20-G-017: Polymer Multi-Layer Capattery

Sandia National Laboratories

ADVANCED FUZING TECHNOLOGY

Low Voltage PML Capacitor Development and Characterization

Presented By:

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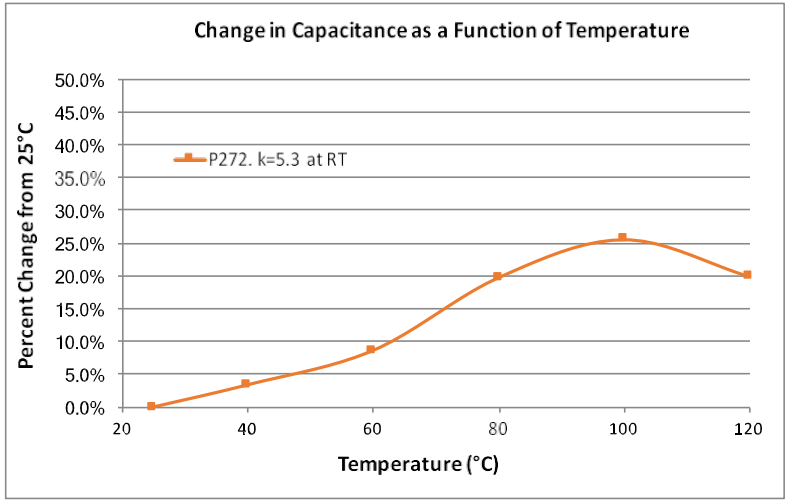
Introduction

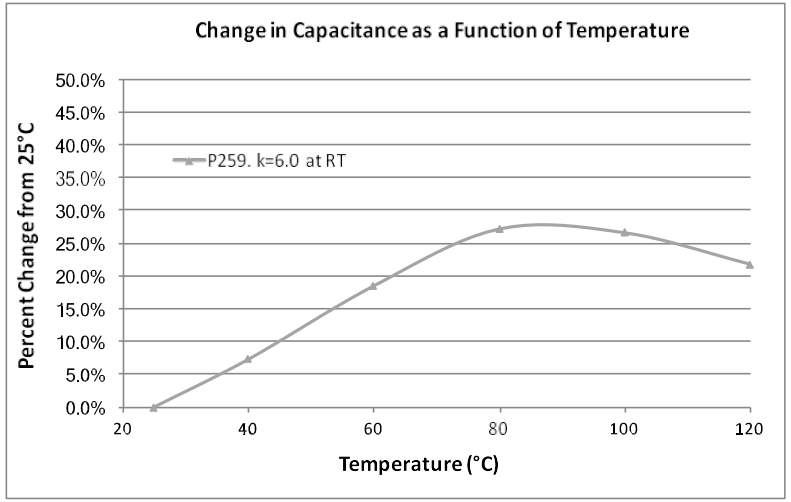
Polymer Multi-Layer (PML) capacitors display advantageous characteristics worth pursuing

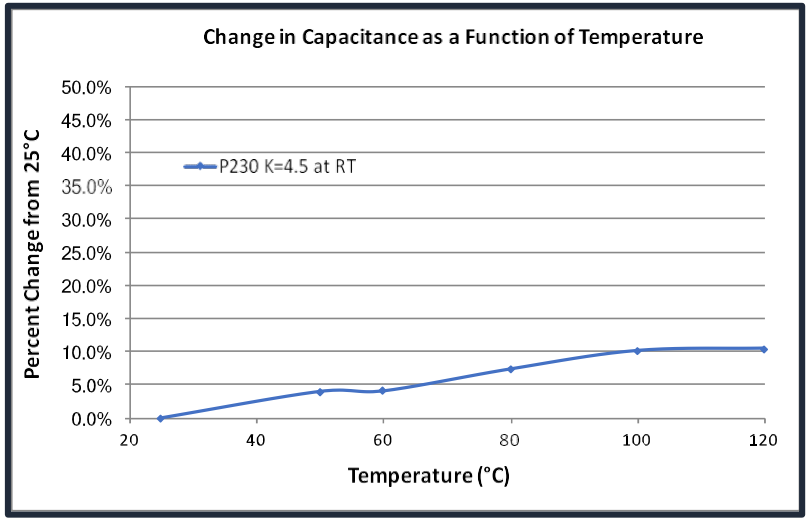
- High energy density
- Lightweight
- Robust
  - Self-healing
- Stable
  - Temperature
  - Voltage

COTS PML capacitors (licensed by PolyCharge America Inc.) not optimized for energy density

- Can be improved through material selection and processing







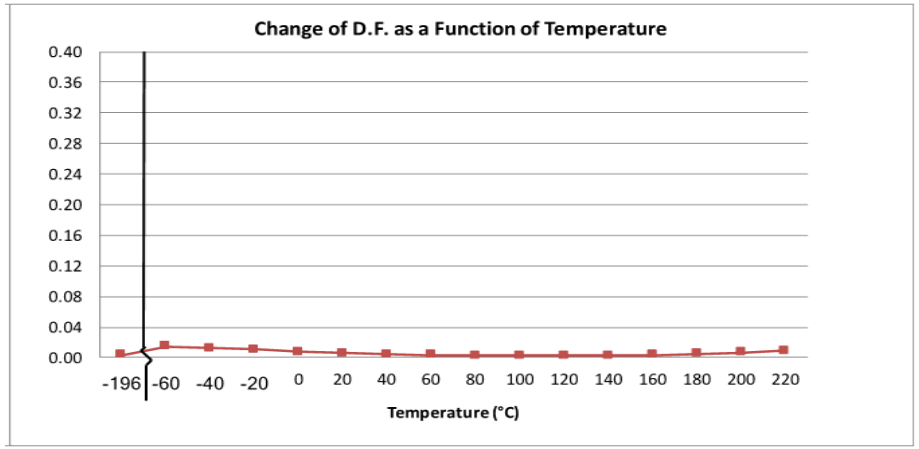
Multiple polymer formulations evaluated for dielectric characteristics

