85 → 125 °C
- **Caps with BOEPN*:**
  - **45%** Voltage Derating when Temp 105 → 135 °C
- **Caps with HTV150:**
  - **4.8%** Voltage Derating when Temp 105 → 130 °C
  - **7.0%** Voltage Derating when Temp 105 → 135 °C
  - **14.0%** Voltage Derating when Temp 105 → 150 °C



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ELCRES™ HTV150 film maintains stable performance at elevated temperatures with minimal derating of capacitor operating voltage.

CONCLUDING REMARKS

- High-heat ELCRES™ HTV150 dielectric films were used successfully to build high temperature capacitors.
- HTV150 films were shown to retain their voltage withstanding ability at high temperatures reaching 150°C.
- Caps with HTV150 film had minimal derating of operating voltage:
  - 4.8% at 130°C
  - 7.0% at 135°C
  - 14% at 150°C
- 5µm-based capacitors were used to construct operating voltage derating curve for 105 - 150°C range.
- Life testing for 2000 hours were used to determine the operating voltage at 105, 130, and 150°C.
- HTV150 film offers opportunities for reducing or eliminating active cooling, downsizing, weight reduction, and lower power consumption.
- Capacitors made with HTV150 film are well positioned to help realizing full benefits of SiC and GaN MOSFETs when used in AC-DC inverters for EV applications.

Co-authors:

Nichicon - Japan: Takeshi Horiguchi, Takashi Mori, and Kenichi Oshita
SABIC – China: Yuan Zhou, SABIC - Japan: Fumio Yu

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