Glass Dielectrics for DC Bus Capacitors

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APE010

Overview

Timeline

- Start date October 08
- End date September 11
- Percent complete 70%

Budget

- Total project funding
  - DOE share $600k
- FY09 $150k
- FY10 $150k

Barriers

- Barriers
  - Availability of high temperature capacitor components to reduce the overall cost and increase performance of APEEM electric propulsion systems.
  - Materials with sufficient high temperature performance for incorporation into a DC BUS capacitor.

Partners

- Argonne National Lab
- Sandia National Lab

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Project Objectives

- The overall objective is to build glass capacitors with high temperature reliability. The purpose is to build and test a capacitor prototype that is capable of operating at 140 °C at 600V (Advanced Power Electronics and Electric Motors - APEEM Goal).
- The research directly addresses the DOE APEEM requirements for HEV/EV/PHEV power modules that do not need internal cooling.
- Leverage the substantial investment has occurred in flat panel display glass ($30 billion over 3 years) for the development for high-temperature capacitors.
- Specific May 09 – May 10 objective is to demonstrate “self healing” in glass capacitors, which is required for long-term operation (APEEM Goal is greater than 10,000 hrs of power module operation)

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Milestone Slide

Month/Year	Milestone or Go/No-Go Decision
Jan-09	Go/No-Go decision: Down select capacitor material Candidate materials included an experimental glass-ceramic dielectric fabricated at Penn State and a commercial flat panel display glass that is commercially available. The commercial flat panel display glass was selected and development activities on the glass ceramic materials ceased.
August-09	Milestone: Demonstrate that commercial flat panel display glass has electrical properties (permittivity and dielectric breakdown strength) that exceed the requirements for a DC bus capacitor.
Dec-09	Milestone: Demonstrate self-healing mode in glass

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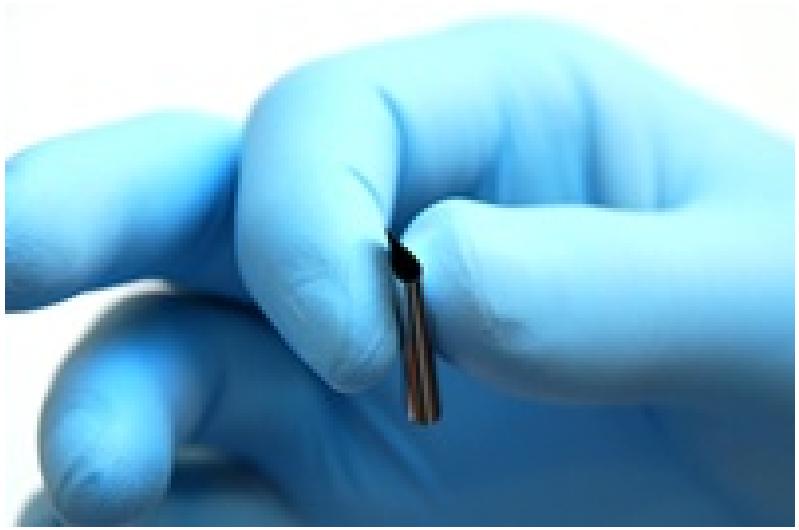
Approach and Strategy

- Approach: Glass is a promising high temperature material that is easily incorporated into a capacitor structure.
- To address reliable capacitor performance, self healing mechanisms are explored in prototype glass capacitors.

Flexibility Demonstration of flat panel display glass



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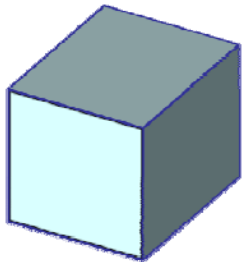
Approach and Strategy

- Use low-cost flat panel display glass in a DC Bus capacitor
- Reduce the total volume of a DC Bus capacitor by incorporating glass materials in the capacitor construction
- Glass has a substantially higher melting point (1400°C) than the melting point of plastics (150ºC) that are presently used in capacitors