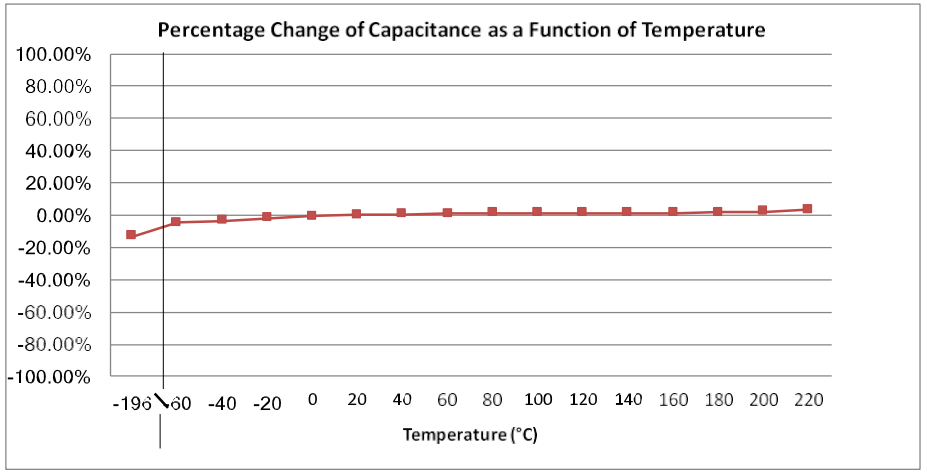
Material Fabrication Challenges

Attempted fabrication of P230 material. Ultimate Failure due to moisture sensitivity

	Sample 1	Sample 2	Sample 3	Sample 4
Initial Leakage (μA)	1117	691	1292	1004
Leakage after vacuum drying (μA)	19	15	87	80
Leakage after 3 hours (μA)	45	44	40	31
Leakage after 24 hours (μA)	1174	924	1241	1800

Returned to standard polymer formulation, using very thin layers



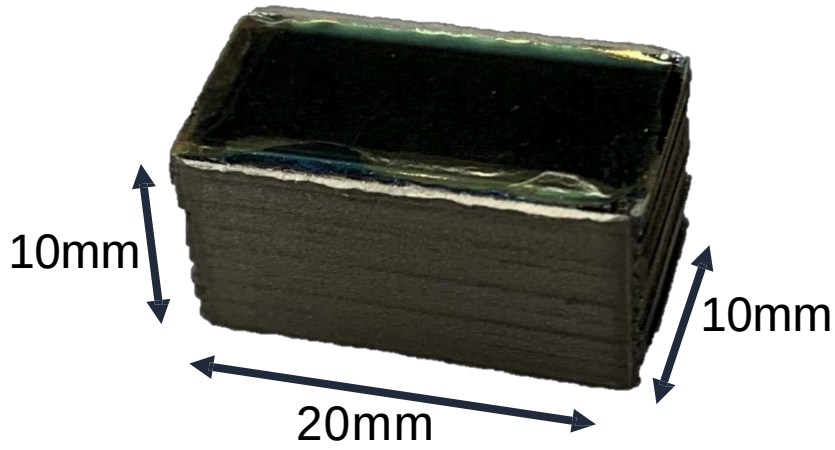


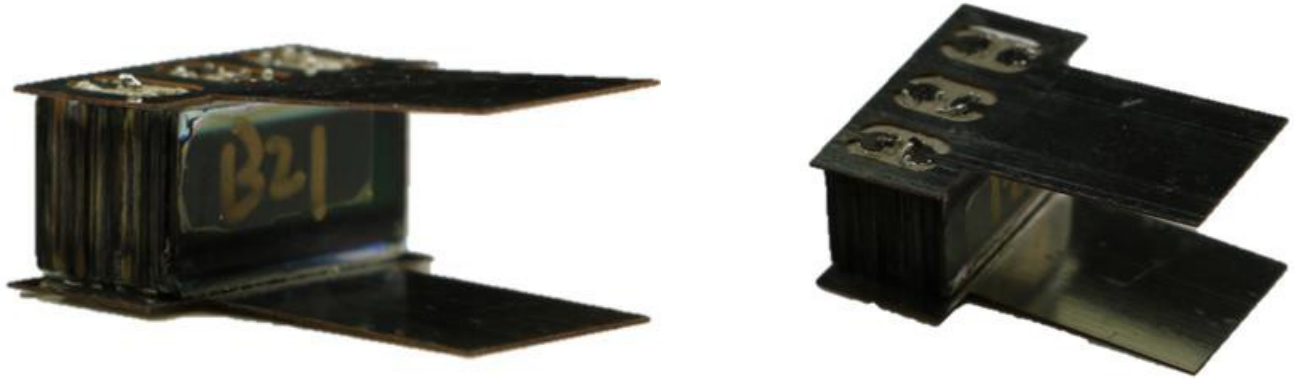
Lower dielectric constant (k=3.2), but extremely stable across temperature and easier to fabricate

Prototype Hardware

Prototype PML Capacitor completed and tested

- Frequency characterization
- Temperature characterization
- Leakage current vs voltage
- Voltage characterization
- Comparison to alternative technologies
  - Ceramics (X7R[1] and X5R[2])
  - Tantalum[3]
  - Hybrid/Wet Tantalum[4]

