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Minimizing Voltage Tuning for Enhanced High Field Capacitance

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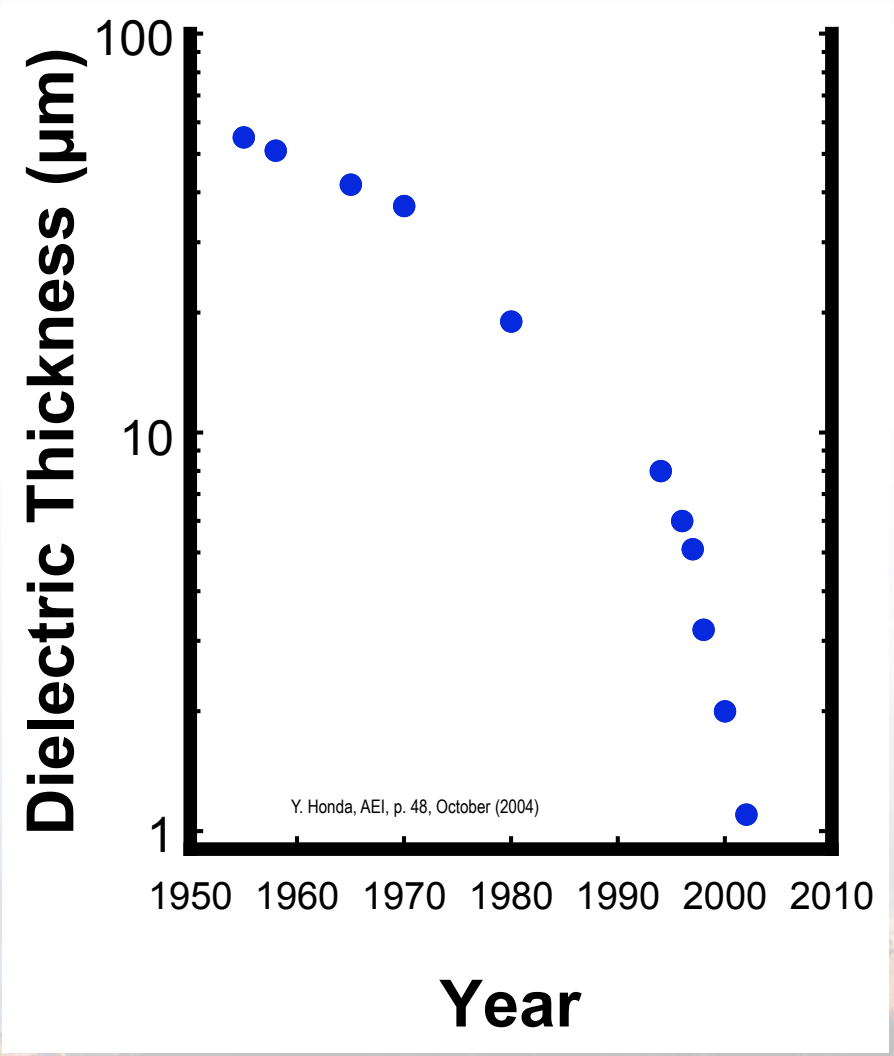
High Field Operation



- Thinner layers means higher operating fields
- Many applications require high energy and/or high capacitance under dc bias (blocking caps, pulse discharge, power electronics, etc.)
- Reliable operation under bias (especially at elevated temperatures) requires precise defect control

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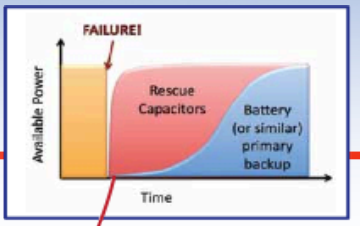
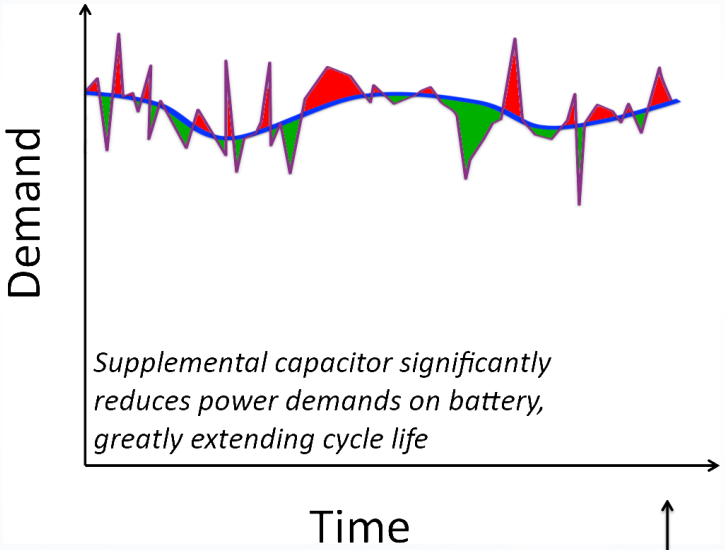
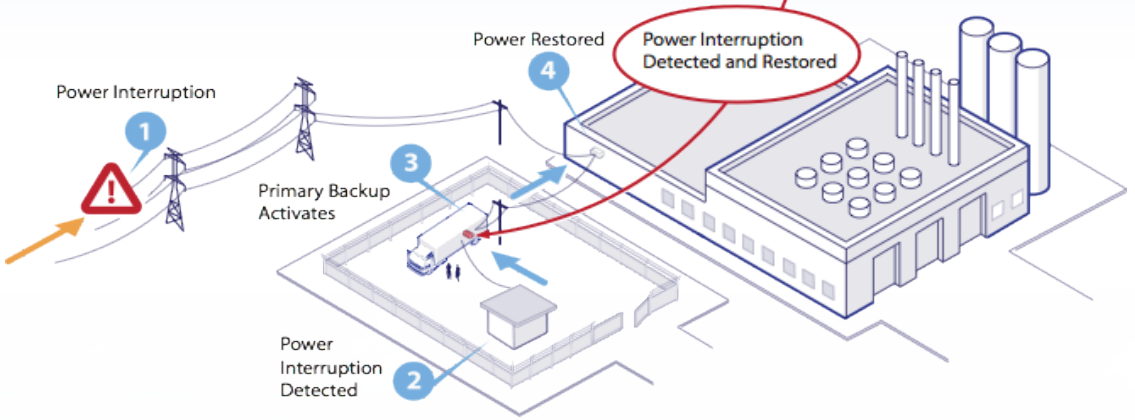
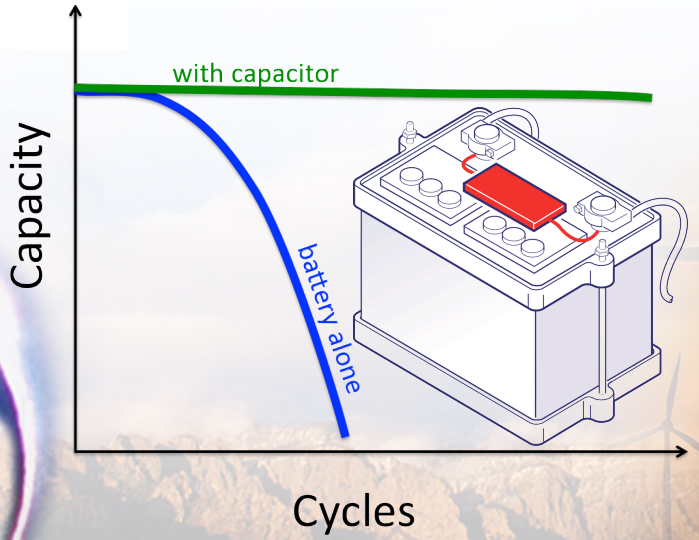
Emerging Grid Storage Needs



