

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

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Chief Scientist  
SABIC SPECIALTY



سابك  
sabic



1976  
Company  
established



Top 2  
Chemical Brand Value\*

nichicon



1950  
Company  
established



Leader  
Film capacitors  
Energy Storage



5,400  
Employees  
around the world

200

JPY bn  
Net Sale



29,000  
Employees  
around the world

38

US\$ bn  
Net Sales



≈ 150  
New products  
each year



11,070  
Global patent  
filings



63  
World-class  
plants worldwide



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.

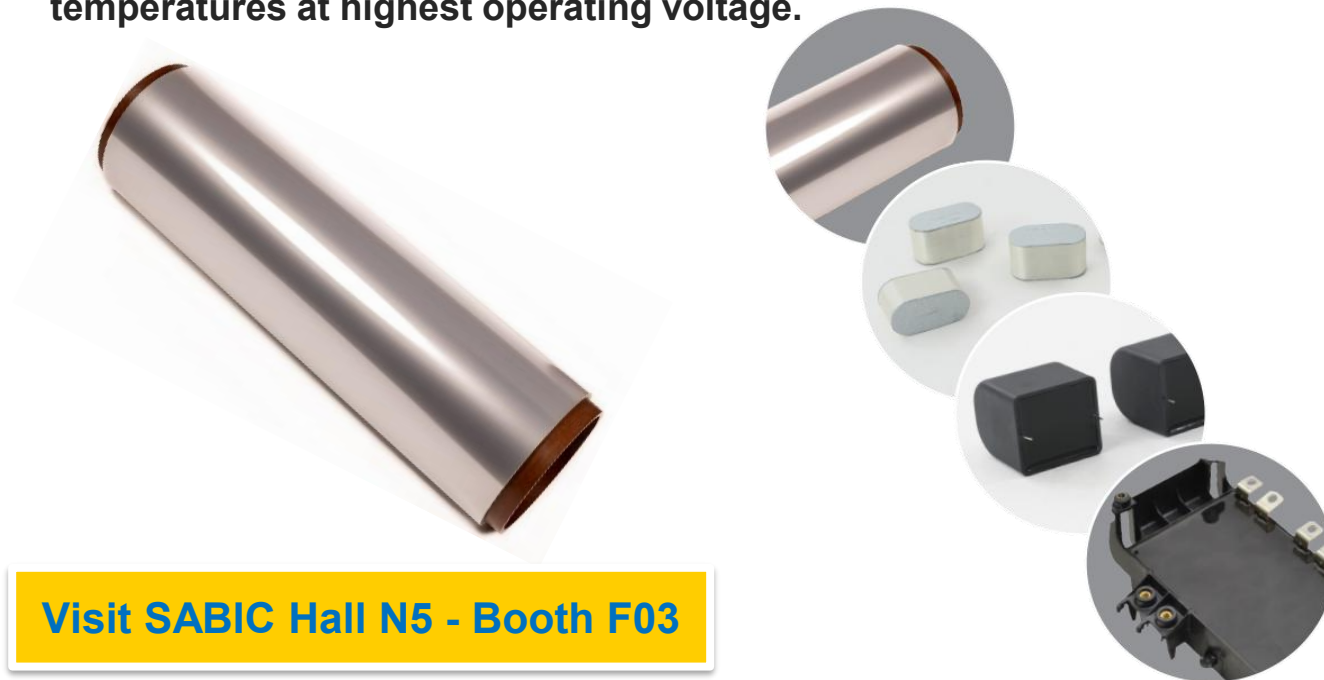
### SOLUTION:

