

Overview of High Heat Capacitor Materials for eMobility Applications

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Industry Challenge:

- Demand for more driving range, fast charging, and increased efficiency necessitated need for reliable operation of DC-Link components (e.g., capacitors) at temperatures reaching **150°C**.
- Without active cooling, incumbent BOPP polymer film capacitors are limited to 105°C. Other films might reach 125°C; however, significant derating and/or increased dissipation losses become excessive at higher temperatures.
- New MOSFET technologies (SiC & GaN) have shown potential for efficiency improvements that are best realized when the module operates under high voltages and at high temperatures reaching up to **150°C**.
- Novel, thin dielectric films, capable of operating at higher temperatures and voltages with minimal derating and reduced losses are needed.

High Temperature Performance:

Polymer films used to make capacitors vary in their electrical and thermal performance when exposed to high temperatures.

Key film characteristics are:

- Breakdown Voltage **BDV** (aka BDS)
- Dielectric constant **D_k**
- Dissipation factor **D_f**
- Self-healing & Voltage Derating in capacitors

Temperature performance of **commercially available polymer films** is reviewed here.

PC-Copolymer based films (HTV150A) is the only commercially available film enabling stable capacitor performance at 150°C without active cooling.

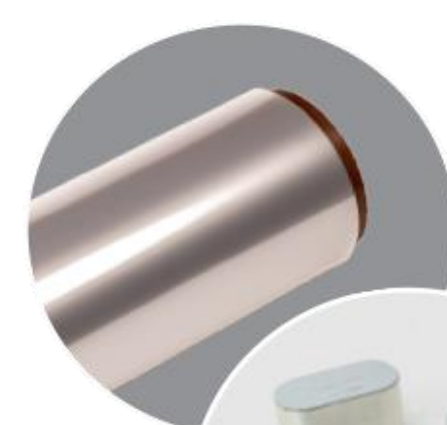


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HTV150A Ultrathin Film rolls
(3~10μm x 5,000~10,000m)



Capacitor windings



Bulk Capacitor
(For Power Module)



Polymer Films for Different Temperatures:

150°C:

- PC-CoPol: Polycarbonate copolymer (HTV150A)
- PEI: Polyetherimide
- PPS: Polyphenylene sulfide