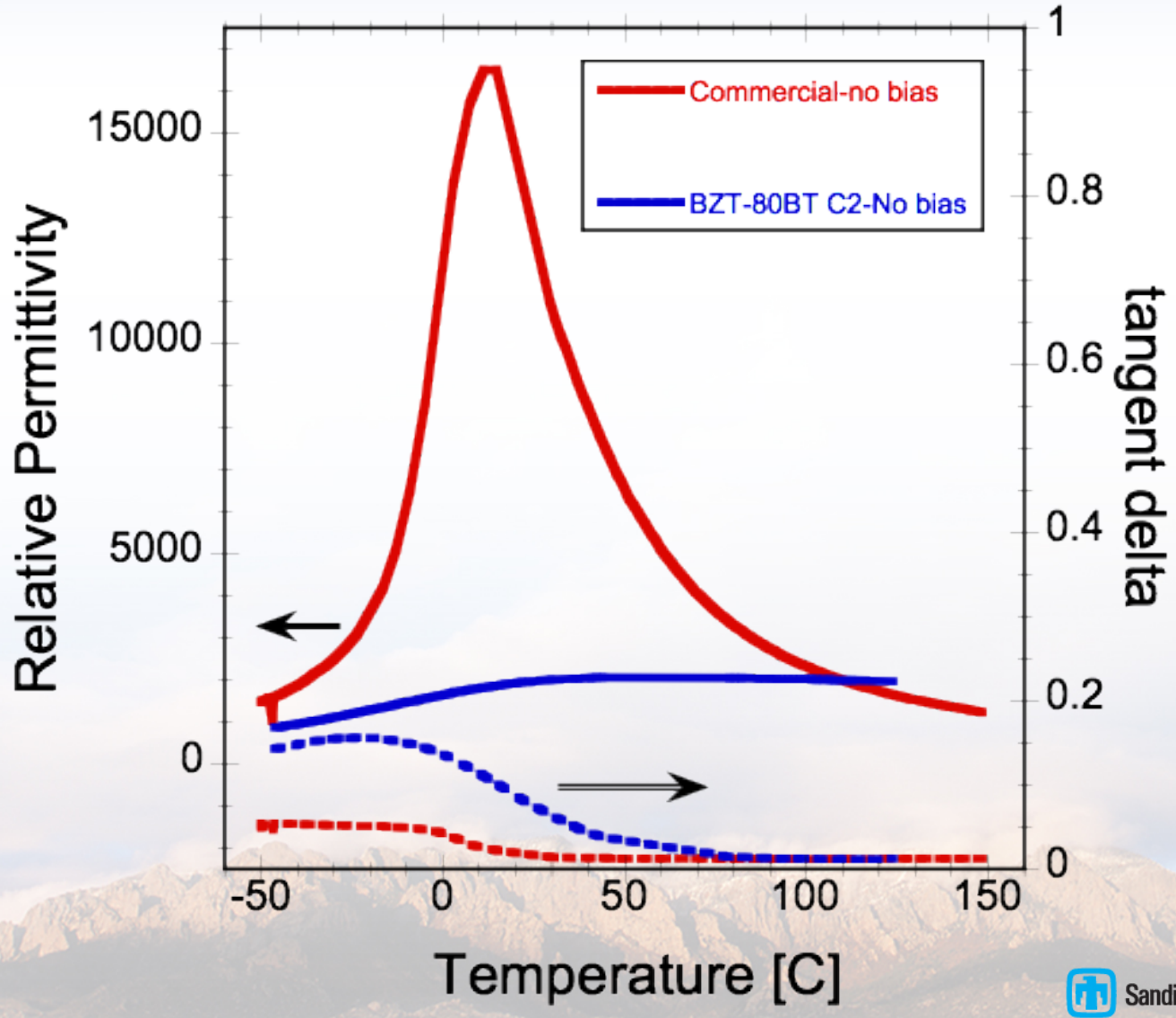


Supplemental capacitor significantly reduces power demands on battery, greatly extending cycle life





Tuning Under Bias



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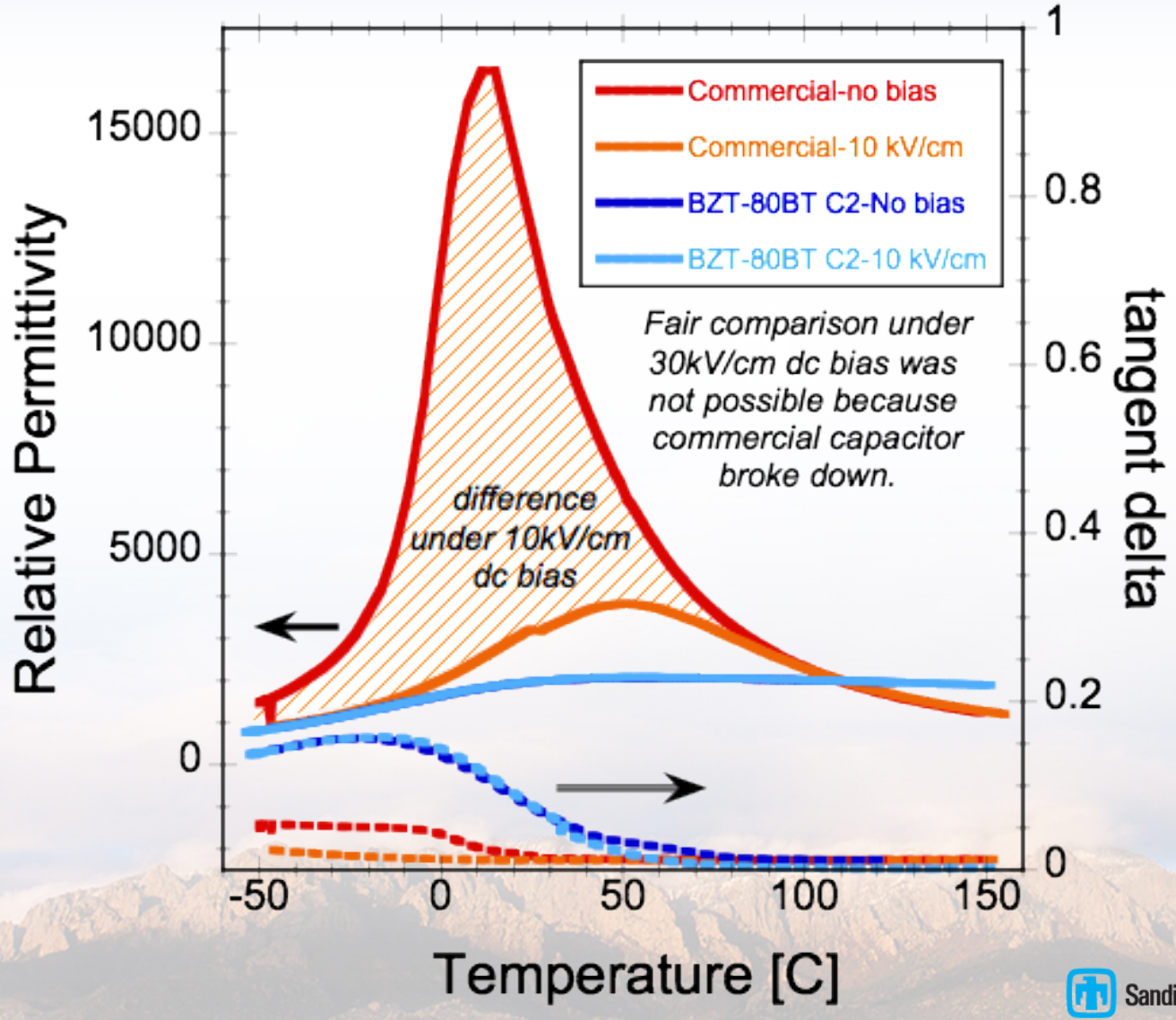
Tuning Under Bias



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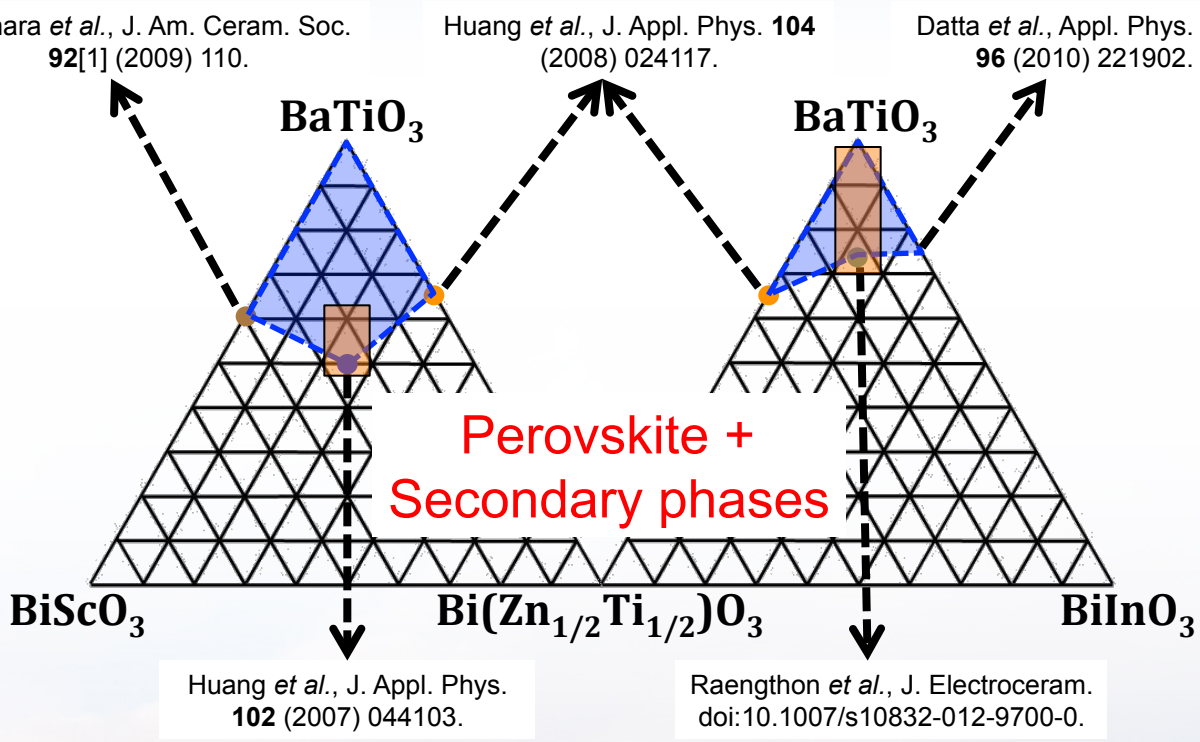
$Bi(M)O_3 – BaTiO_3$ Solid Solutions