#### 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

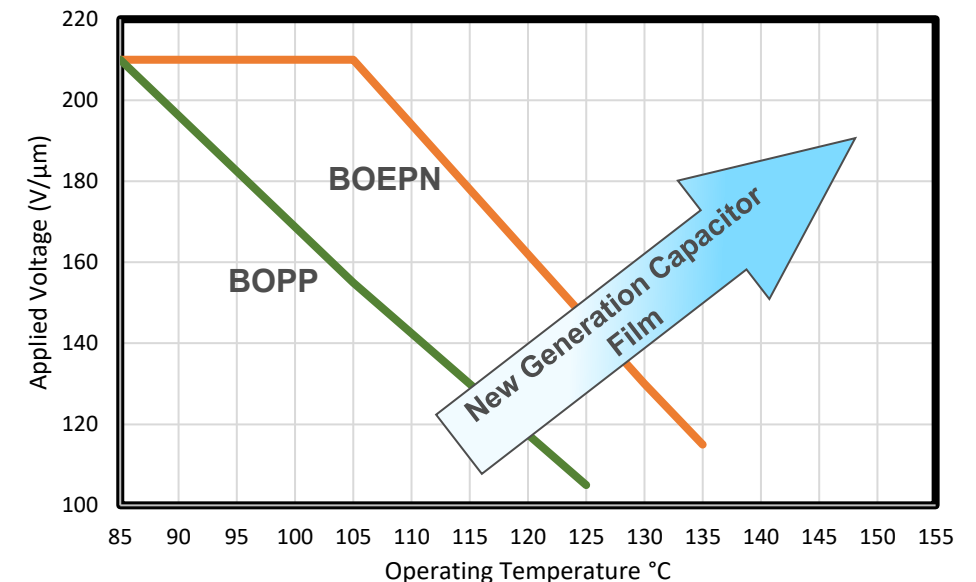


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## WHAT IS “DERATING” OF OPERATING VOLTAGE?

- 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

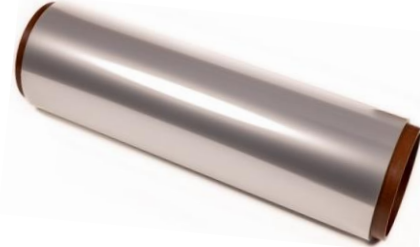


\*U. Wahner, and C. Alba, “Polymers in Film Capacitors – The Next Generation Material is available!”, PCIM Europe 2023, pp. 144-149, 2023



