Improving Electrostatic Energy Storage Density by Minimizing Voltage Tuning

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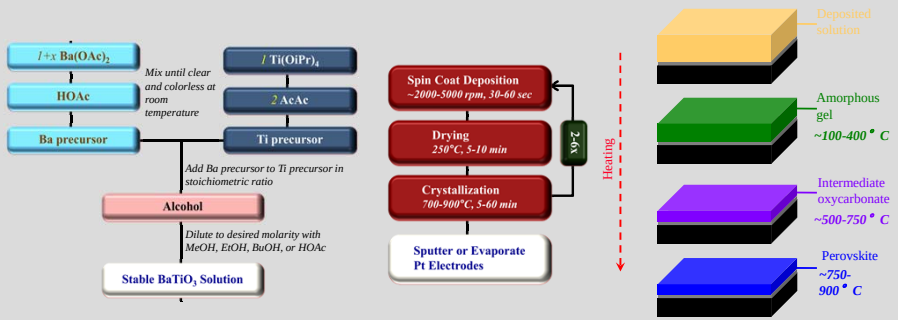
Introduction

High power and high permittivity ceramic capacitors have a myriad of uses throughout the world of energy storage. However, their use in high-field applications is hindered by a decrease in permittivity with applied electric field, resulting in a low energy density. Weakly-coupled relaxors such as $Bi(Zn,Ti)O_3$-modified $BaTiO_3$ (BZT-BT) ceramics and thin films show promise of countering this trend by maintaining high permittivity with high electric fields, and thus, a high energy density. By alloying the prototypical high-permittivity perovskite, $BaTiO_3$, with a material such as $Bi(Zn,Ti)O_3$ or $Bi(Sc,Ti)O_3$ (which is unstable as a stand-alone perovskite phase), the lattice becomes frustrated and exhibits an absence of electric-field tuning out to fields in excess of 100kV/cm, as well as remarkable temperature stability. In addition, the presence of a significant amount of Bi cations significantly improves sinterability leading to dense parts with large breakdown strengths.

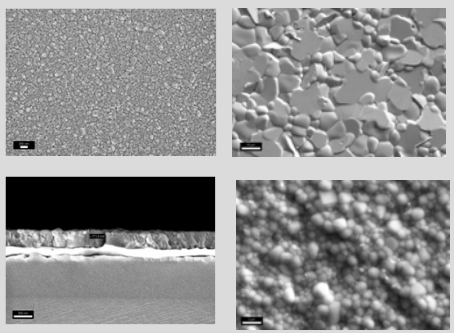
Fabrication

Sol-gel techniques were used to fabricate thin films, while traditional ceramic processing methods were used for the bulk samples.



Data and Results

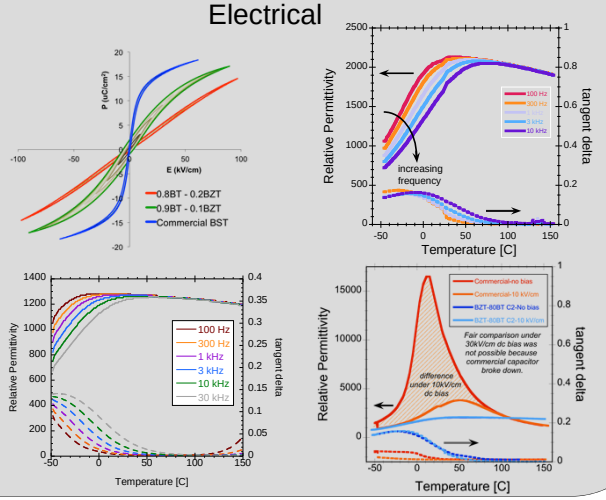
SEM



Thin Films

Bulk

Electrical



Applications

Electrostatic capacitors are inherently high-power devices: for example, they store significantly less energy than batteries, but are able to deliver this energy orders of magnitude more quickly without any loss in performance, even after millions of cycles. Batteries often lose significant portions of their capacity after 10s or 100s of cycles, a situation which is only worsened by high power demands. Integration of (relatively) high energy density capacitors with batteries allows the capacitors to isolate the battery from high power transients and greatly extend the battery life with no degradation in system performance and minimal added weight or volume.

Our ceramic capacitors also offer improved reliability and temperature stability vs. electrolytic and double-layer capacitors, making them particularly attractive for use in automotive and other power electronics packages.

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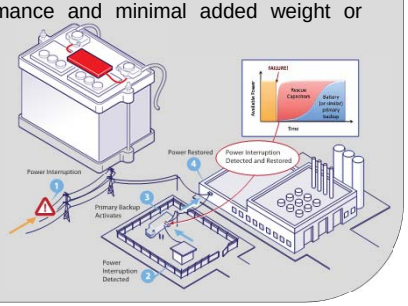
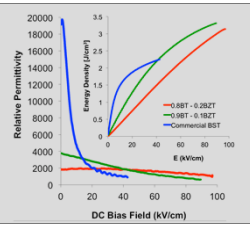


Conclusions

With their ability to maintain high permittivity at high electric fields—thus improving energy density—both $Bi(Zn,Ti)O_3$-modified $BaTiO_3$ (BZT-BT) ceramics and thin films show great promise for energy storage applications.



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