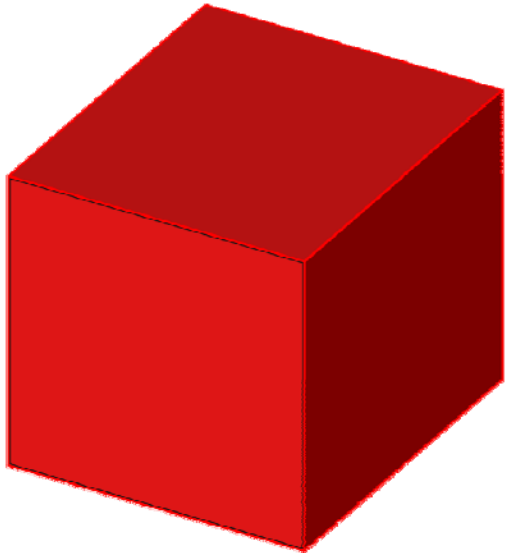
Volume of 1000 µF 600V capacitors in a Hybrid Electric Power Converter

Current Capacitor



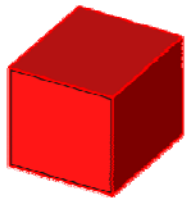
Volume = 1.4 Liters
85ºC Rating

Current High Temperature Capacitor



Volume = 21.6 Liters
125ºC Rating

Future Glass Capacitor



Volume =1.2 Liters
140ºC Rating

Technical Progress and Accomplishments

- Prior to FY10: Demonstrated that flat panel display glass can operate as a capacitor up to temperatures of 250°C
- FY10: Demonstrated thickness dependent dielectric breakdown and the statistics for making glass capacitors more reliable
- Patent disclosure “Self healing high energy glass capacitors”.

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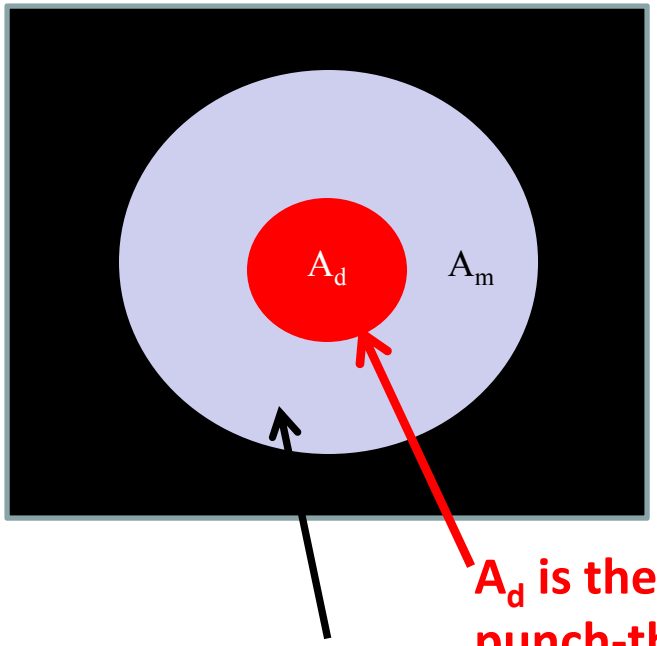
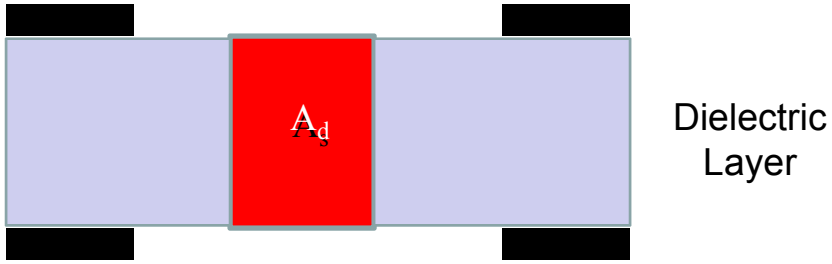
Anatomy of Dielectric Breakdown in Glass

Top view of dielectric breakdown region, demonstrating the relative areas of the dielectric punch-through and electrode clearing regions



Side view of the metal/insulator/metal capacitor structure



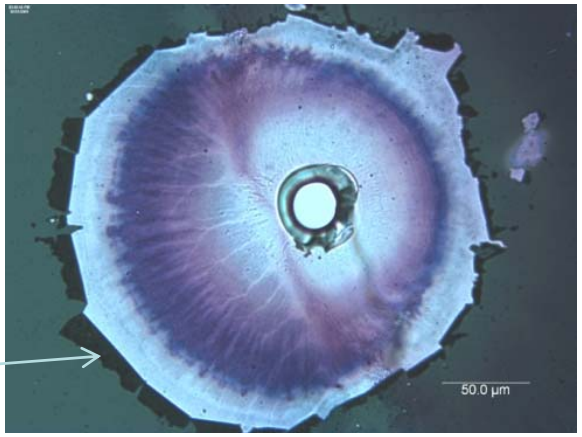
A_d is the area of the dielectric punch-through region