# NEW GENERATION HIGH TEMPERATURE HIGH VOLTAGE CAPACITOR FILM

ELCRES™ HTV150



## 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

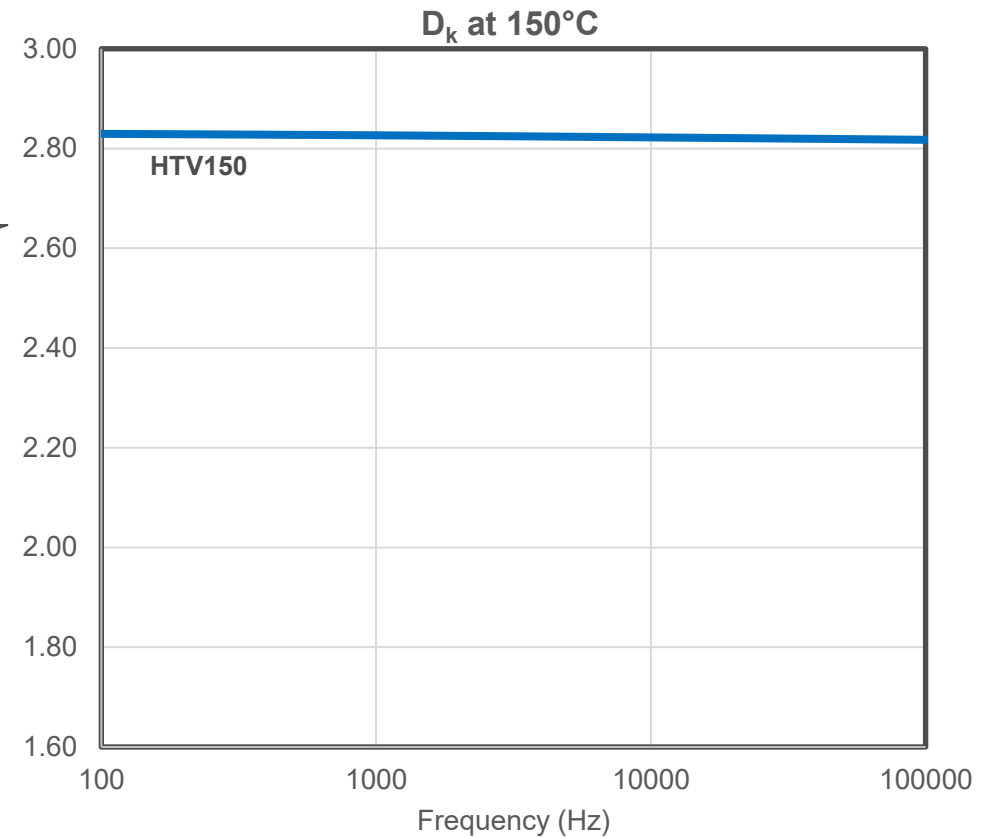
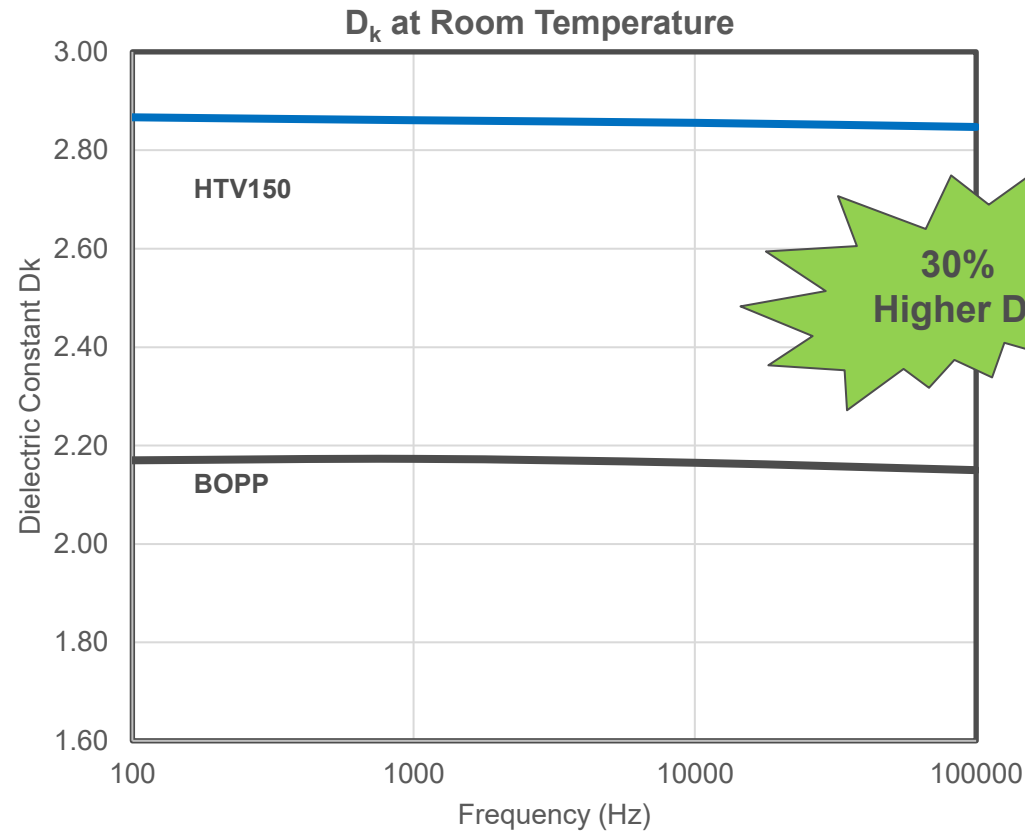
Motor Drives and  
Controls