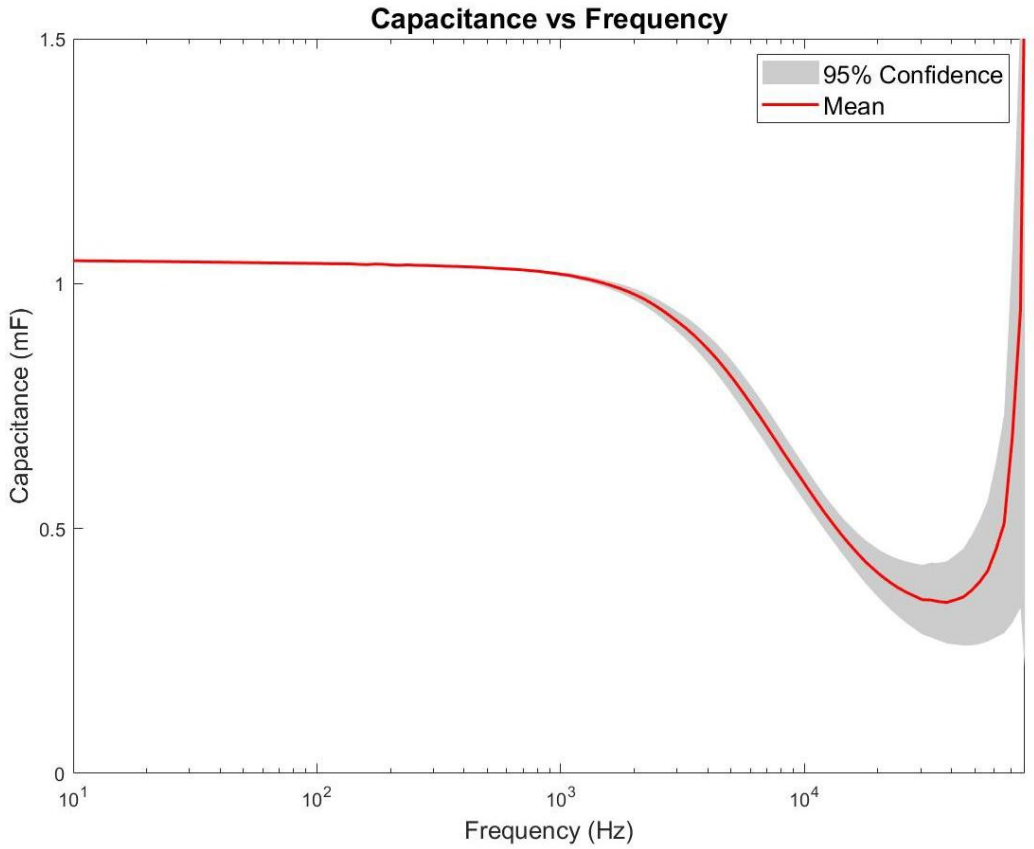




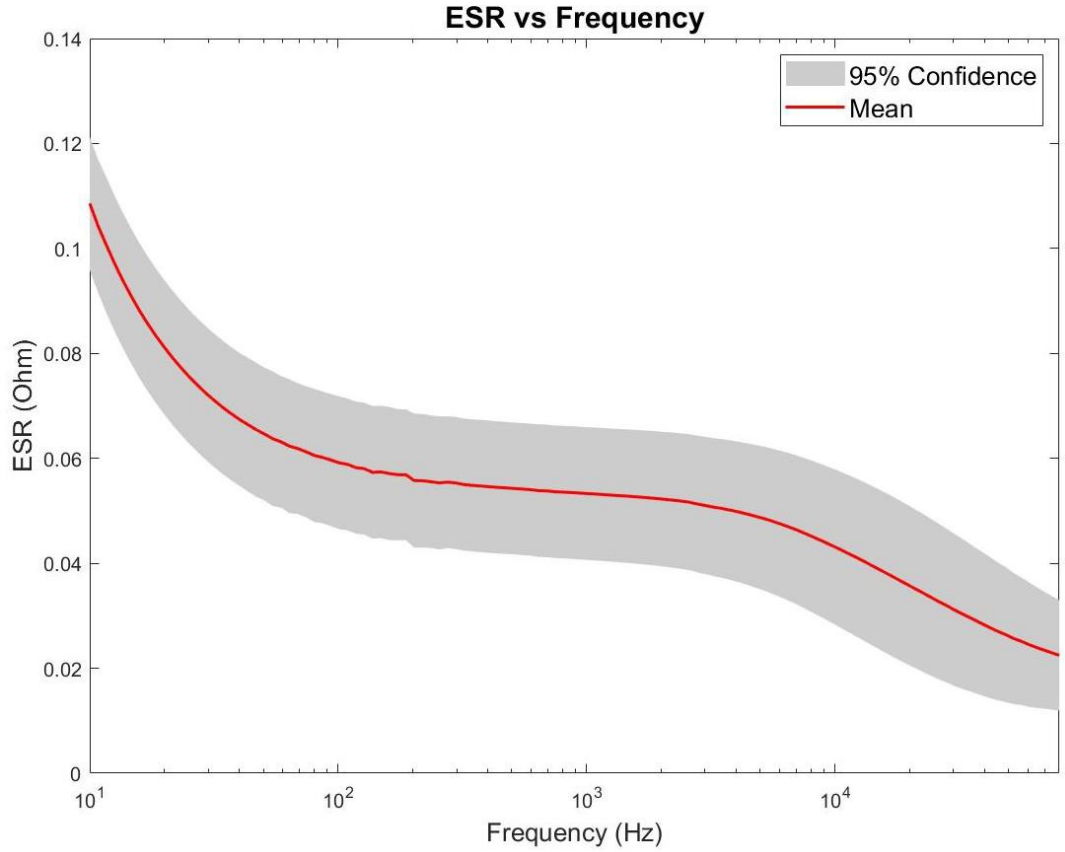
15 Capacitors Received and Tested

Comparisons made to the following part numbers
(1) P/N: GCJ21BR71C475KA01, (2) P/N: GRM31CR61C476ME44
(3) P/N: TAJE337M016RNJ, (4) P/N: HC2B025102