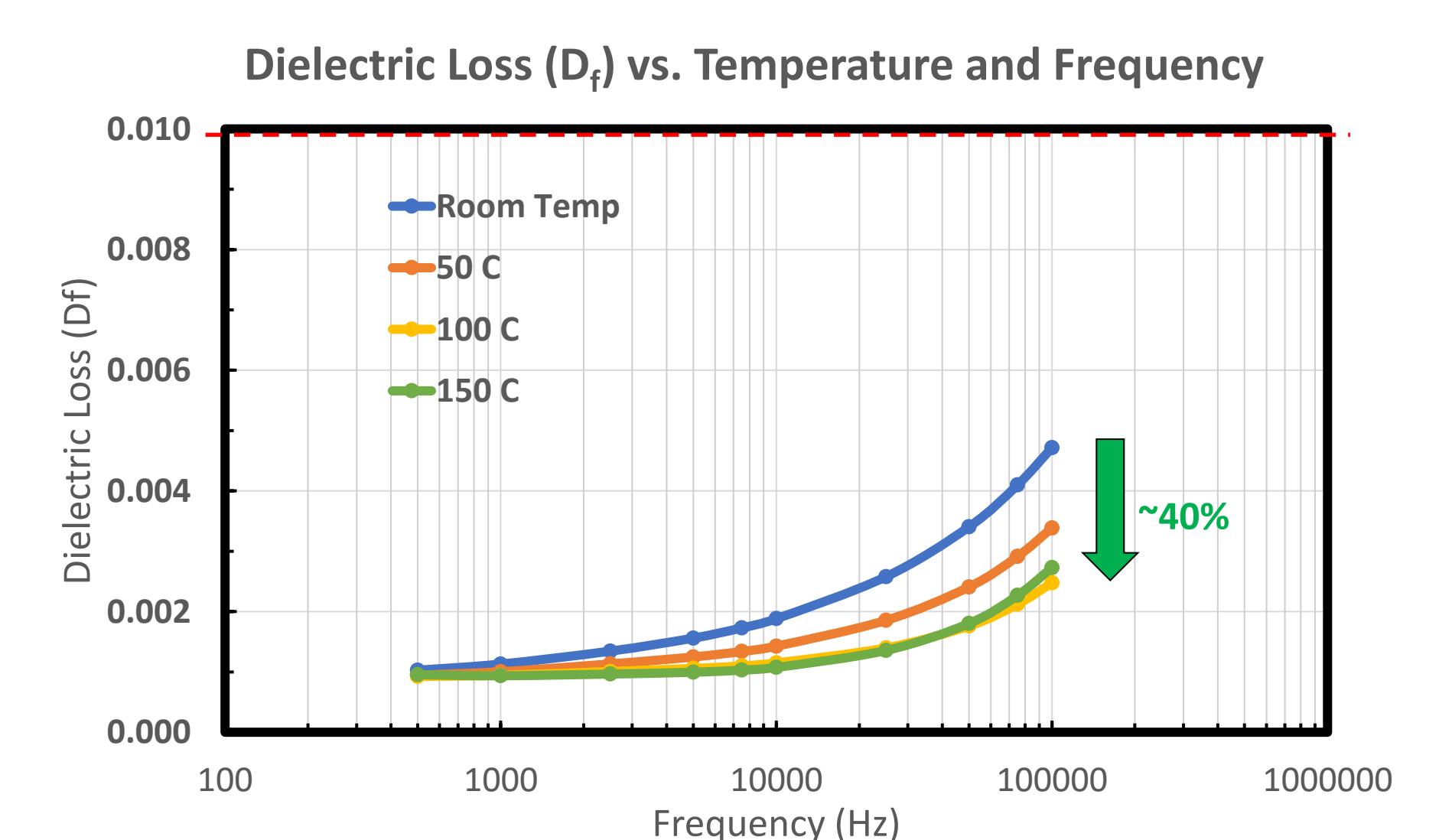
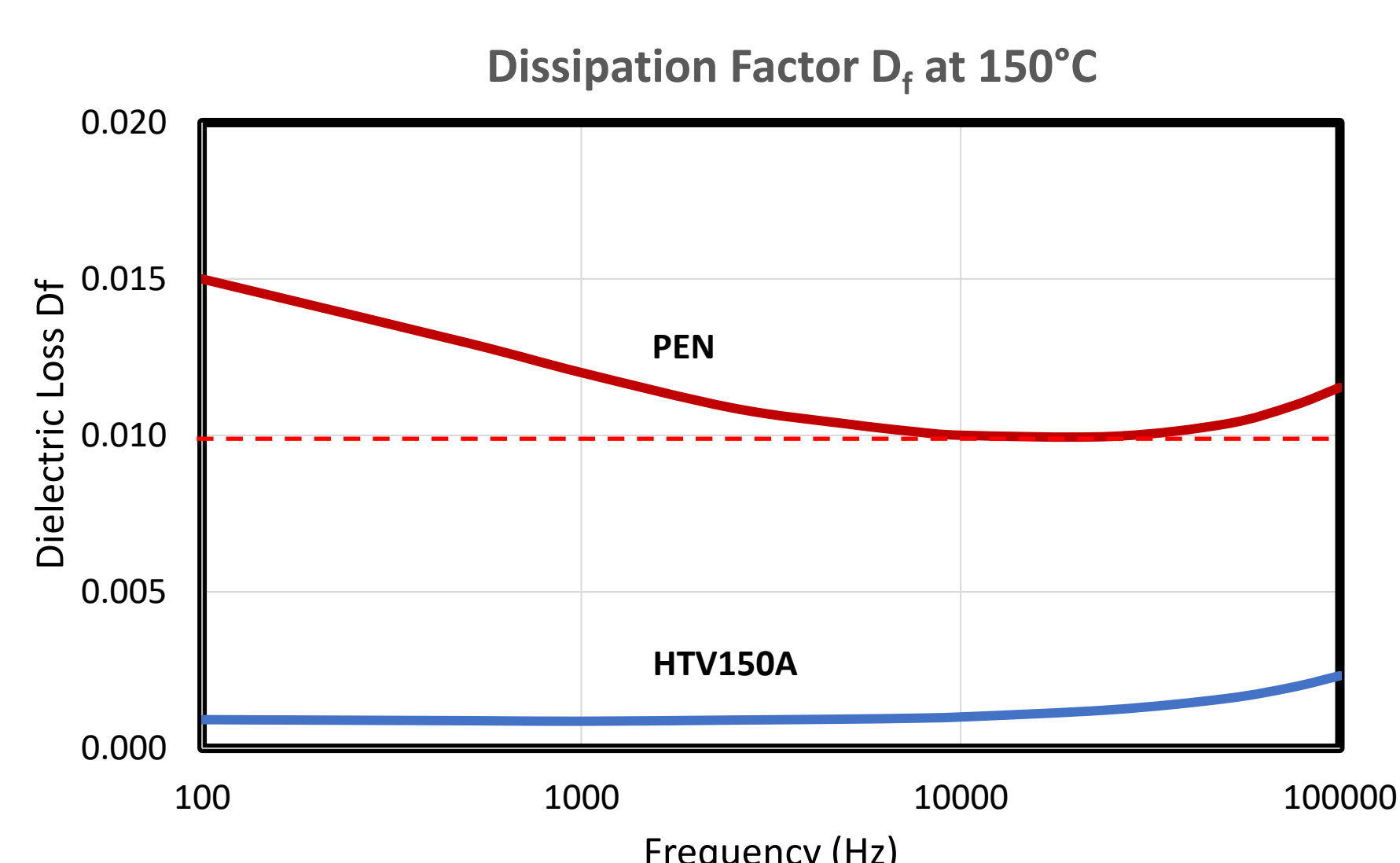