Mass  
Transportation

Inverter

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

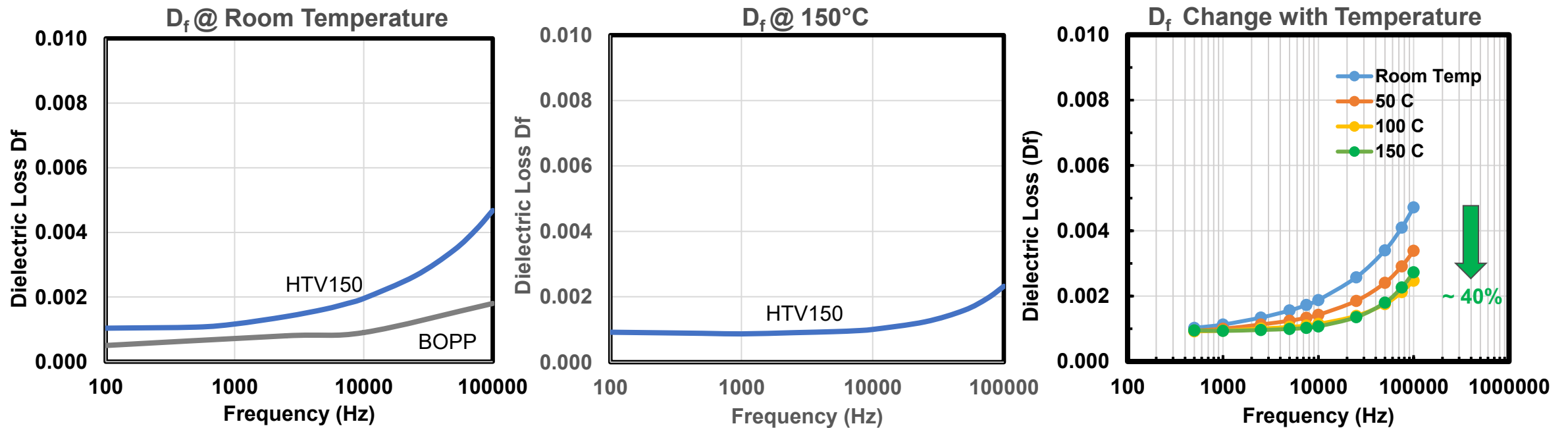
## DIELECTRIC CONSTANT ( $D_k$ )



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

## ELCRES™ HTV150 FILM CHARACTERISTICS

### FILM DIELECTRIC LOSS $D_f$



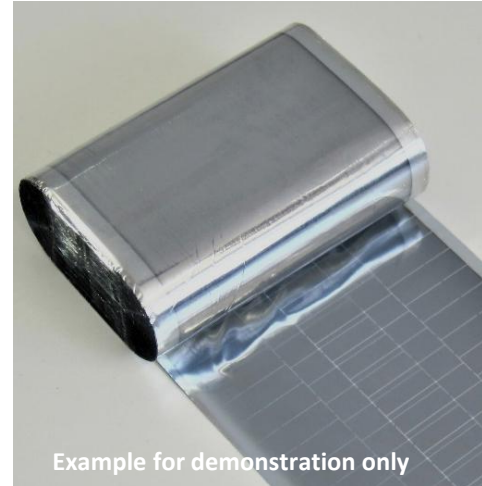
**ELCRES™ HTV150 film offers lower dielectric losses at higher temperatures and frequencies**

## 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.

- Monitored:
 

• Capacitance change	ΔC%
• Insulation Resistance	IR
• Dissipation loss	Tan δ
• Equivalent Series resistance	ESR