Frequency Characterization

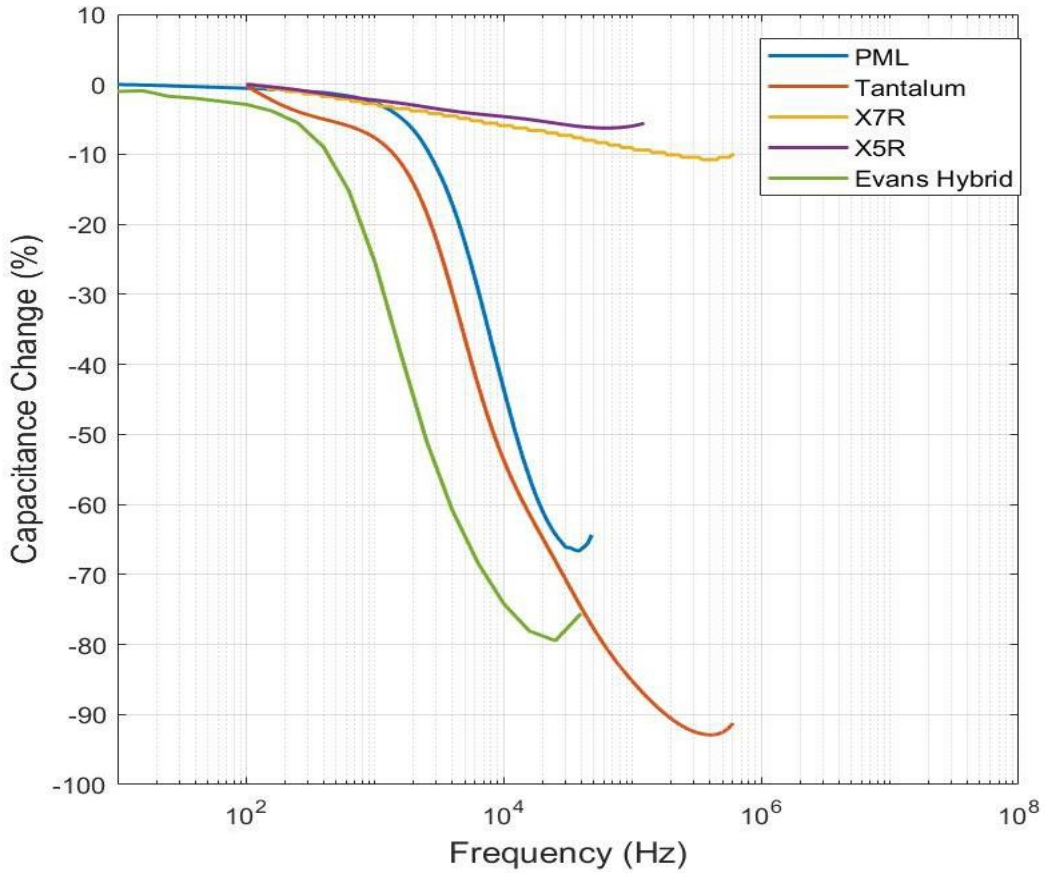


Capacitance roll-off after 1kHz

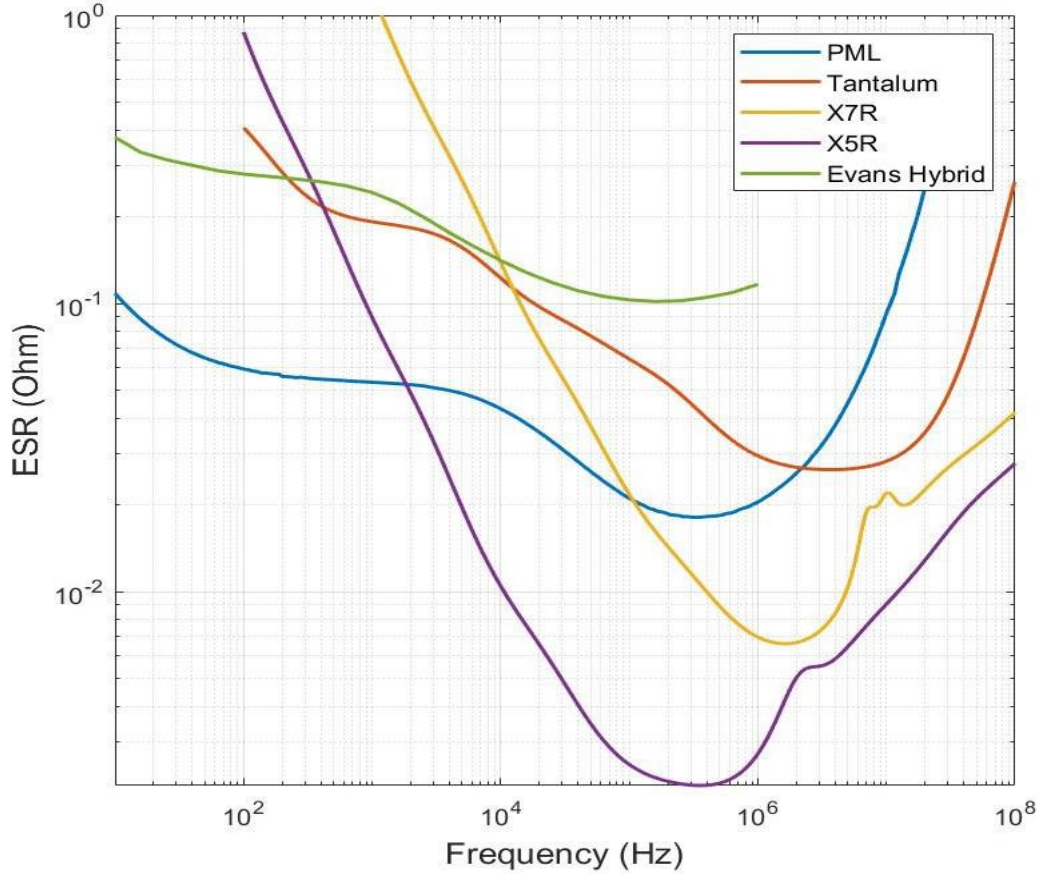


Low ESR