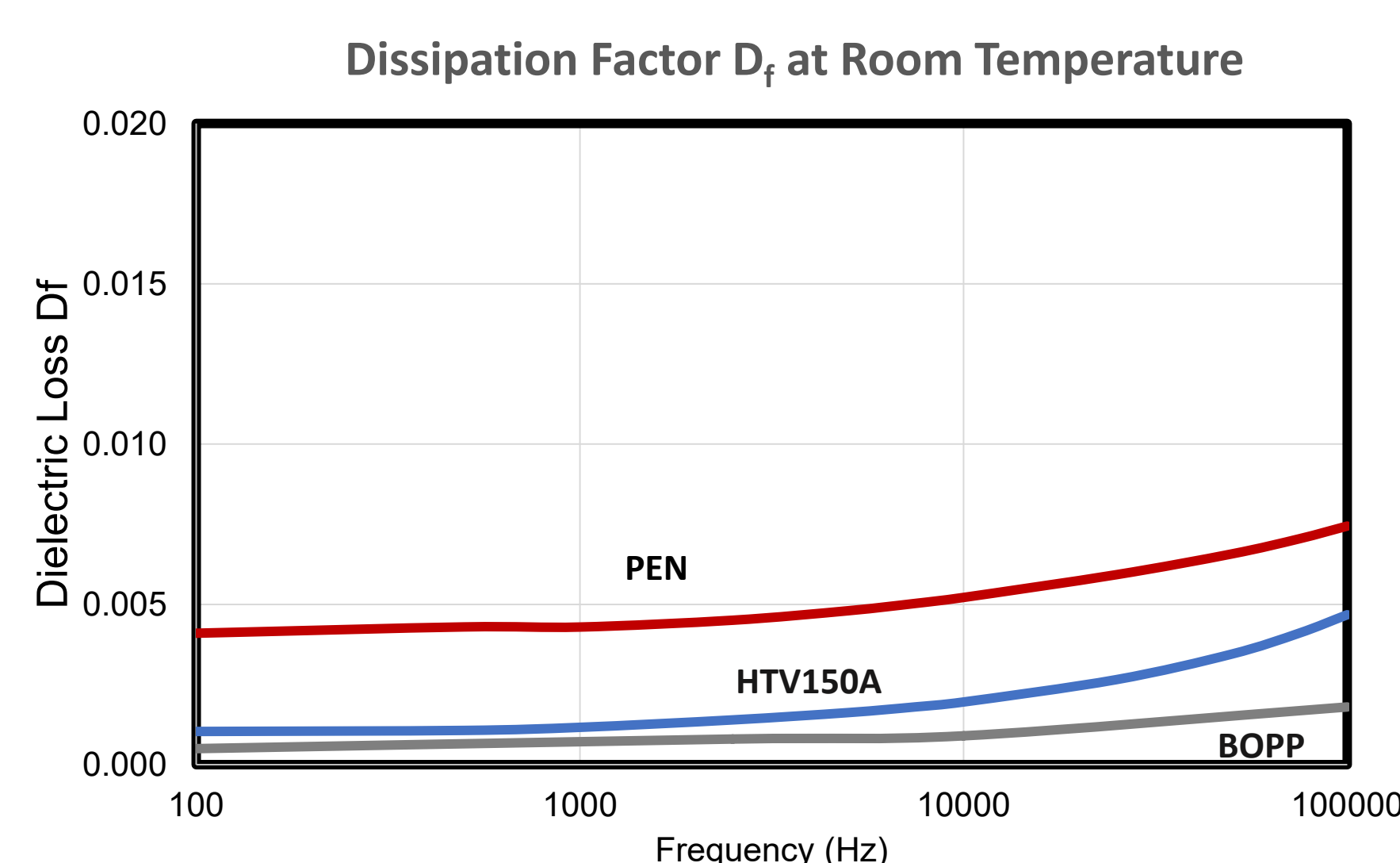