A_m is the area of the metal clearing region

Required for DC Bus Capacitor Reliability

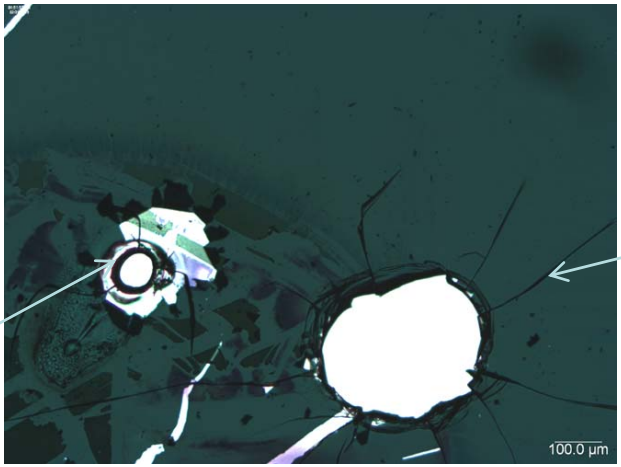
Observation of Failure Sites in a Thin Glass Capacitor

Thin glass (10 µm) has a self healing mode with significant clearing of the electrode away from the glass and very little damage to the glass.



Clearing and no cracks

Thick glass (50 µm) has significant cracking which leads to poor capacitor reliability.