Frequency Comparison

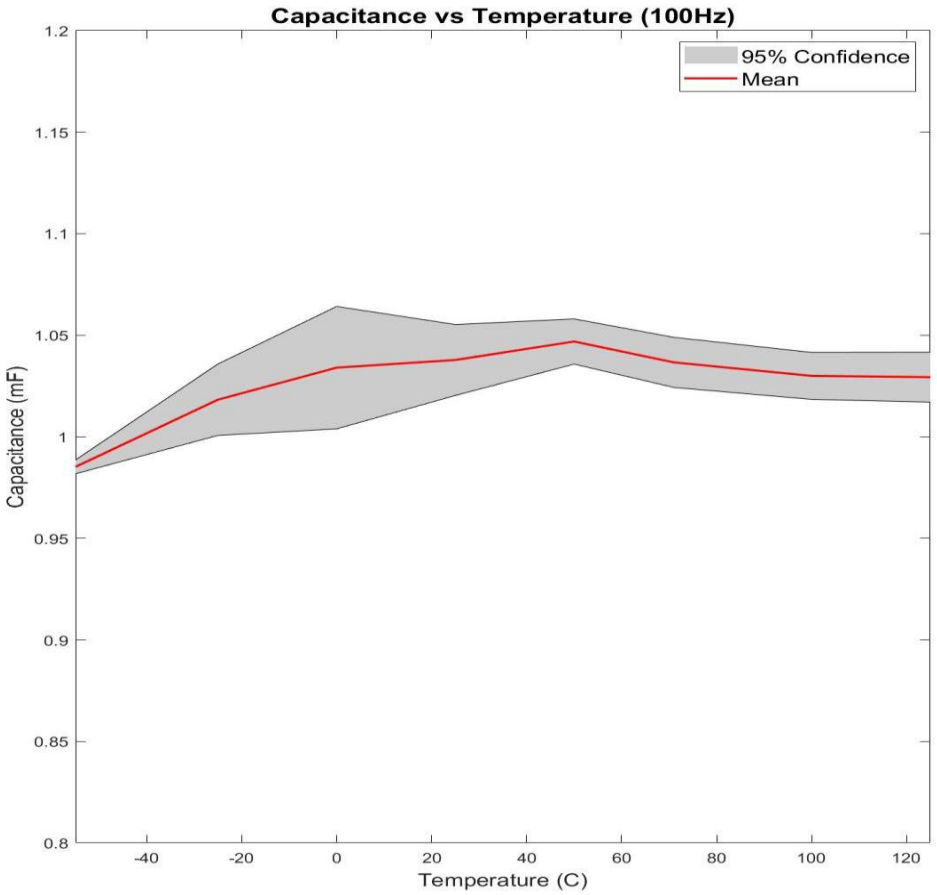


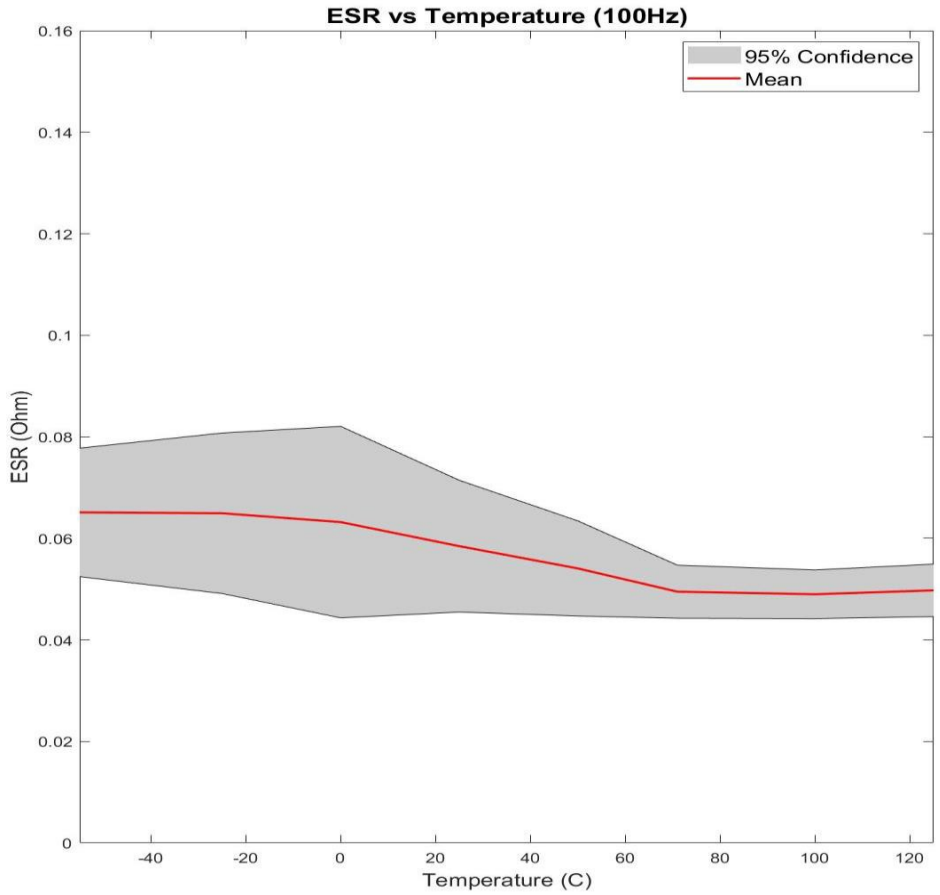
Similar roll-off to tantalum
Ceramics stable