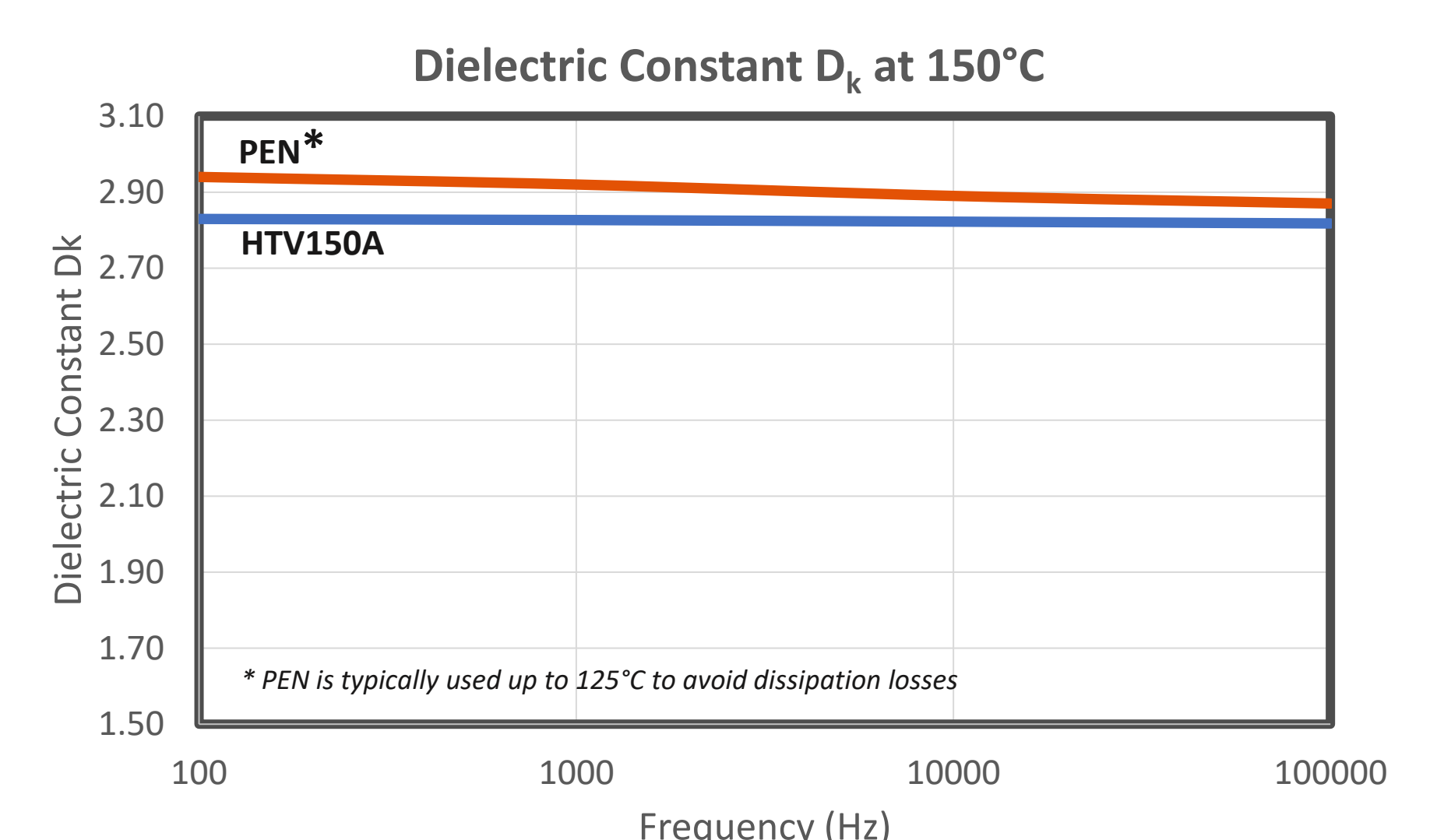
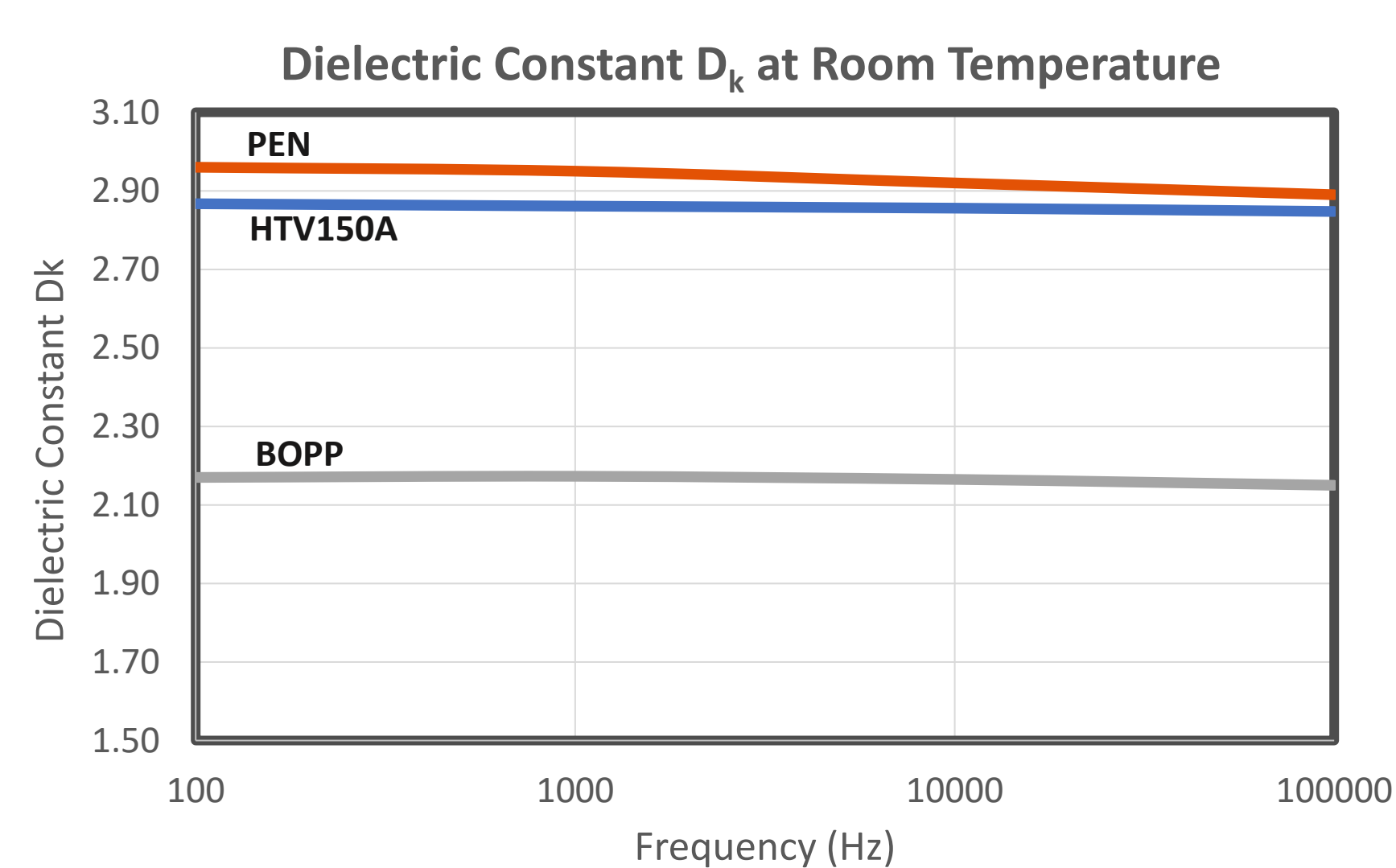