(M)

Sc
In
Fe
$Mg_{0.5}Ti_{0.5}$
$Mg_{0.5}Zr_{0.5}$
$Zn_{0.5}Ti_{0.5}$
$Zn_{0.5}Zr_{0.5}$
$Ni_{0.5}Ti_{0.5}$
$Mg_{0.75}W_{0.25}$
.
:



Eitel and Randall performed pioneering work on Bi-based solid solutions with $PbTiO_3$ for high-T_C piezoelectrics following simulations from Davies *et al.*
Also literature on $Bi(Zn_{0.5}Ti_{0.5})O_3$ as end member with $NaNbO_3$, $Bi(Na,K)TiO_3$, etc.

Majority of work on these systems has focused on maximizing piezoelectric response

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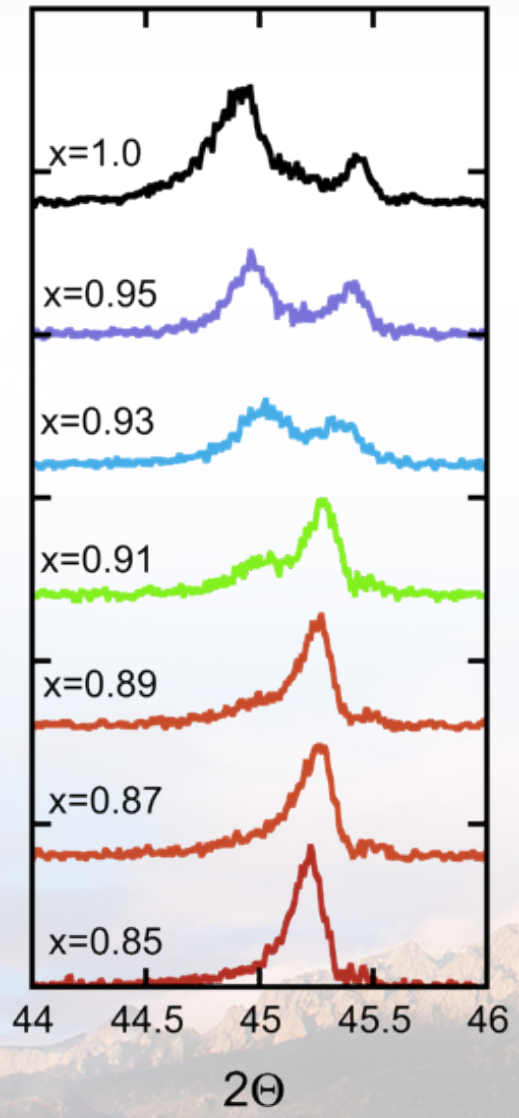
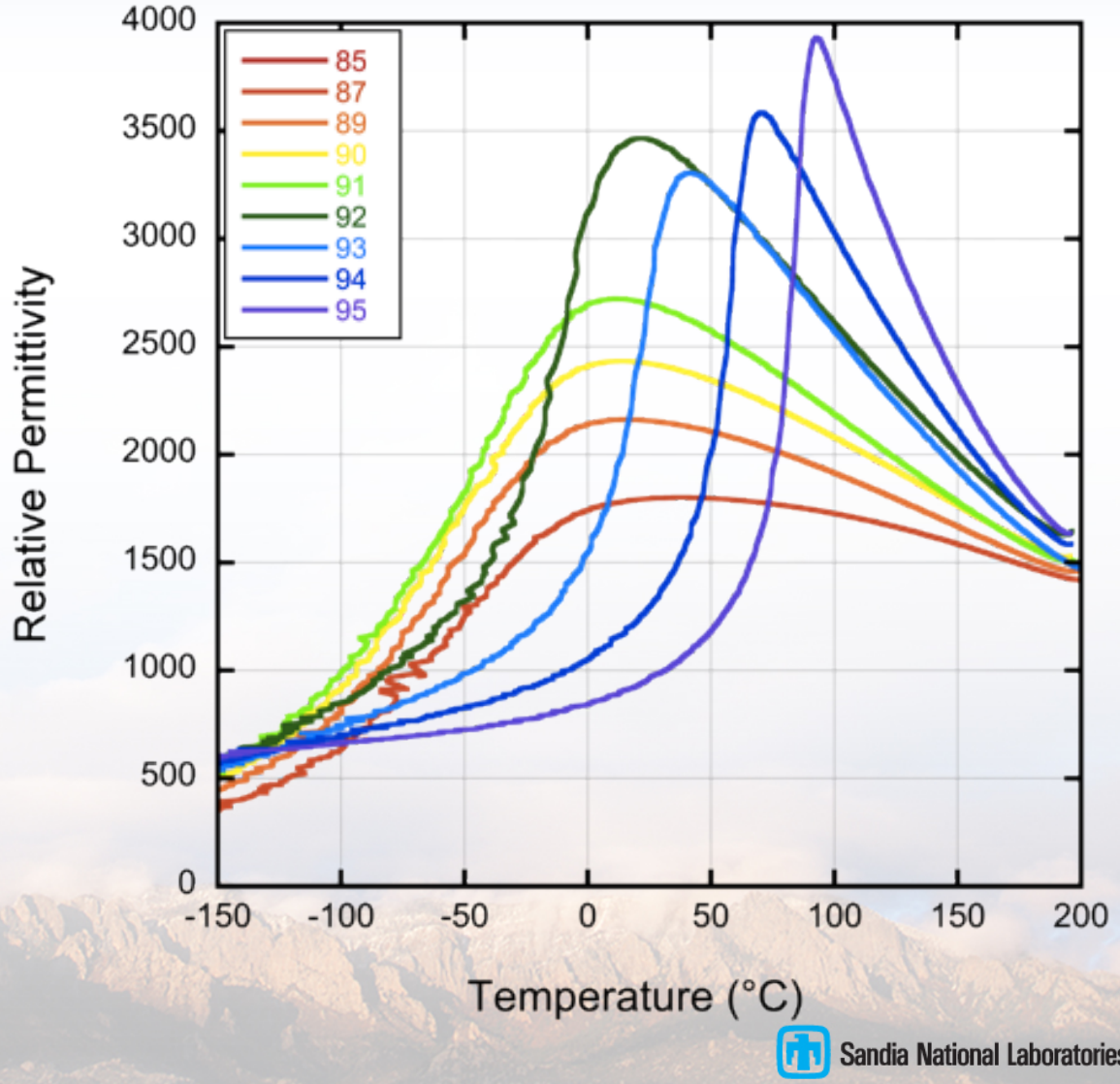
$(1-x)Bi(Zn_{0.5}Ti_{0.5})O_3 - xBaTiO_3$