ESR comparable, best at low frequency

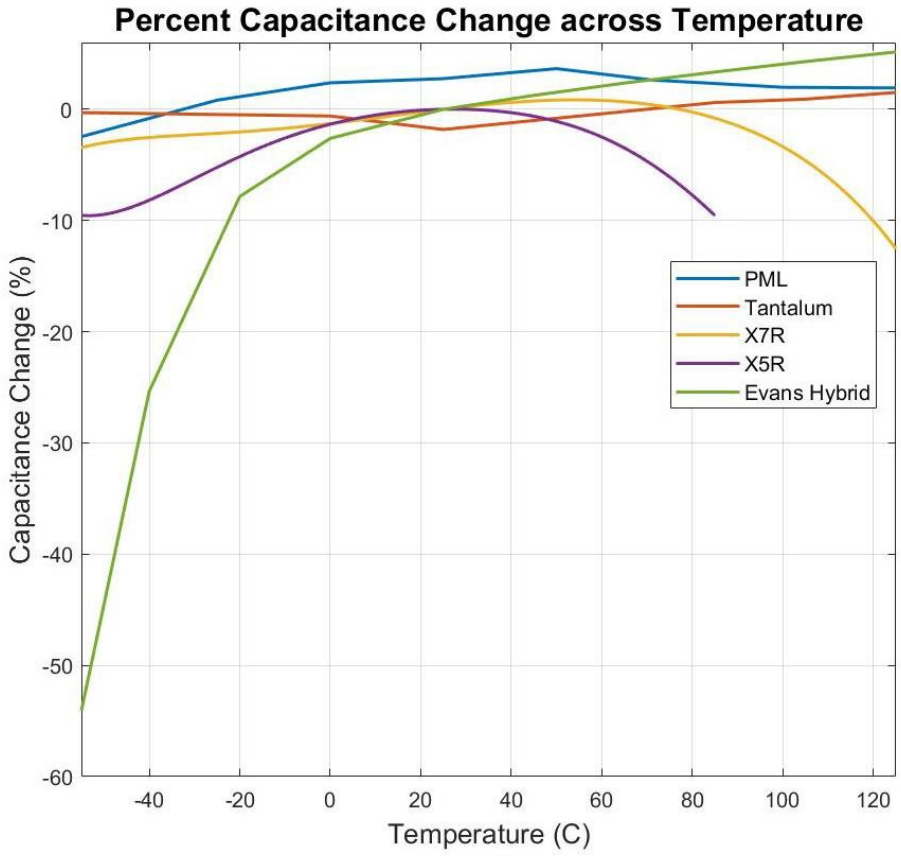
Temperature Characterization



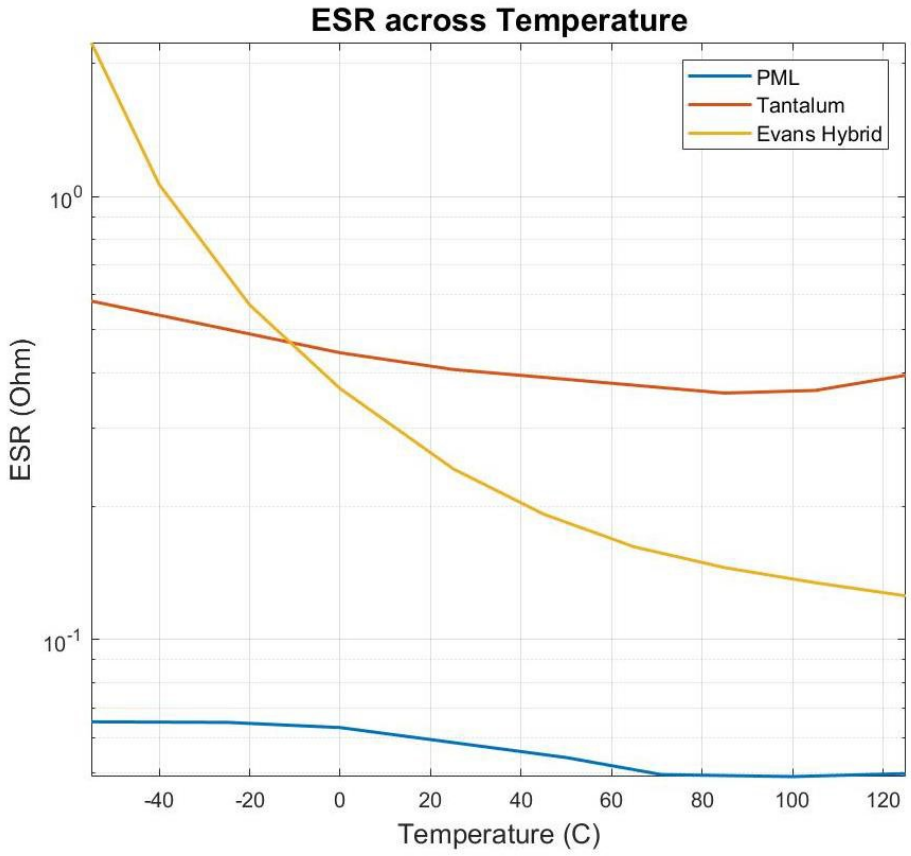


Very stable across temperature

Temperature Comparison



PML and tantalum are top performers

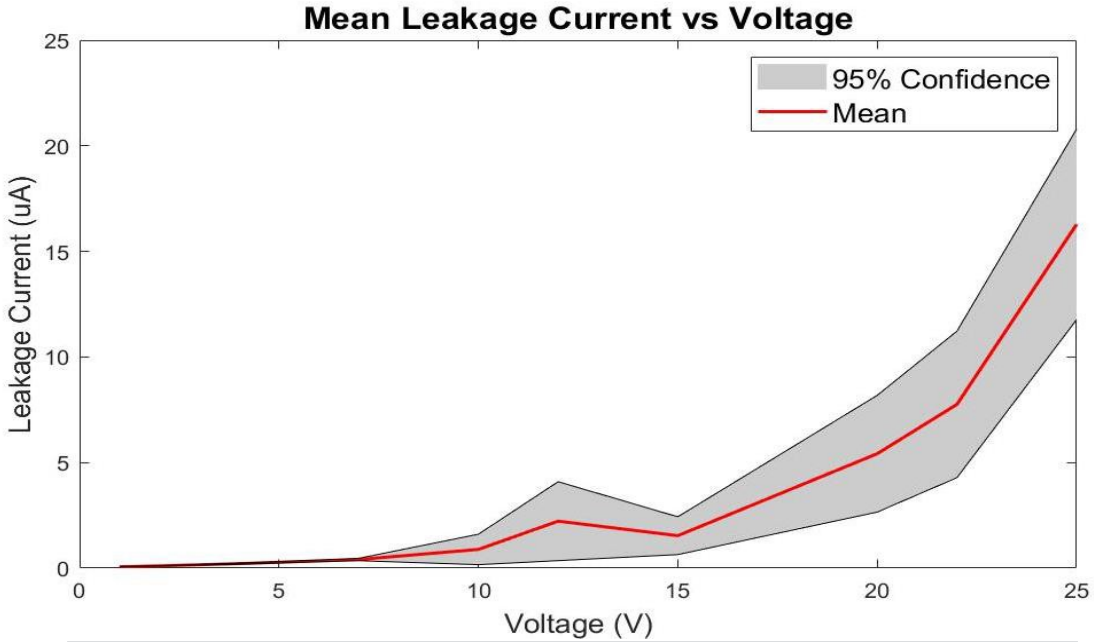