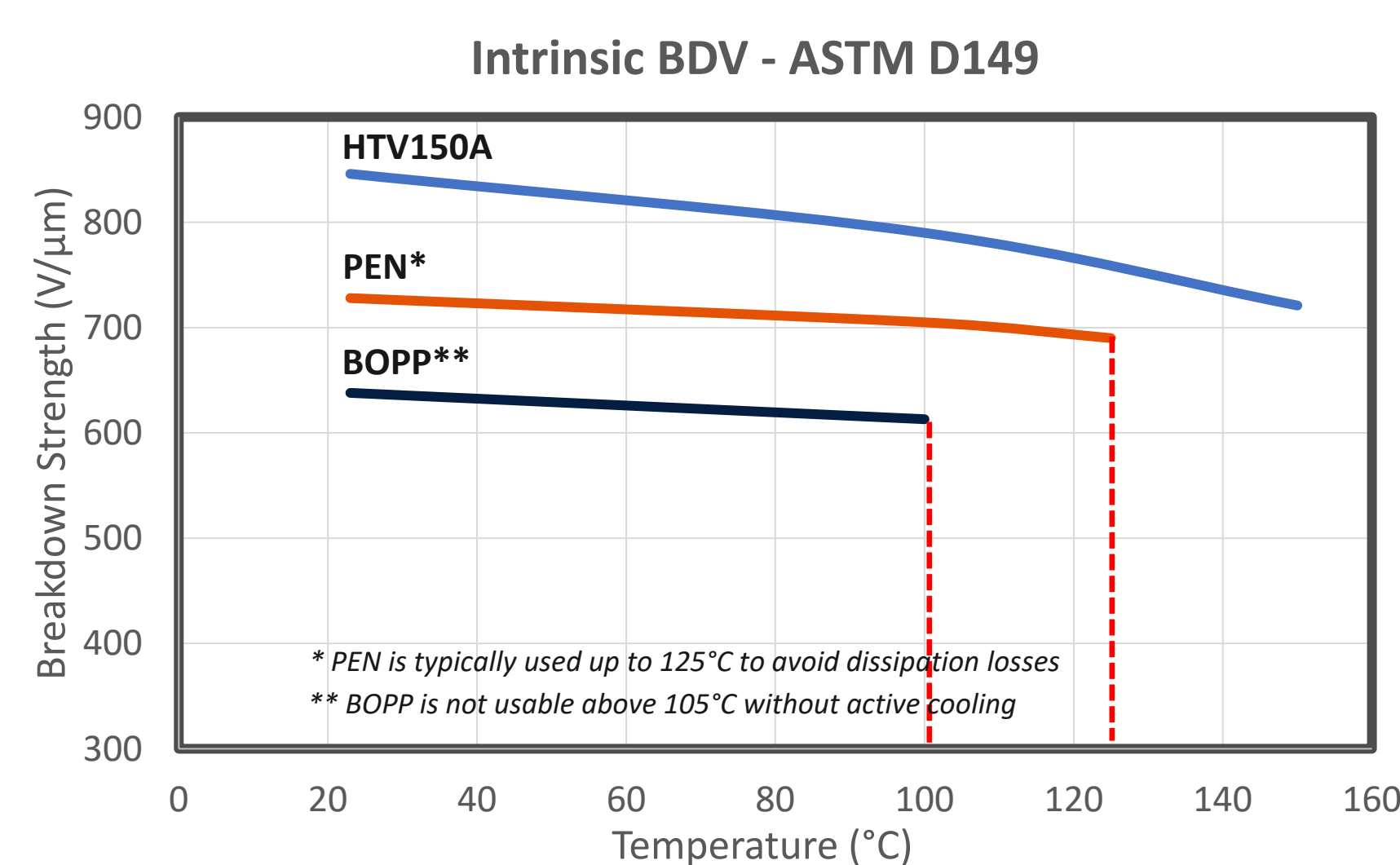
125°C:

- PET: Polyethylene terephthalate
- PEN: Polyethylene naphthalate
- PP-COC: Polypropylene - cyclic olefin copolymer

85°C – 115°C:

- BOPP: Biaxially oriented polypropylene
- High Crystallinity

Electrical Characteristics:



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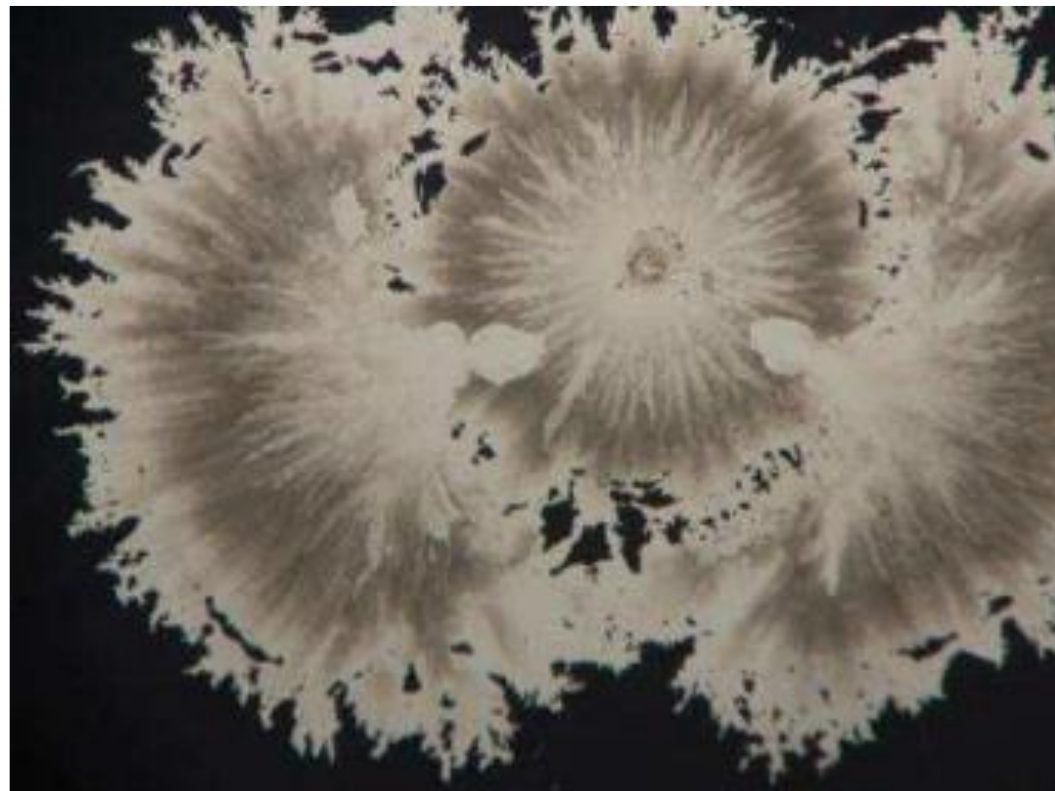
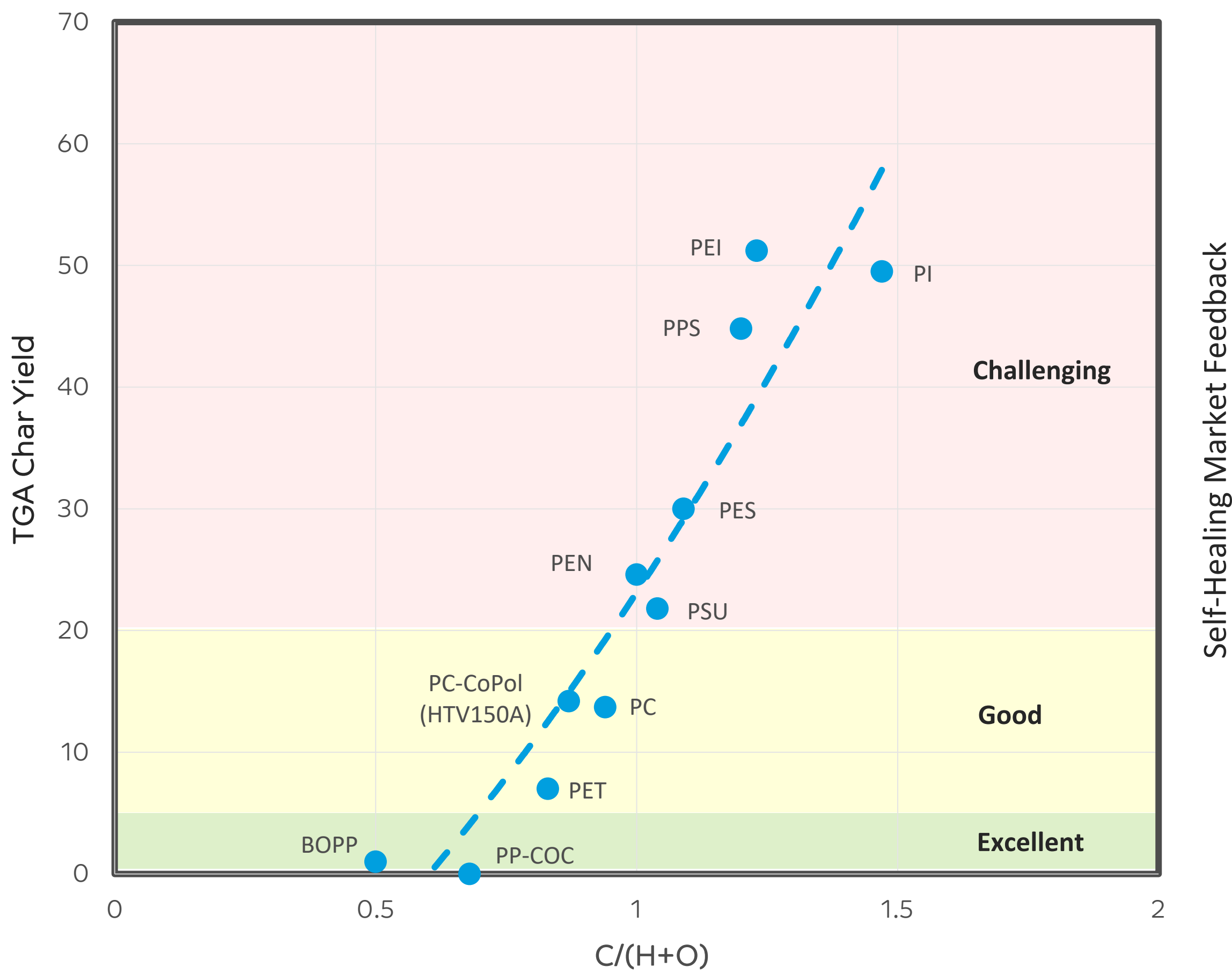
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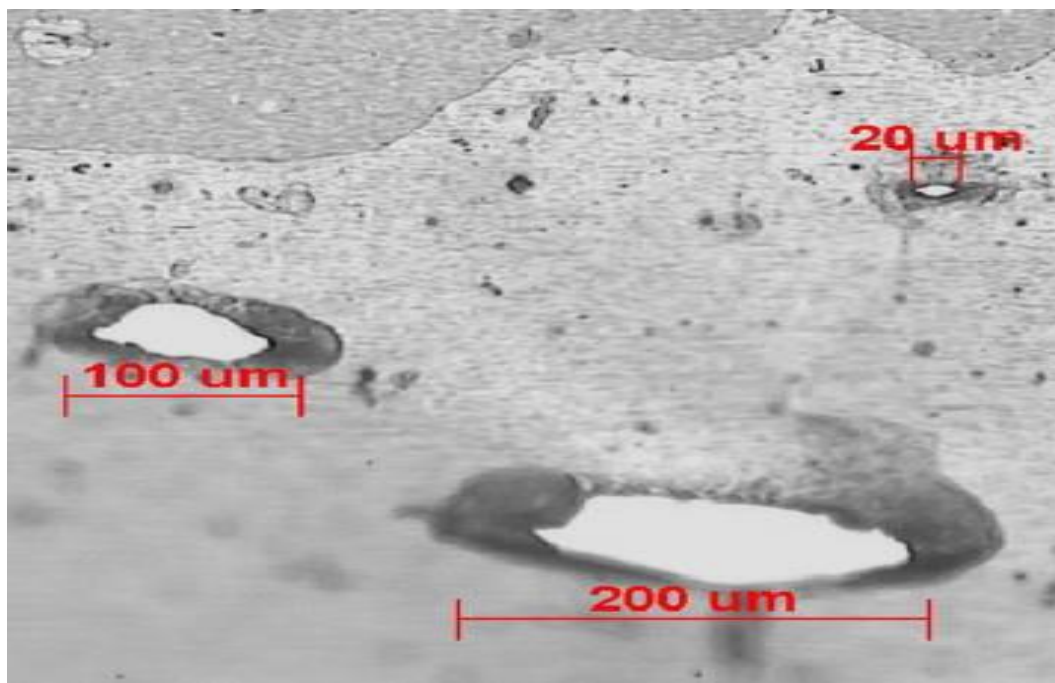
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Self-healing of polymer films in capacitors