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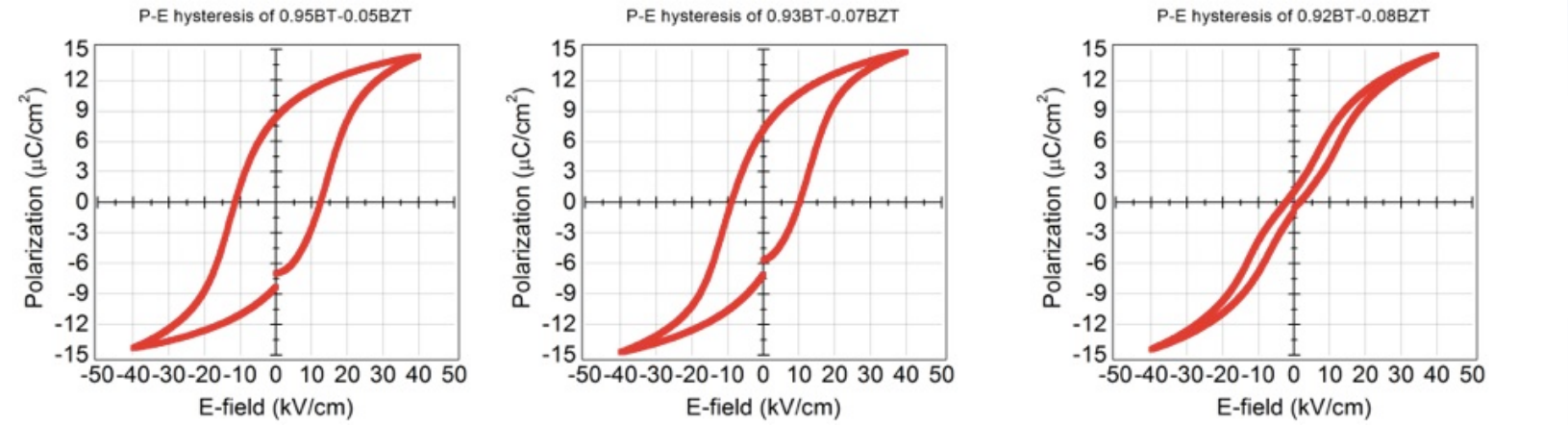
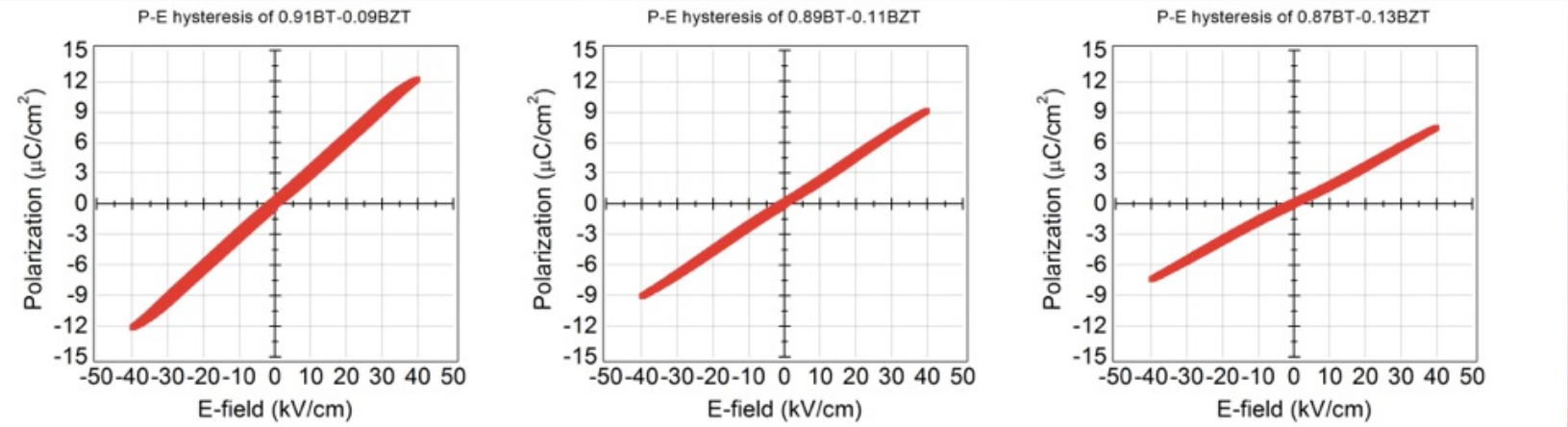
$(1-x)Bi(Zn_{0.5}Ti_{0.5})O_3 - xBaTiO_3$



x = 0.95 x = 0.93 x = 0.92



x = 0.91 x = 0.89 x = 0.87

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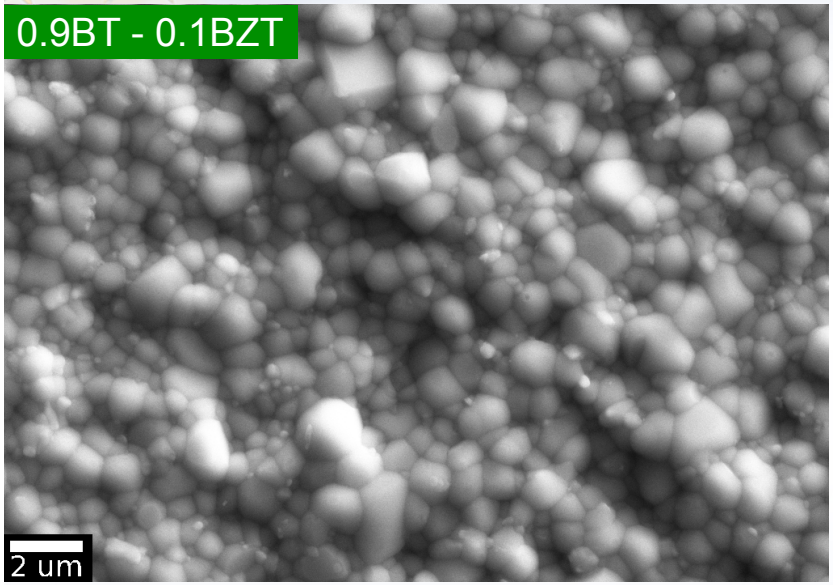
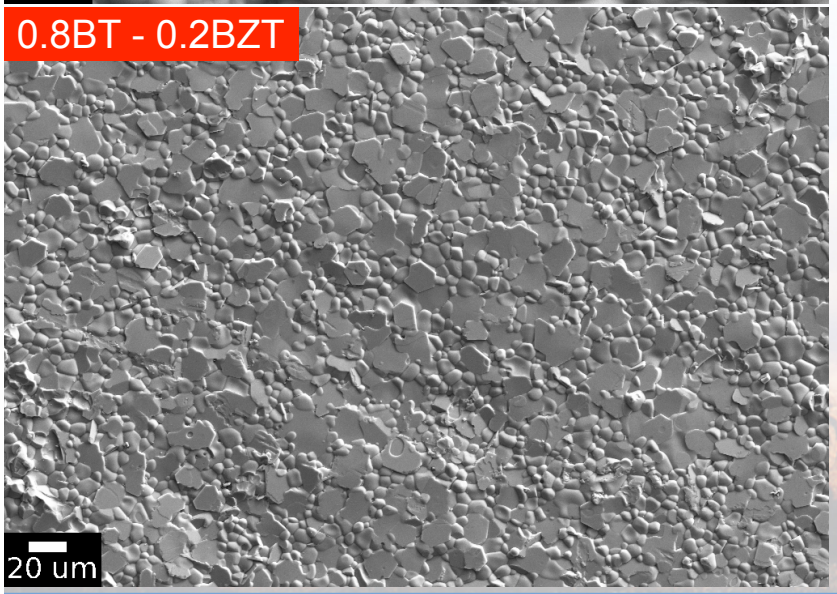
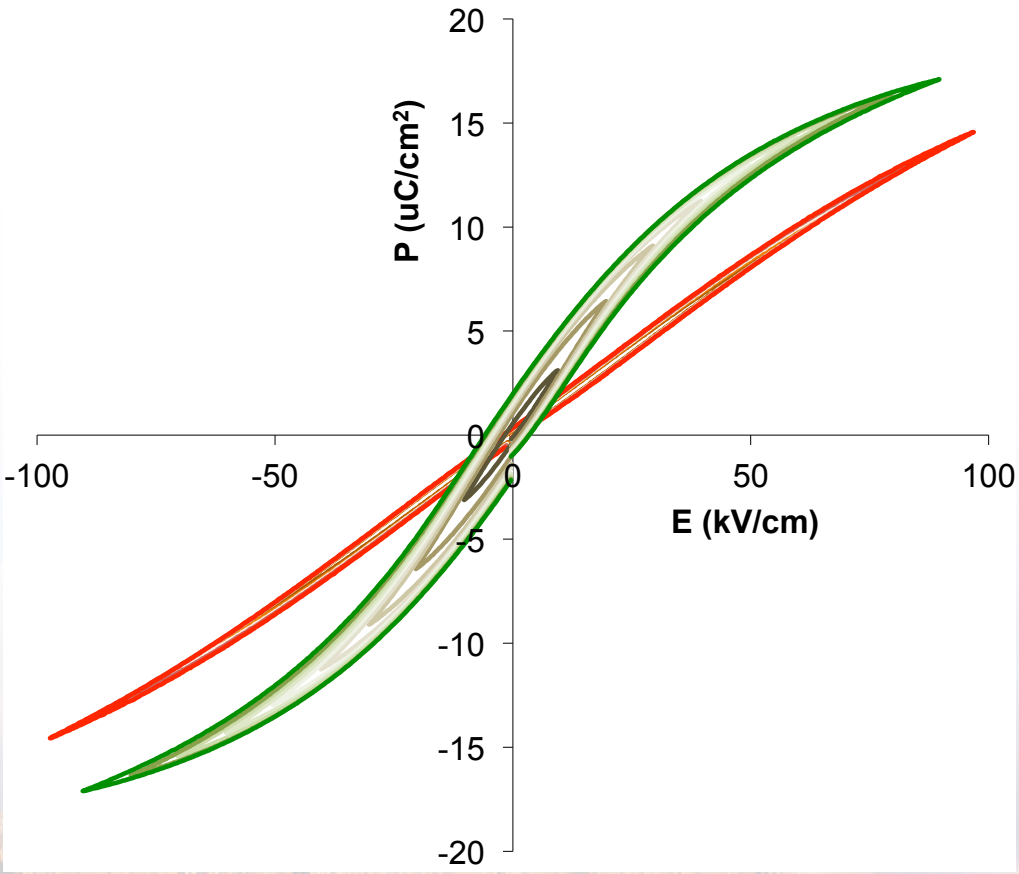
$(1-x)Bi(Zn_{0.5}Ti_{0.5})O_3 - xBaTiO_3$