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**nichicon**

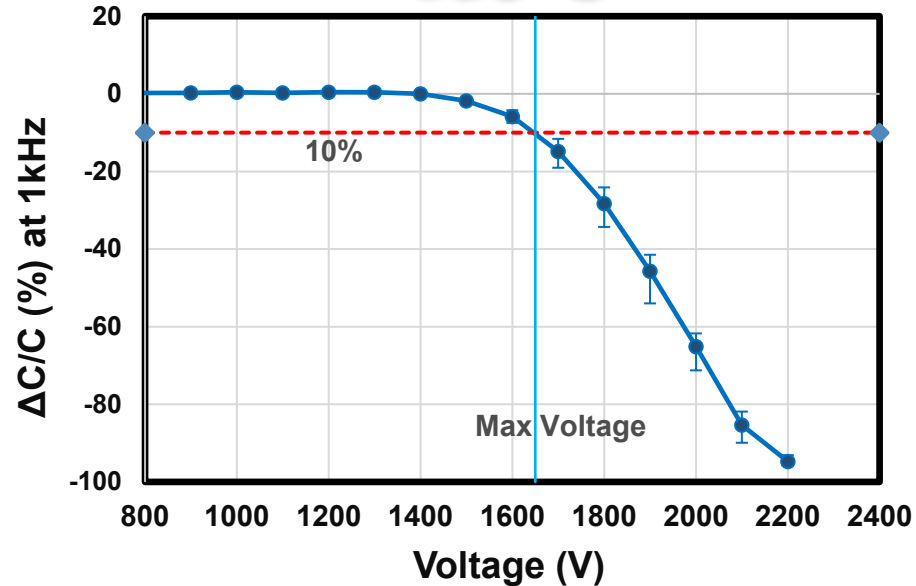


➤ **ELCRES™ HTV150 films are compatible with existing downstream metallization, slitting and capacitor building technologies**

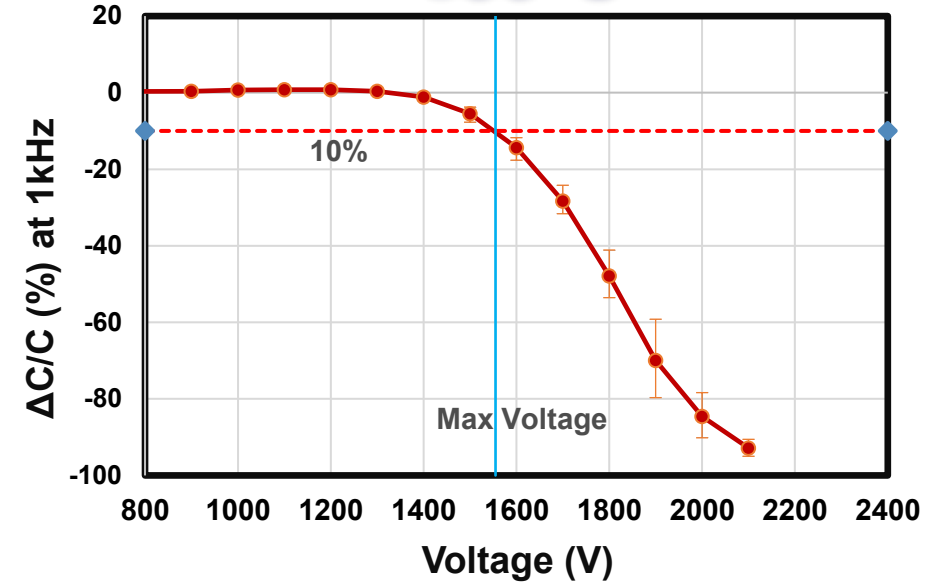


## CAPACITOR VOLTAGE STRESS TEST (5 $\mu$ m film)

130°C



150°C



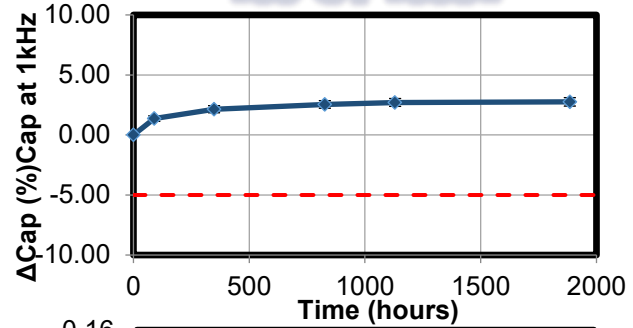
For 10% Drop in C	Max Voltage	Operating Voltage
@ 130°C	1650V	1000V
@ 150°C	1550V	900V

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

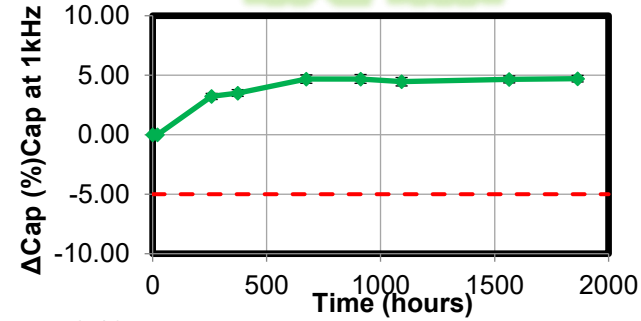
# RELIABILITY LIFE TESTING OF HIGH HEAT CAPACITORS