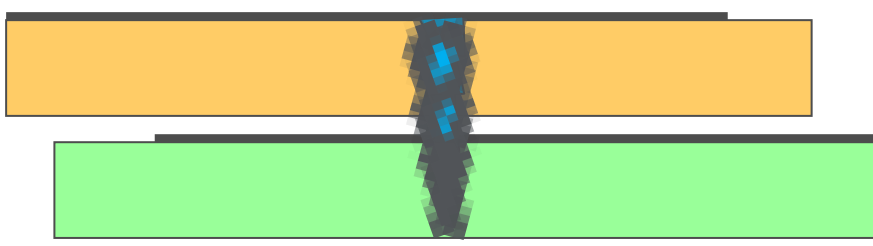


* M. Carlen (2003)

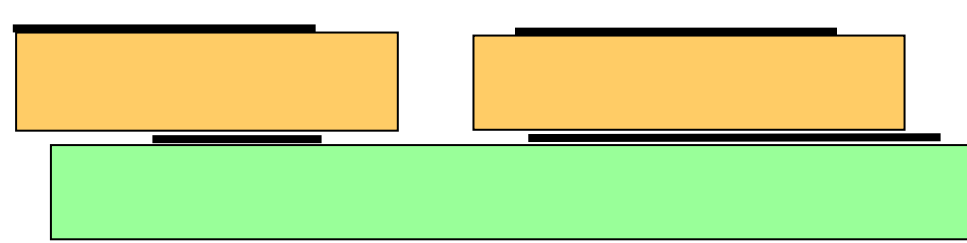


* M. Carlen (2003)

