

# Advanced Capacitors for Future Power Conversion Systems

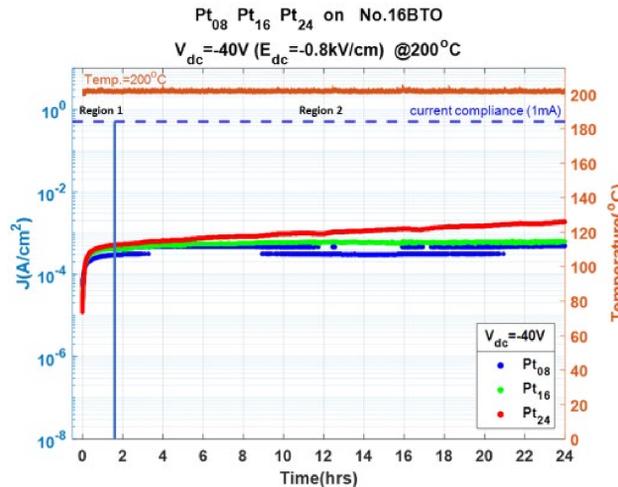
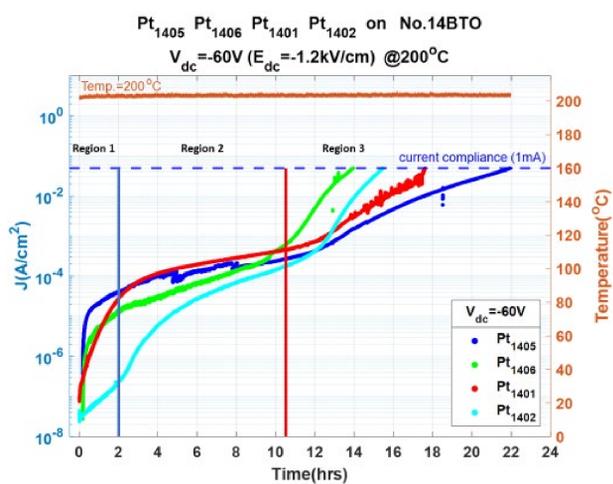
Project # 1853191

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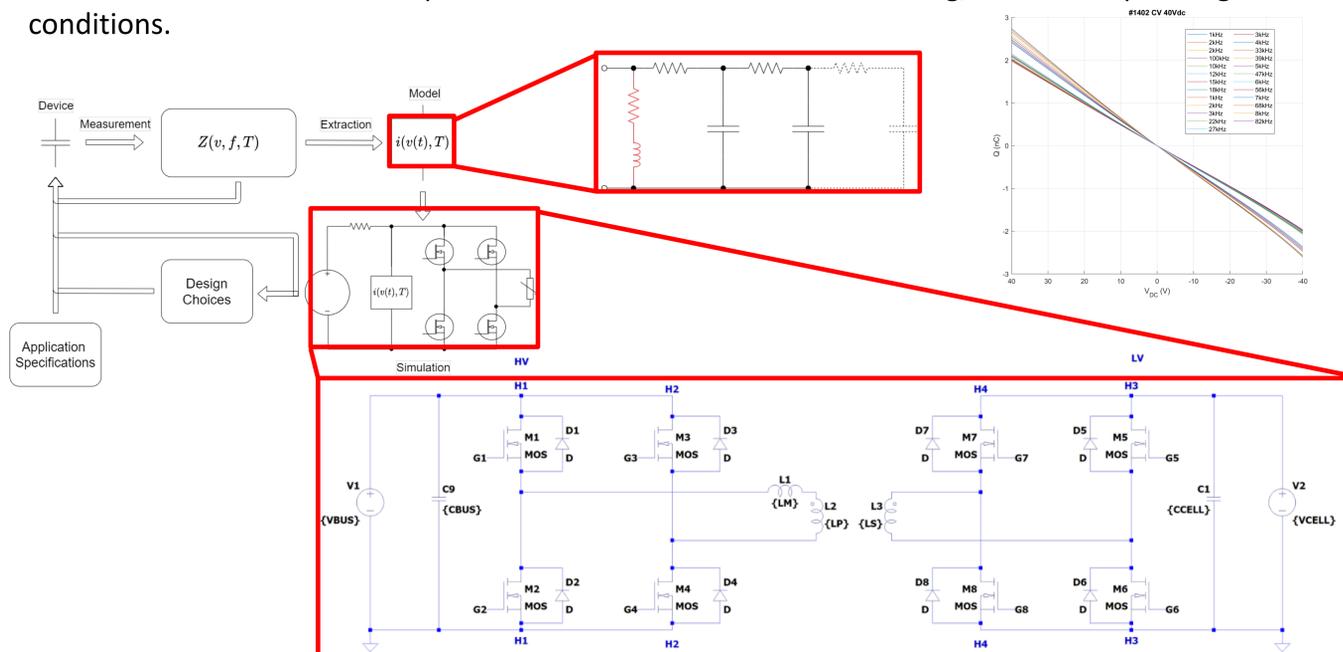
## Abstract

The overall goal of the project is to improve reliability of high density, high voltage capacitors, which allows higher frequency operation, reducing the size and cost of passive components in the power converter. SPICE models can be used to optimize the required capacitor characteristics. Capacitors are critical for voltage source converter functionality. DC-link capacitors are known to have reliability issues. Resistance degradation at high temperature is one of the primary failure modes in capacitors.

### BaTiO<sub>3</sub> capacitor structure



At a DC field of -1.2 kV/cm the capacitors go through three distinct degradation phases (left figure). Stage 1- leakage current density increases sharply; Stage 2 - the leakage current density increases slowly; Stage 3 - the leakage current density increases quickly until reaching compliance limit. When a DC field of -0.8 kV/cm is applied, the capacitors appear to stay in the 2<sup>nd</sup> stage for extended periods (see right figure). It shows the degradation of single crystal BaTiO<sub>3</sub> capacitors depends strongly on electric field. This can have implications for both accelerated life testing, as well as operating conditions.



## Accomplishments

### 2019:

- Demonstrated there are two different conduction mechanisms in BaTiO<sub>3</sub> with different activation energies, needed to develop accelerated life testing

### 2020:

- Demonstrated that a conductive oxide layer deposited between the cathode and single crystal BaTiO<sub>3</sub> can improve resistance degradation in BaTiO<sub>3</sub> capacitors

### 2021:

- Developed a SPICE model for a dual bridge converter topology which allows us to simulate the operating characteristics of the converter as a function of capacitor characteristics and degradation
- BaTiO<sub>3</sub> capacitors show 3 different stages of degradation, with the 3<sup>rd</sup> region being a rapid increase in resistance degradation. The lifetime of the capacitors can be extended by operating at lower electric fields (<1kV / cm)

## 2022 Objectives

- Experimentally verify the dual bridge converted simulator tool performance
- Develop simulation tool for other power converter topologies
- Use simulation tool to determine required capacitor performance metrics for different power converter topologies

## Conclusion

- Understanding degradation as a function of capacitor operating characteristics is critical to reliable power converter design.

## Acknowledgements

This work is supported by the DOE Energy Storage program and Dr. Imre Gyuk. We would like to thank Dr. Stan Atcity and Dr. Jon Bock, both from Sandia National Lab, for their technical leadership and many thoughtful technical discussions.

## Related work

Working with Texas Instruments to understand impact of radiation on wide bandgap-based power electronics components

Capacitor measurements are made to extract model parameters for use in SPICE simulations. This allows for the identification of anomalous system behavior that could be caused by the interaction of component parameters and the control loop used to regulate the converter. These insights can then be used to inform component design choices to aid in overall system performance.