PML ESR ~10X better ESR than tantalum. No data on ceramics.

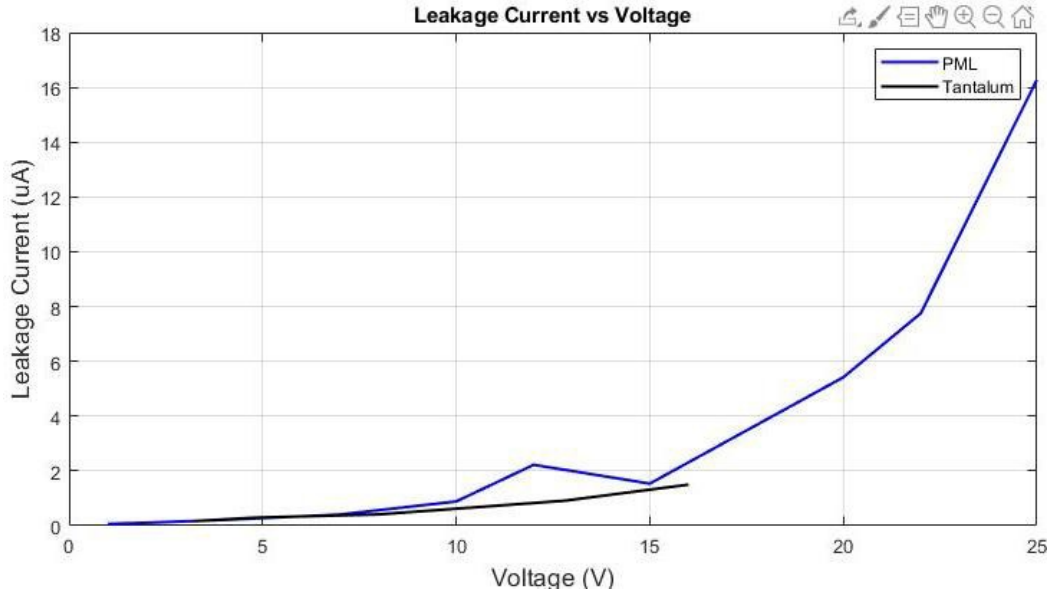
Leakage Current

Limited Leakage Current Data

- **X5R: 15.1µA at 16V**
- **X7R: 17µA at 25V**
- **Hycap: 7.5µA (unknown voltage)**
- **Tantalum: 1.7µA at 16V (plot below)**