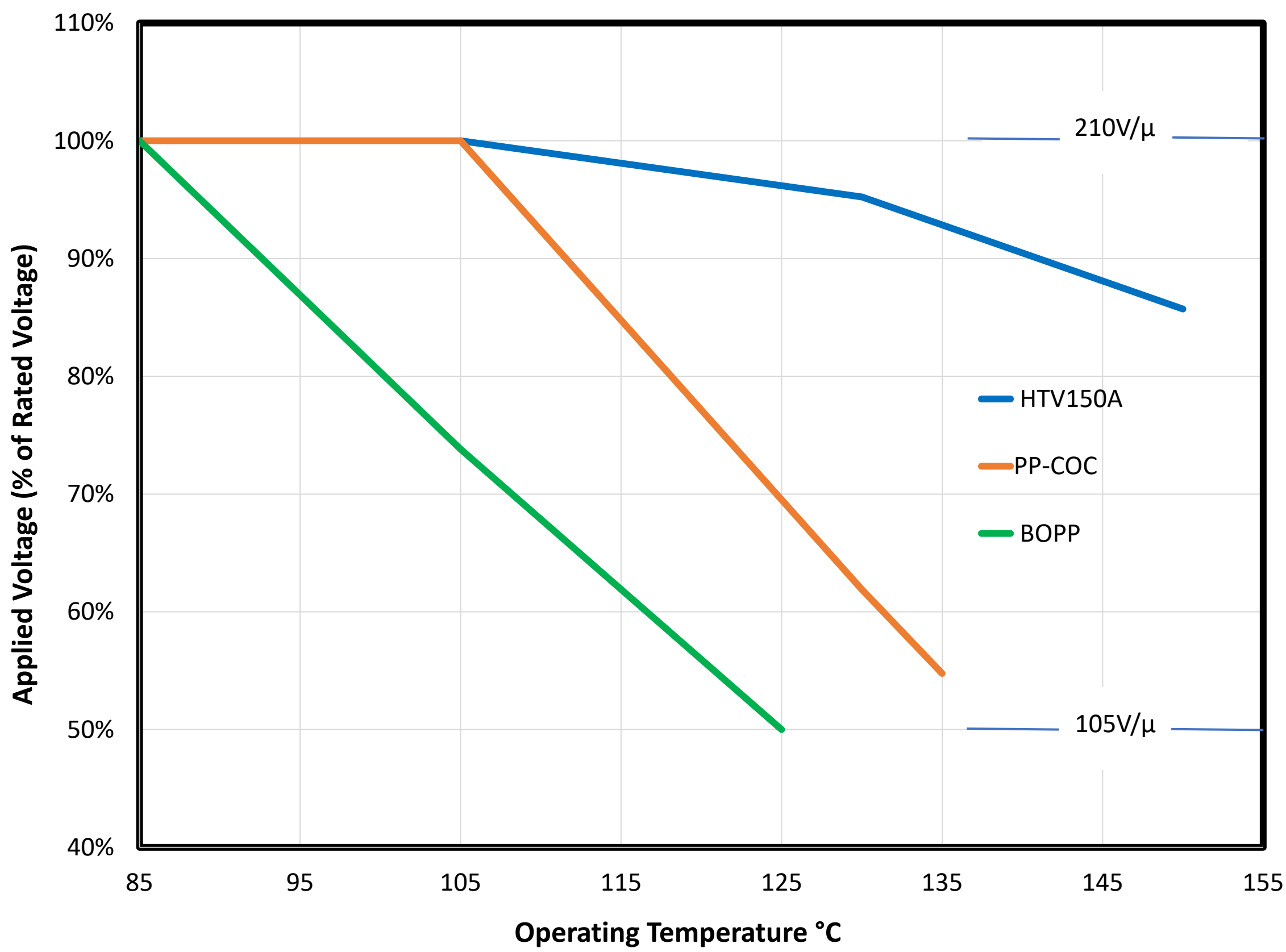
Ineffective self-clearing
(Conductive path- electrical short)



Effective self-clearing
Isolated primary clearings
(No electrical short)



Voltage derating in capacitors made with HTV150A, BOPP, and PP-COC polymer films



- **Caps with PC-CoPol (HTV150A):**
 - 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

- **Caps with BOPP*:**
 - 50% Voltage Derating when Temp 85 → 125°C

- **Caps with PP-COC (BOEPN*):**
 - 45% Voltage Derating when Temp 105 → 135°C

*U. Wahner, and C. Alba (2023)

Performance characteristics of materials used in polymer film capacitors

	BOPP	PP-COC	PET	PEN	PPS	PEI (UTF120)	PC-Copolymer (HTV150A)
Intrinsic BDS 23°C (V/μm)	690	700	800	660	530	590	850
Intrinsic BDS 150°C (V/μm)	NA	NA	NA	NA	465	510	700
Dk at 1 kHz	2.2	2.2	3.3	3.0	3.0	3.1	2.9
Df at 1 kHz	0.0007	0.0007	0.0040	0.0040	0.0005	0.0020	0.0017
Temperature Range (°C)	-55 to +105	-55 to +125	-55 to +125	-55 to +140	-55 to +150	-55 to +175	-55 to +150
Self-Healing 23°C	●●●	●●●	●	●	●	●	●●
Self-Healing 150°C	●	●	●	●	●	●	●●
Metallization	REQUIRES PLASMA	REQUIRES PLASMA	●●	●●	●	●●	●●
Solder Reflow Capable	NO	NO	NO	YES	YES	YES	YES
Available Thickness (μm)	>2.0	>3.0	>0.5	>1.2	>1.2	>4.0	>3.0
Cost	LOW	HIGH	MEDIUM	HIGH	VERY HIGH	HIGH	HIGH
Commercial Availability	●●●	●	●●●	●	●	●●●	●●●
Overall Performance at 150°C	●	●	●	●	●	●●	●●

●●● Excellent ●● Good ● Moderate ● Poor ● None

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