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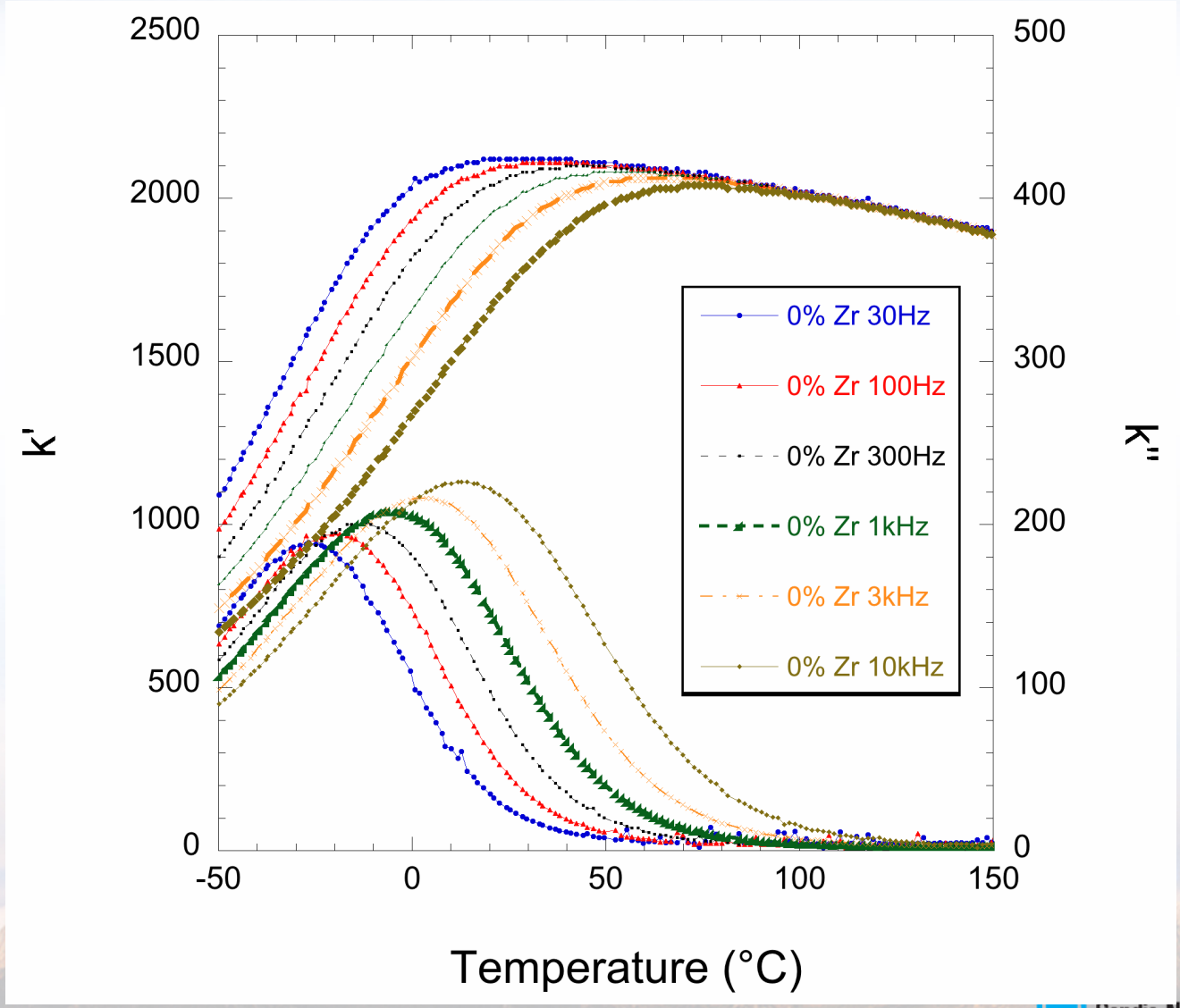
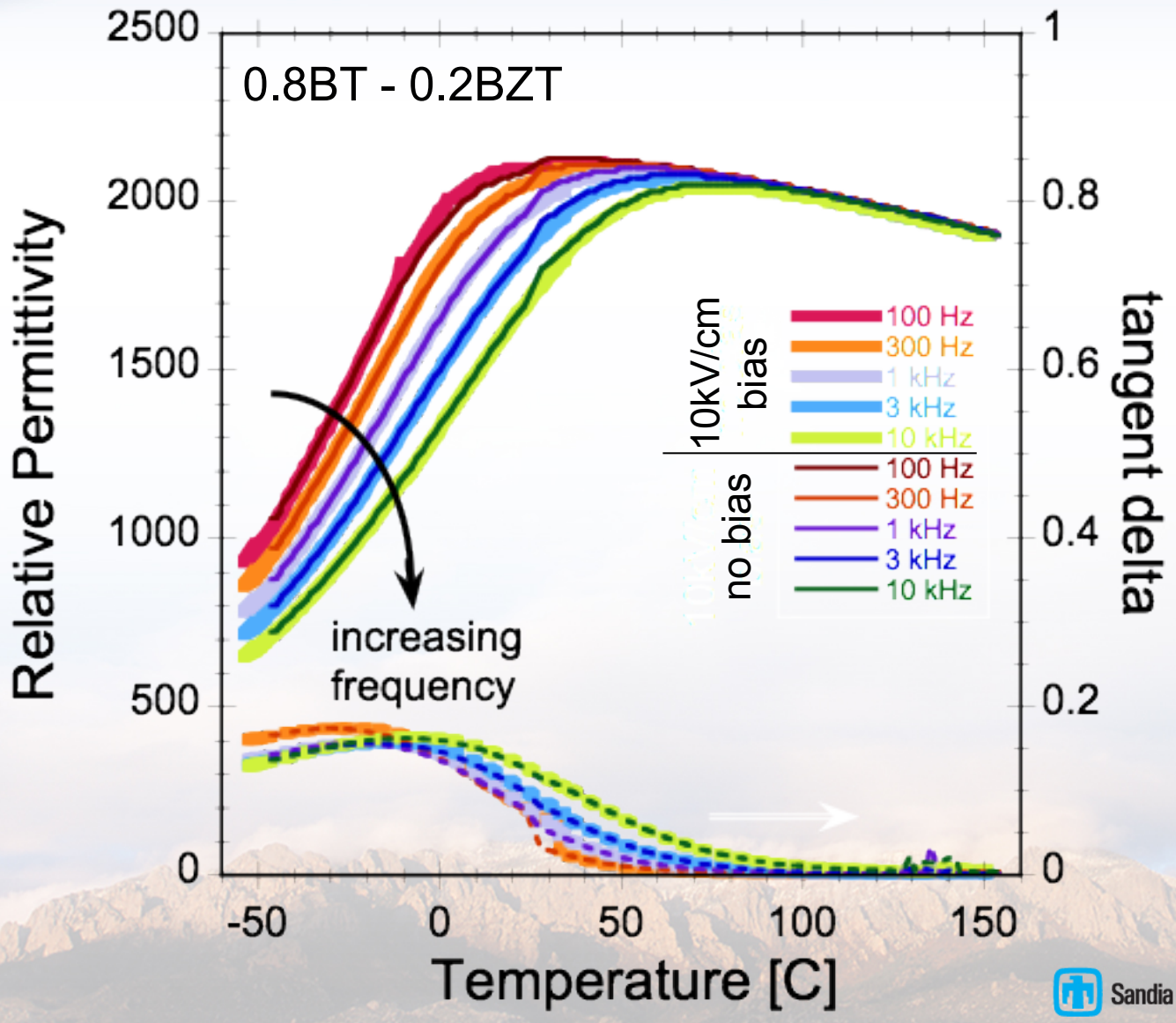
Relaxor Behavior