$\Delta C$  (%)

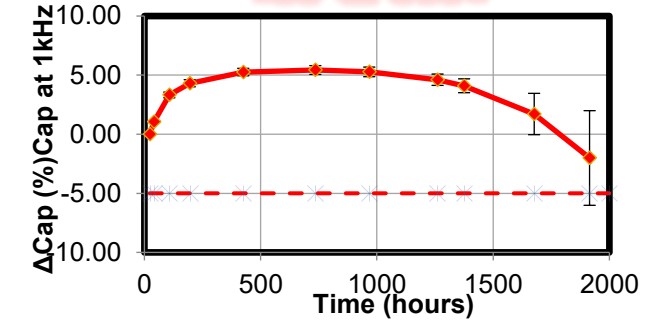
105°C / 1050V



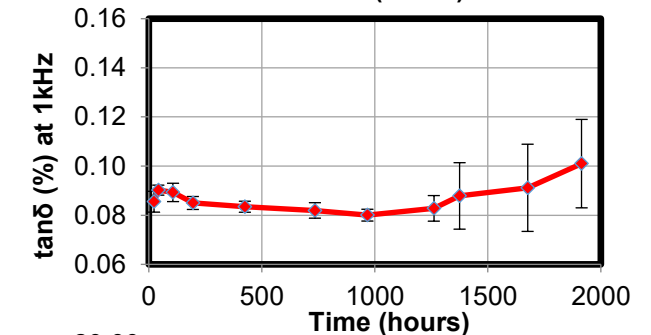
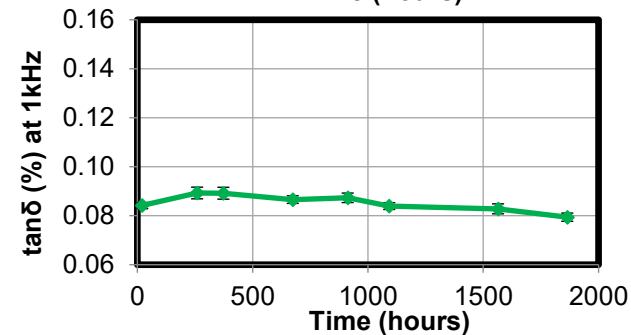
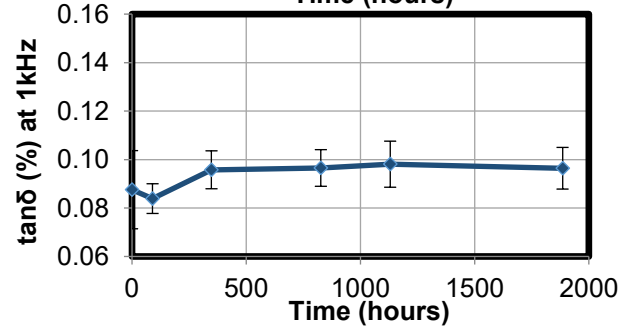
130°C / 1000V