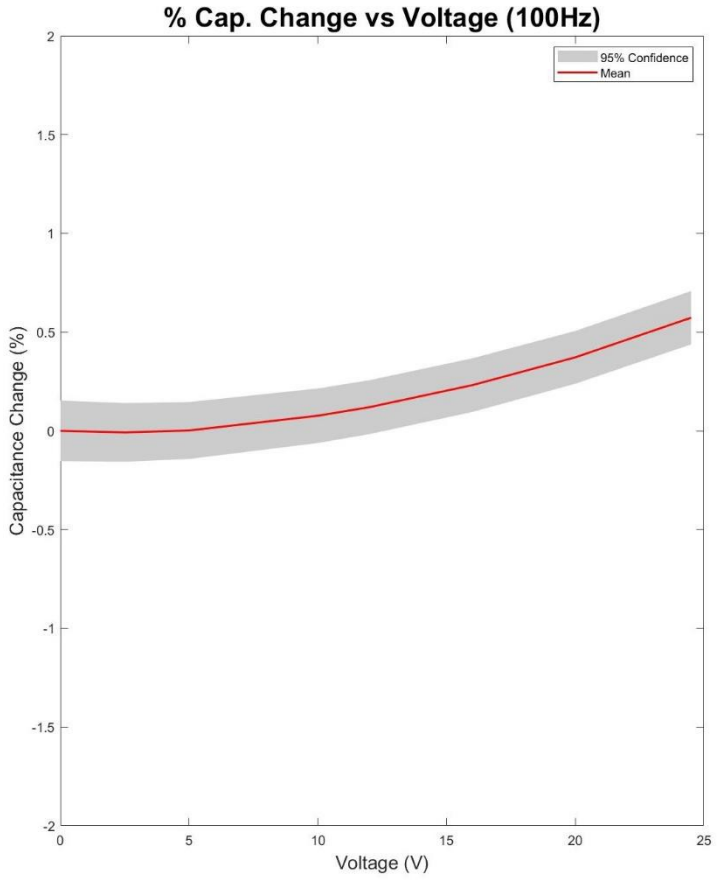
PML Leakage Current

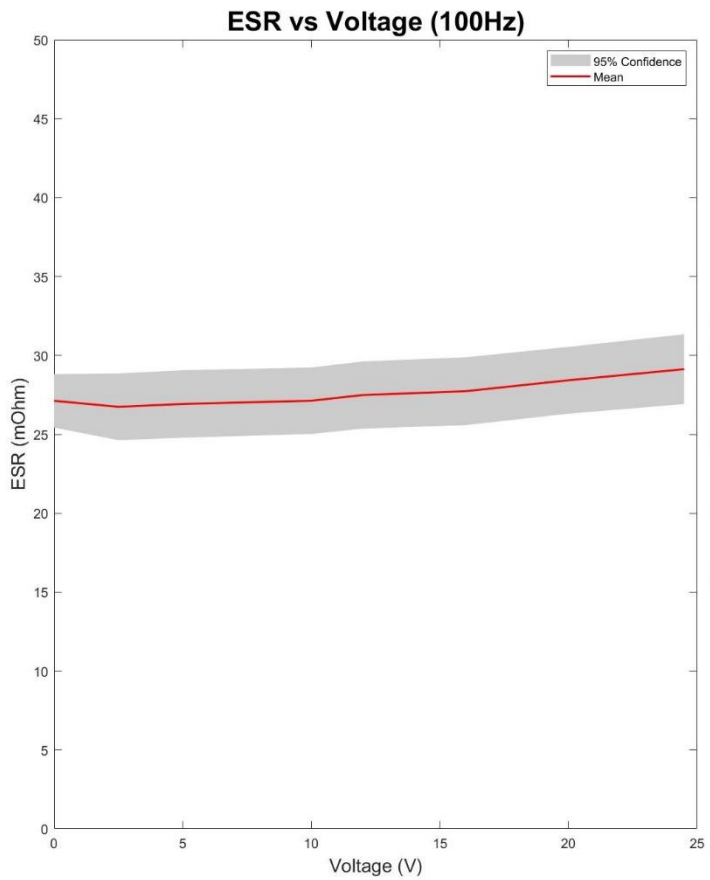


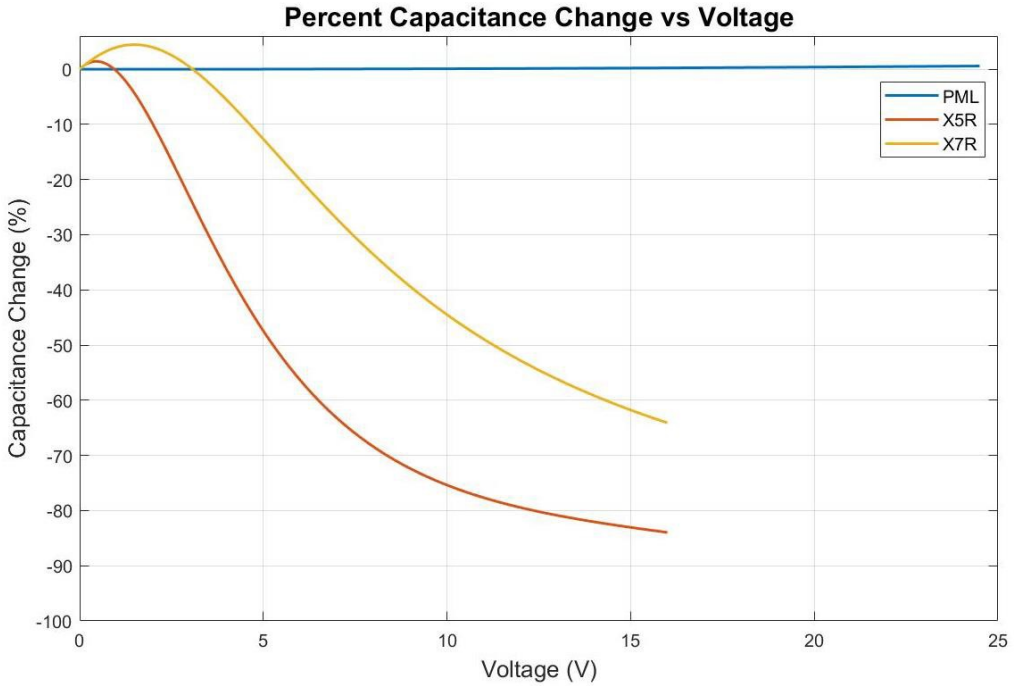
Comparison to Tantalum

Comparable leakage current to alternatives

Voltage Characterization







Extremely stable across voltage
Known capacitance loss with ceramics

Comparison Chart

Volumetric Capacitance (VC): Capacitance (mF) / Volume (cm^3)

Capacitor	VC at 0V	VC at 12V	VC at 125C at 12V	VC at -55C at 12V
PML Prototype	.52	.52	.52	.52
X7R Ceramic	1.5	.54	.52	.48
X5R Ceramic	5.74	1.18	1.07 (@ 85C)	1.07
Tantalum	2.56	2.56	2.64	2.54
Evans Hybrid	1.54	1.54	1.68	.72
COTS PML	.28	.28	.28	.28

Inherent stability makes comparisons more favorable for PML
ESR, reliability, and robustness (not captured in chart) add to PML desirability

Conclusions

- Initial development and demonstration of prototype PML capacitor complete!
- Great electrical and mechanical characteristics inherent in the material
- Continuing to develop improved designs for increased energy density and usability
  - Prototype 2: 1mF, 10mm x 10mm x 10mm (half the size!)
  - Prototype 3: Same material as 2 in 5mm x 5mm x 5mm footprint
- Mechanical testing to come

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