Relaxor Behavior Stable Under Bias



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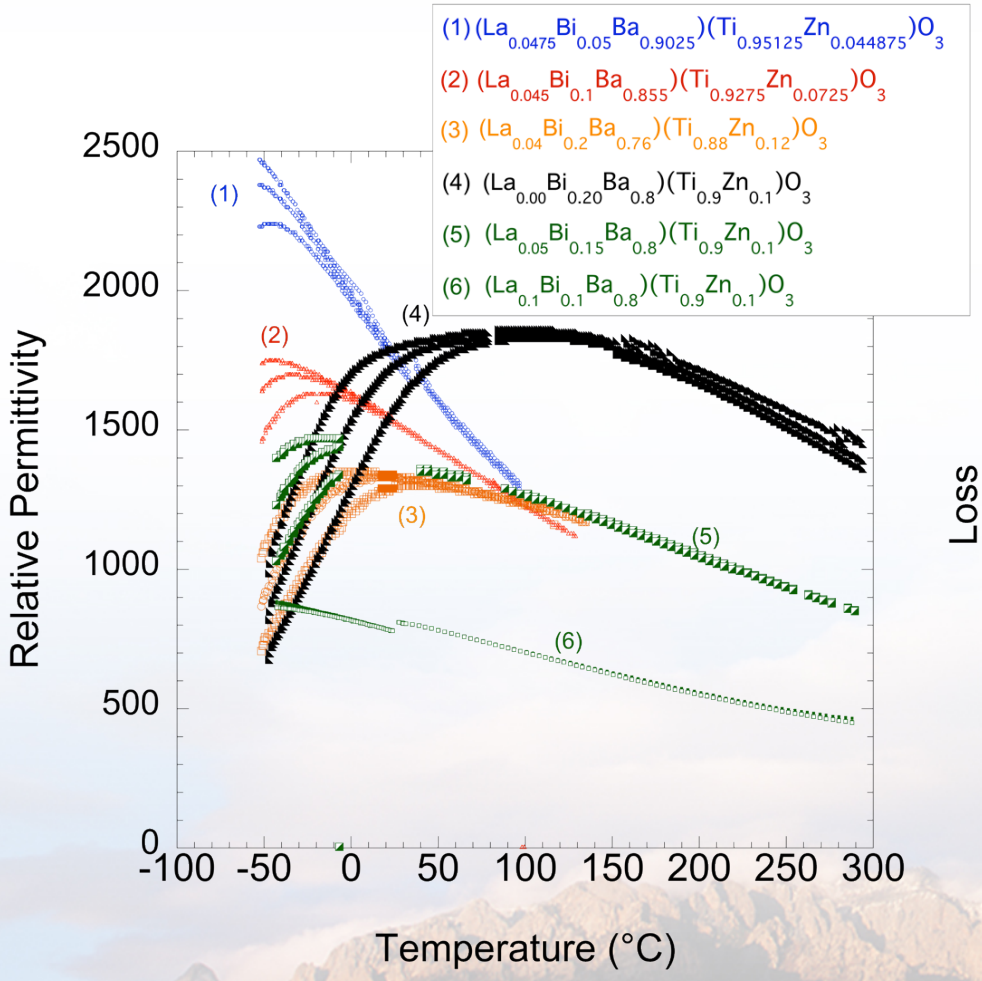
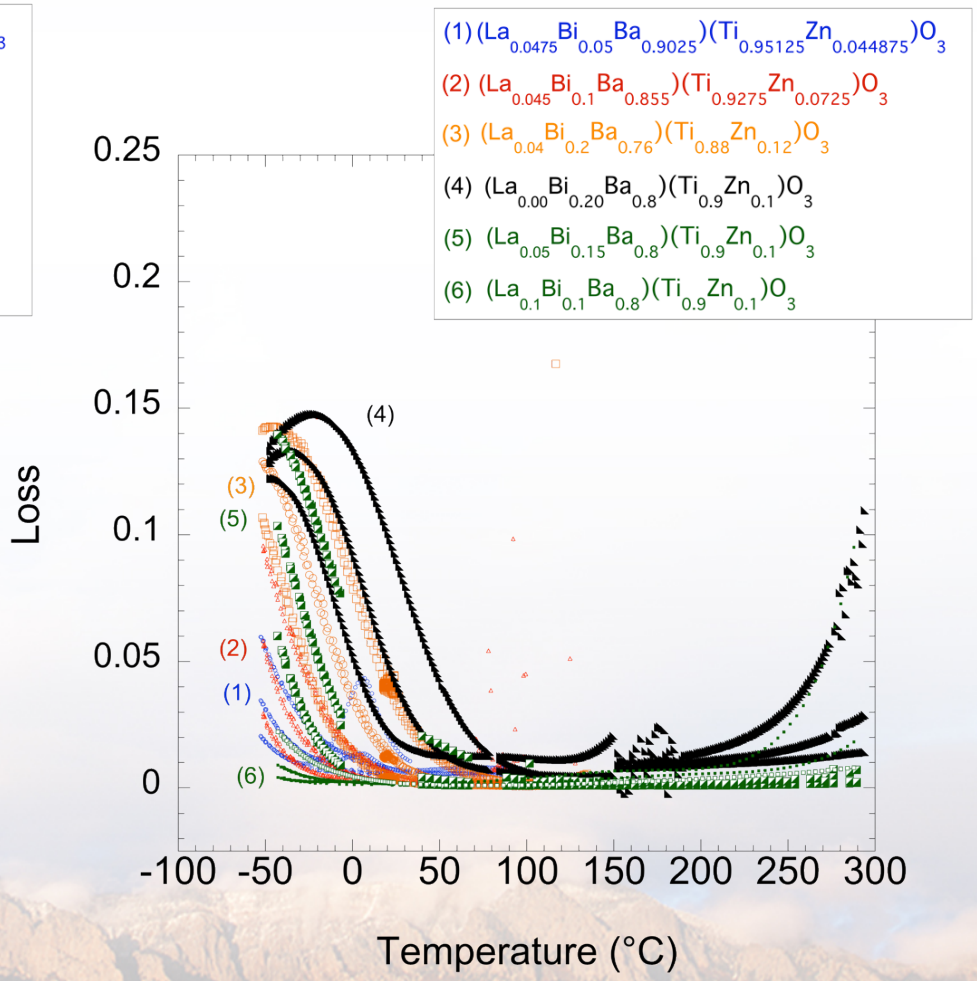
Shifting Relaxor Temperature