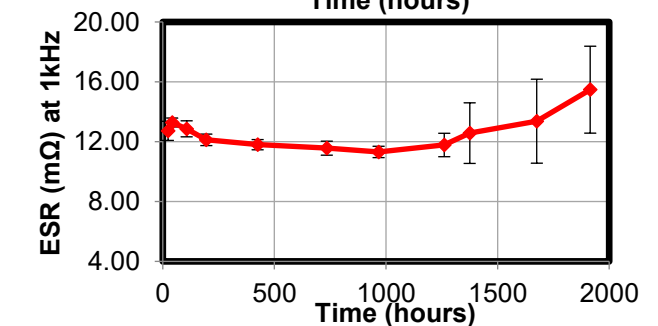
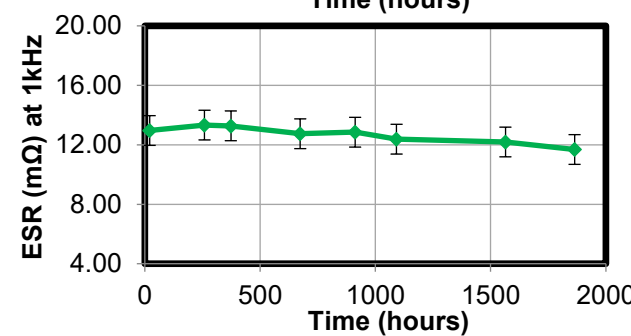
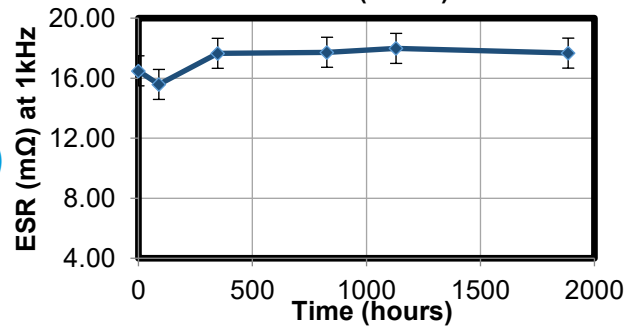
150°C / 900V



$\tan \delta$



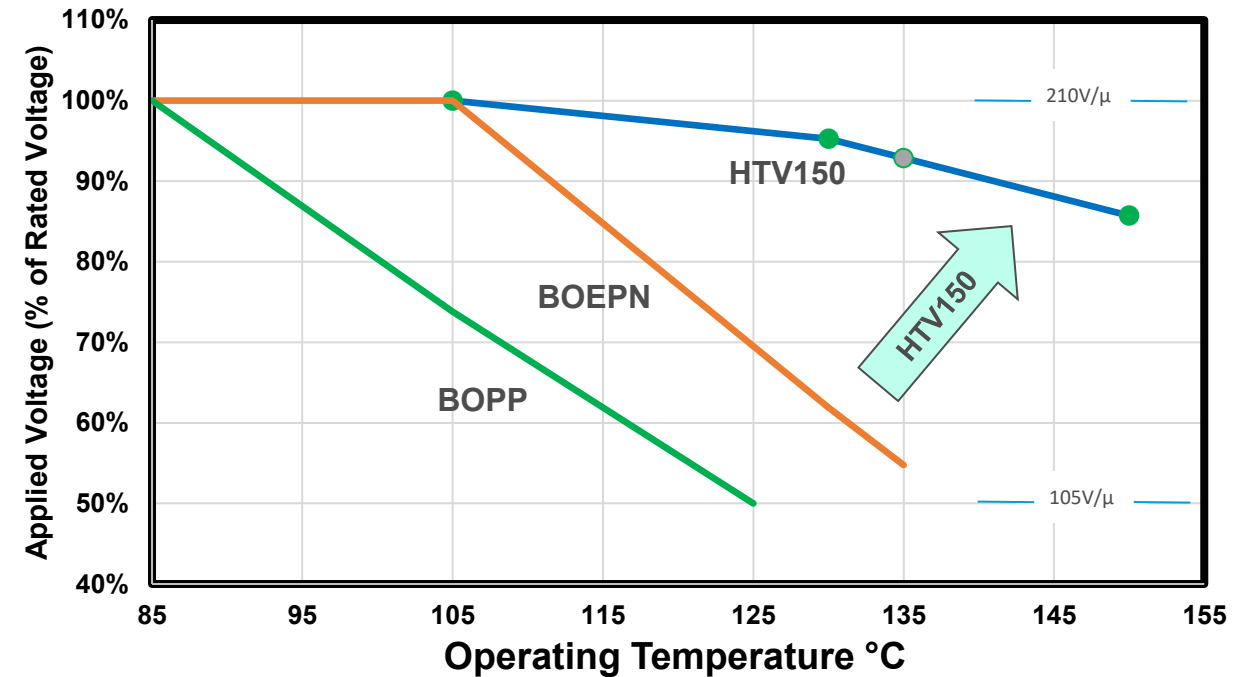
ESR (mΩ)



$\Delta C < 5\%$ ,  $\tan \delta < 2x$  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



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

➤ **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.

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