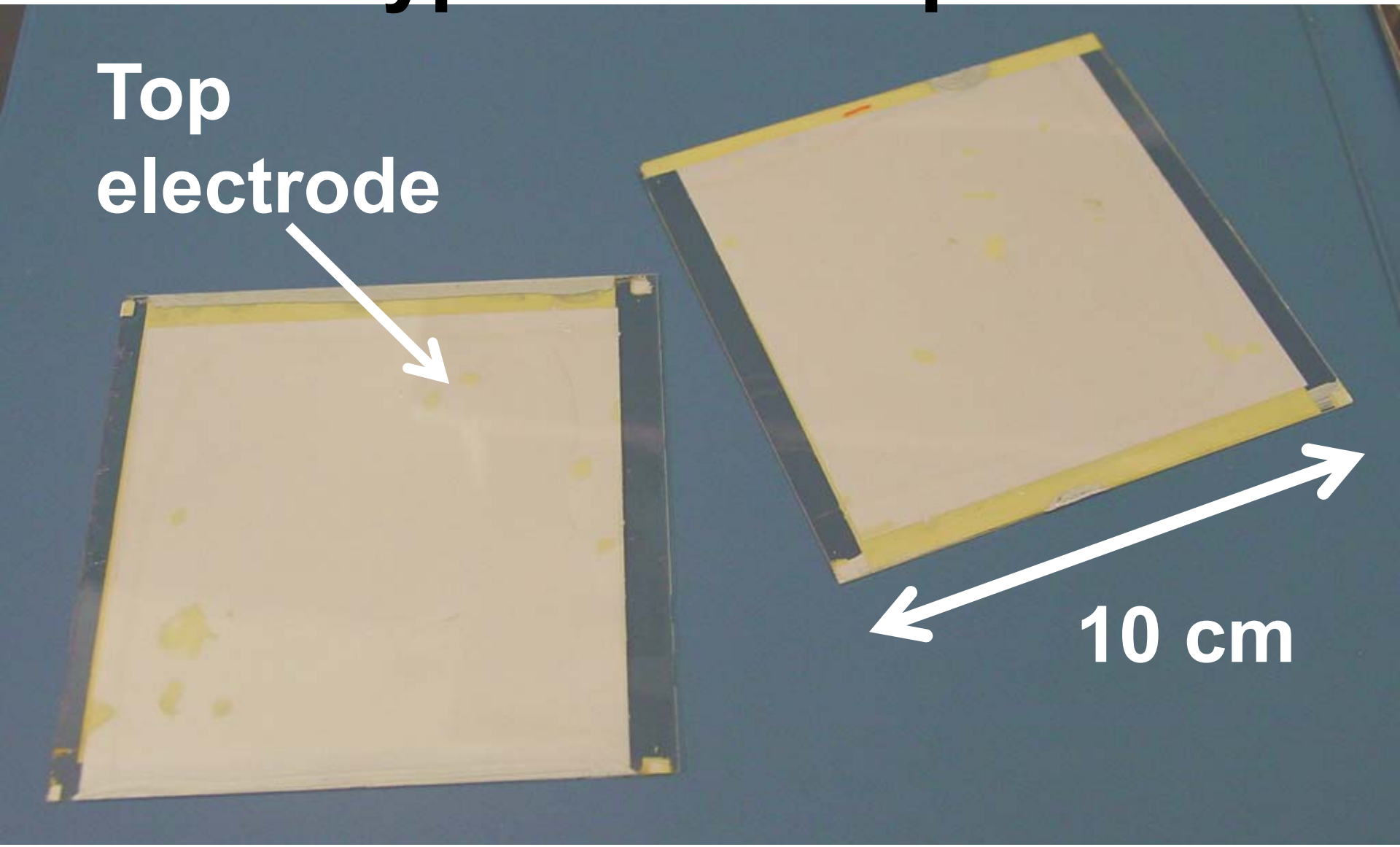


Cracks

No Clearing and Cracks

Required for DC Bus Capacitor Reliability

Prototype Glass Capacitors



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Demonstration of Scale-up Potential

Collaborators

- Argonne National Laboratory
  - Prime contractor
  - Penn State characterizes Argonne capacitors
- Sandia National Laboratory
  - Collaborate on the defining capacitor specifications for APEEM
- AVX Corporation (US capacitor manufacturer)
  - Explore scale-up opportunities for glass capacitors
- Glass Industry
  - Corning, Schott and NEG
  - Educate flat-panel display glass manufacturers on the commercial opportunities in the capacitor industry

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Proposed Future Work

- Develop Highly Accelerated Life Test (HALT) protocols for predicting capacitor life of DC Bus capacitors. APEEM has specific temperature and service life requirements for power inverters and capacitors must
- Continue to test high voltage reliability of thin glass sheets.
- Upcoming milestone: Downselect conductor material that will be used in conjunction with the flat panel display glass to fabricate DC Bus capacitors.
- Link capacitor manufacturers and glass manufacturers to establish a production strategy. Connection between AVX (capacitor manufacturer) and NEG (glass producer) have been initiated by Penn State.

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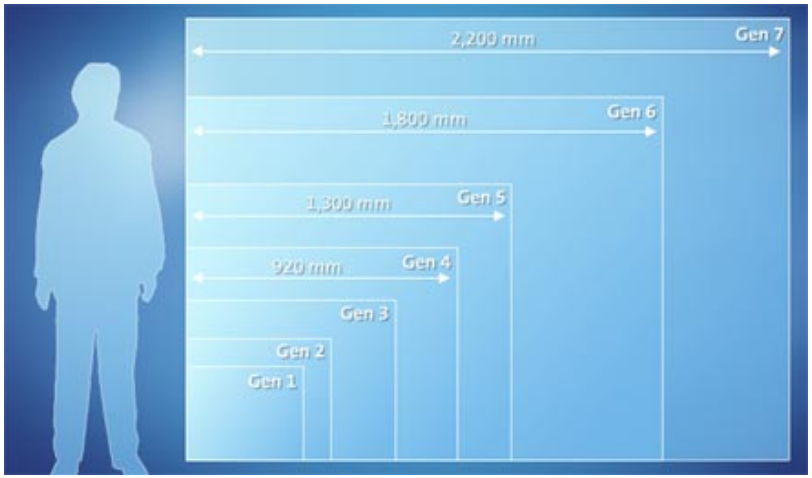
Summary Slide

- **There has been a substantial world-wide expansion in flat panel display glass in the past decade.**
- **This project leverages a large investment ($30B) that has been made in display glass for a completely different technology* – DC bus capacitors for Power Electronics.**



Corning projections for flat panel display sizes

- **In FY10 a self –healing mode has been demonstrated in prototype glass capacitors which is important for achieving >10,000 of life in a DC bus capacitor and power module in a HEV, EV or PHEV.**

*http://investintaiwan.nat.gov.tw/en/news/200601/2006010401.html