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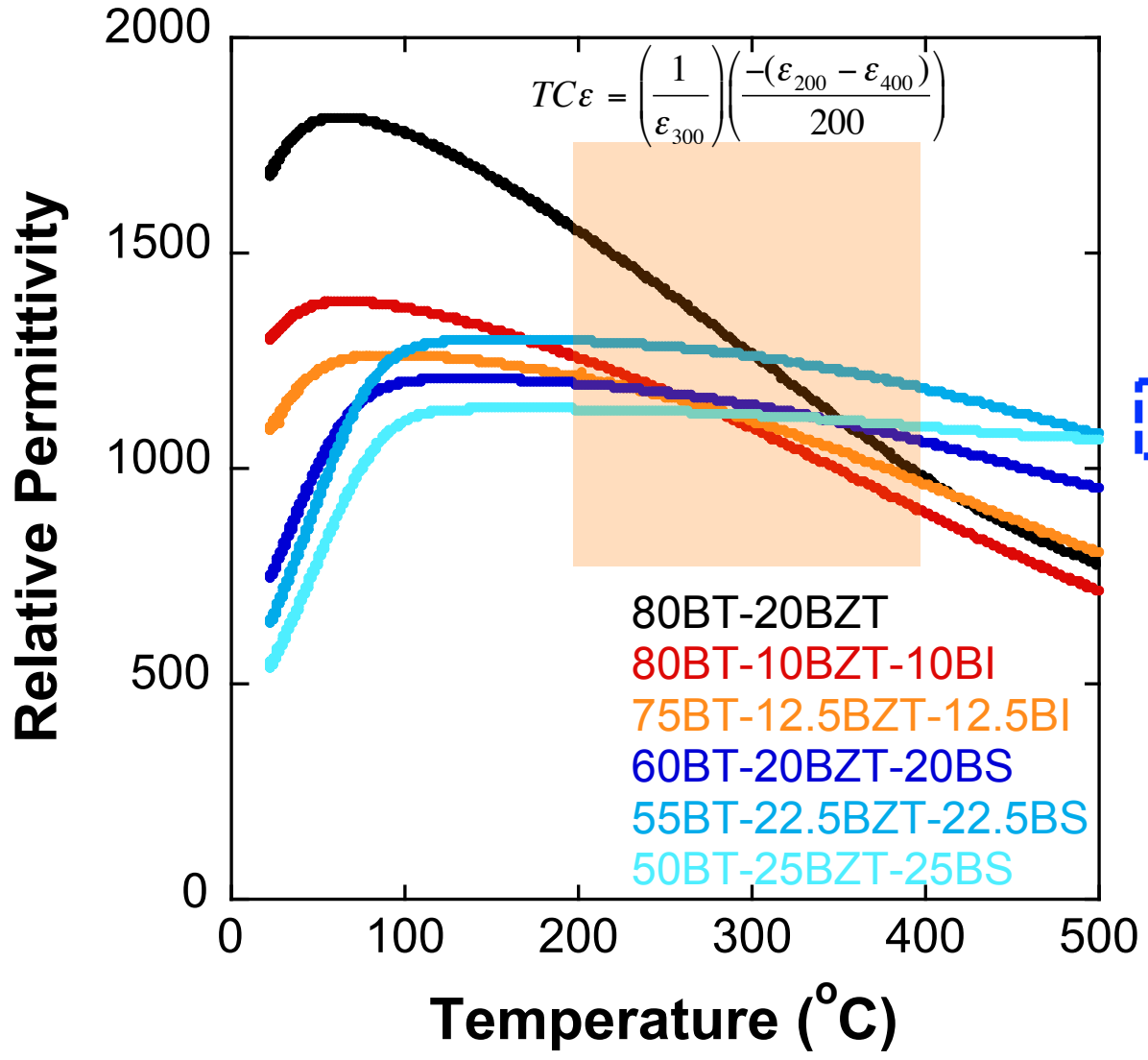
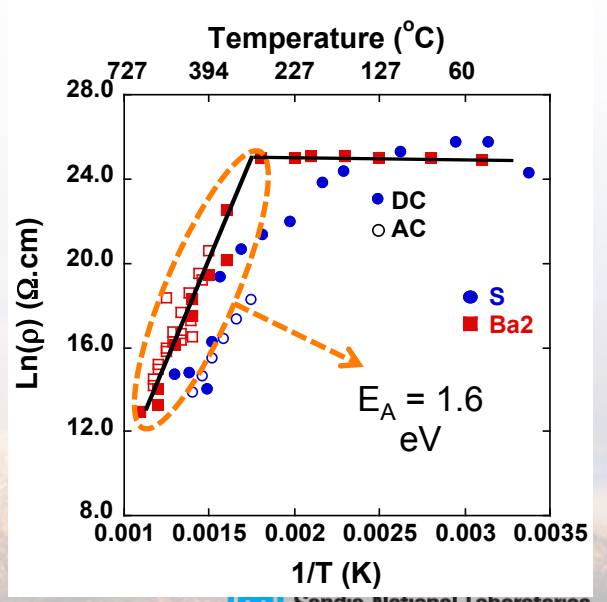
Extending Operating Temperatures



Compound	TCε (ppm/ºC)
80BT-20BZT (-2Ba)	-2441
80BT-10BZT-10BI (-2Ba)	-1644
75BT-12.5BZT-12.5BI (-2Ba)	-1114
60BT-20BZT-20BS (-2Ba)	-590
55BT-22.5BZT-22.5BS (-2Ba)	-447
50BT-25BZT-25BS (-2Ba)	-182



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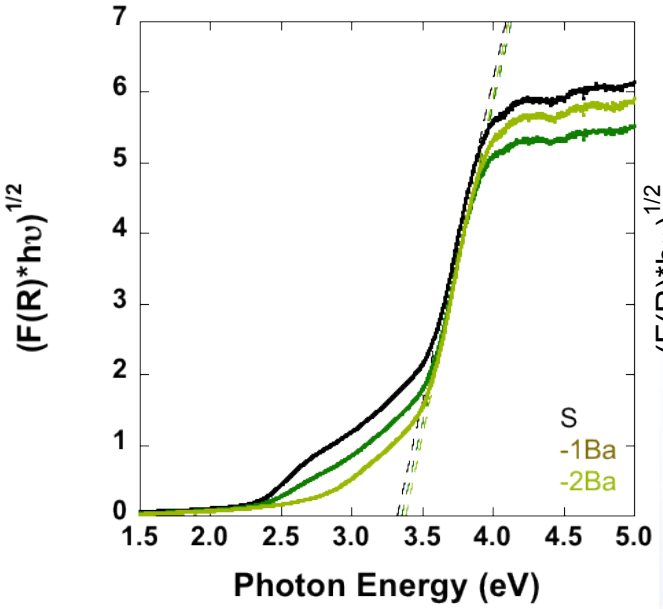
Defects and Carriers: Optical

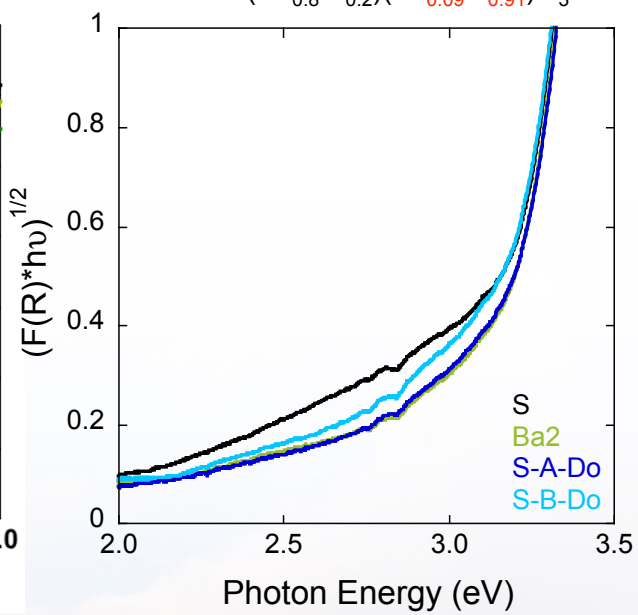
Ba deficiency

- S: nominally-stoichiometric
- Ba-def: $(Ba_{0.78}Bi_{0.2})(Zn_{0.1}Ti_{0.9})O_3$



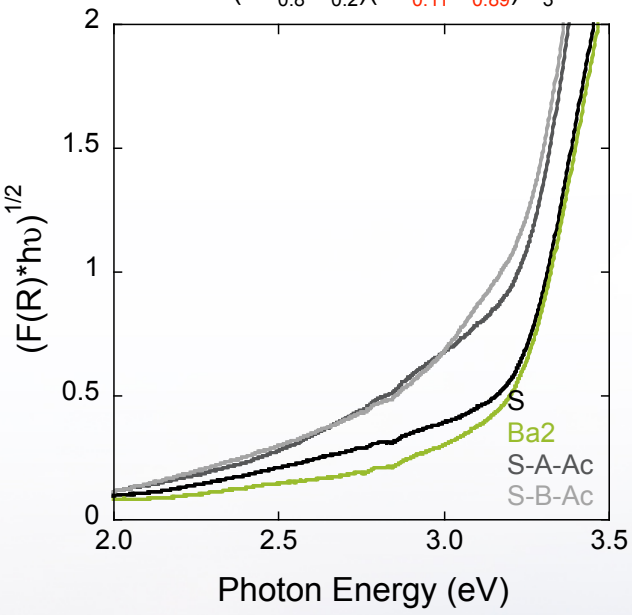
Donor

- A-site: $(Ba_{0.78}Bi_{0.22})(Zn_{0.1}Ti_{0.9})O_3$
- B-site: $(Ba_{0.8}Bi_{0.2})(Zn_{0.09}Ti_{0.91})O_3$



Acceptor

- A-site: $(Ba_{0.82}Bi_{0.18})(Zn_{0.1}Ti_{0.9})O_3$
- B-site: $(Ba_{0.8}Bi_{0.2})(Zn_{0.11}Ti_{0.89})O_3$



	E_g (eV)
S	3.162
Ba2	3.174

Urbach tail offers qualitative information about mid-gap defect states

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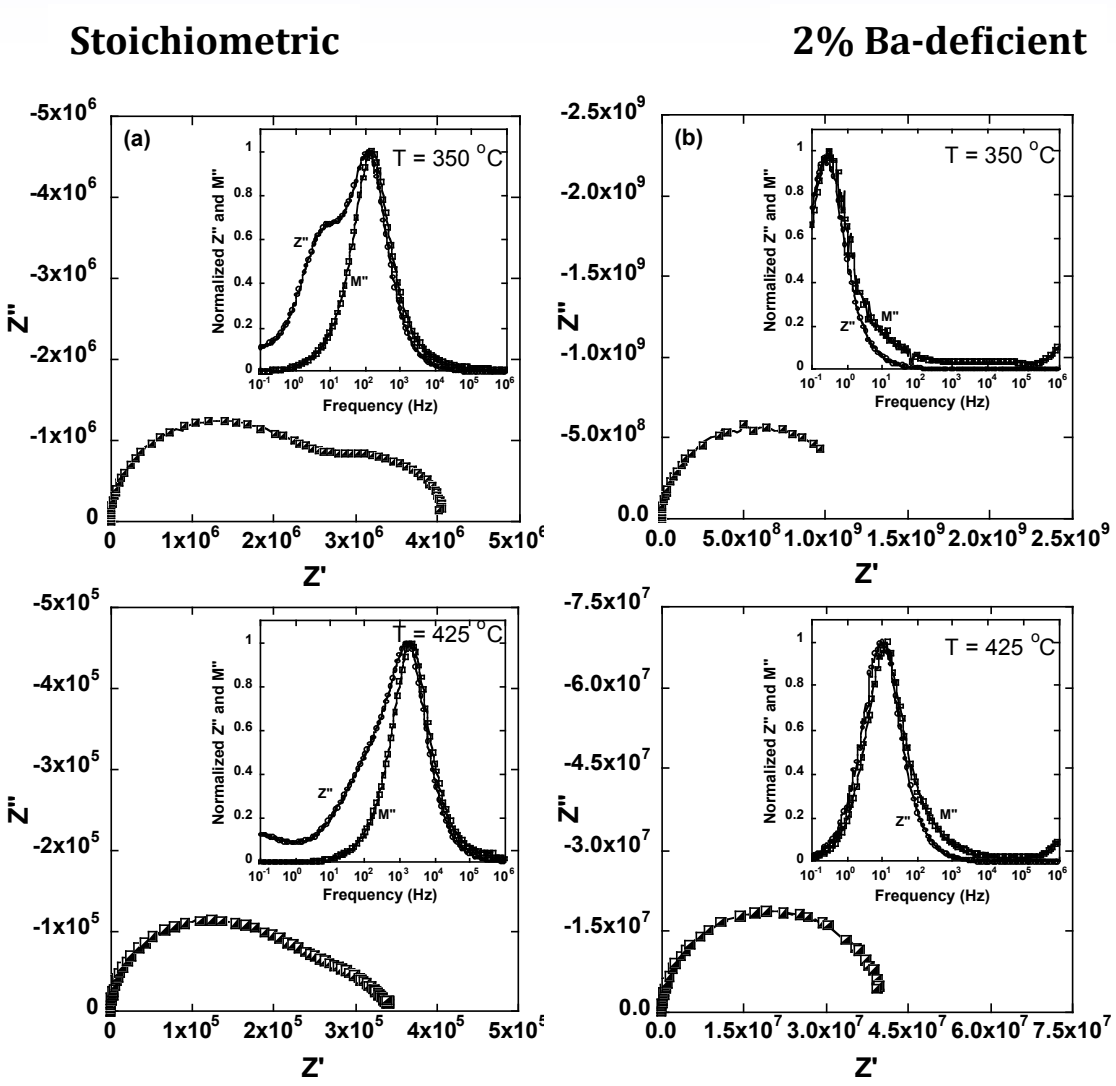
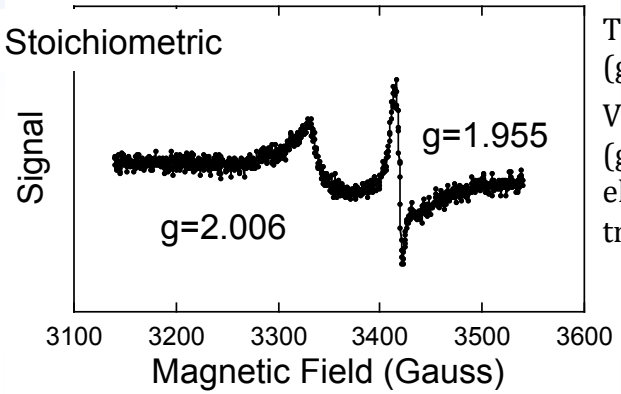
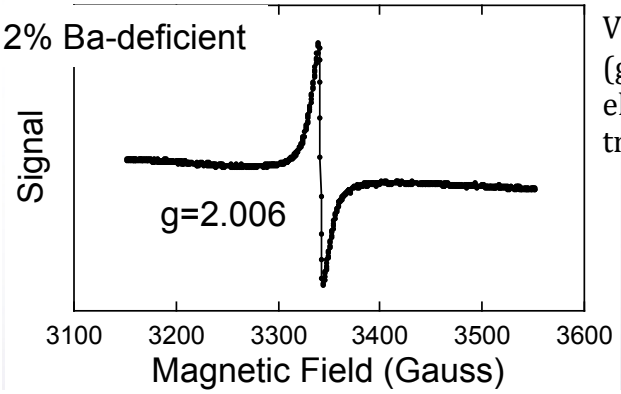
Defects and Carriers: Electrical





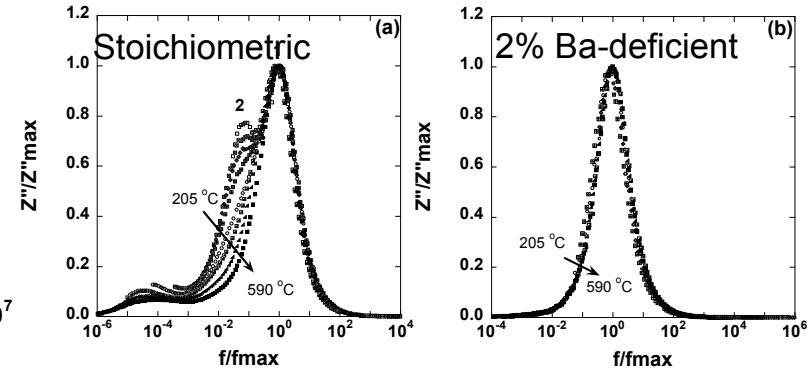
Ti^{3+}-V_O (g=1.955)

V_{Ba}-V_O (g=2.006) = electron trapped site



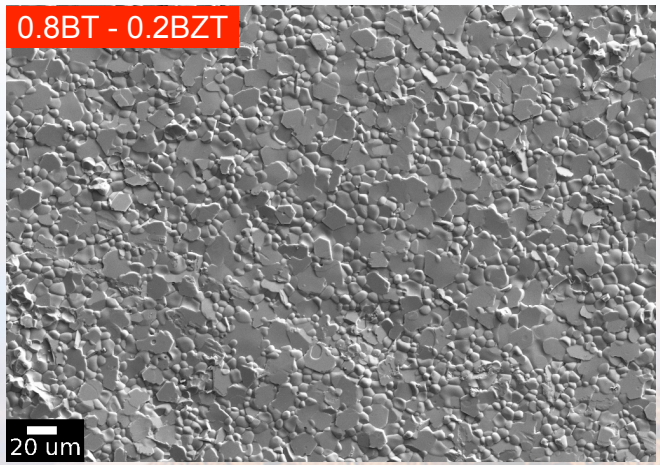
V_{Ba}-V_O (g=2.006) = electron trapped site

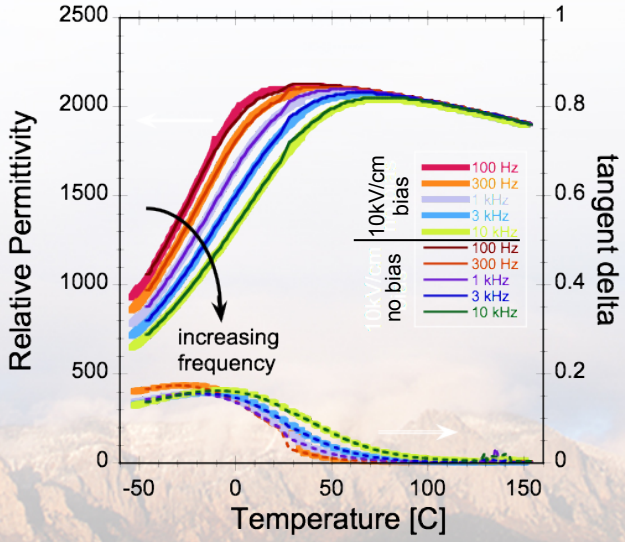
EPR run at 77K



Summary

- ‘Frustrated’ perovskite solid solutions continue to offer exciting opportunities for capacitor applications
- Studies into mechanisms are ongoing; new insights into unusual relaxor behavior could open up more avenues for optimization





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