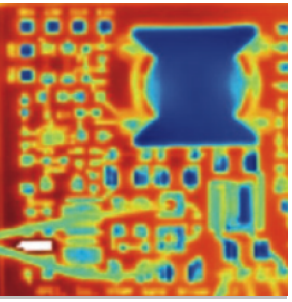
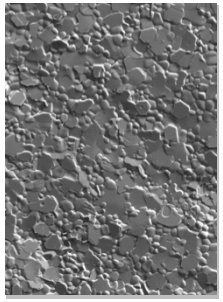
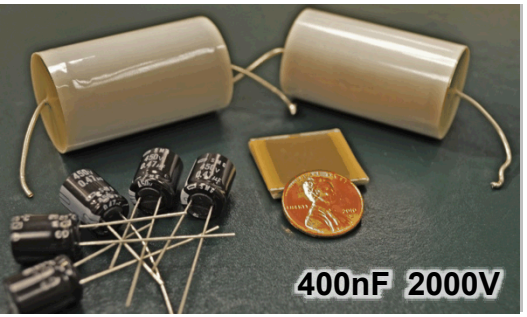
SAND2013-5962C







Processing of $Bi(Zn_{1/2}Ti_{1/2})O_3$-$BaTiO_3$ dielectrics for reliable high field operation

or: what you don't know can't hurt you… can it?

Geoff Brennecka, Harlan Brown-Shaklee and Mia Blea

Sandia National Laboratories

Natthaphon Raengethon and David Cann

Oregon State University

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Sandia National Laboratories

Exceptional service in the national interest

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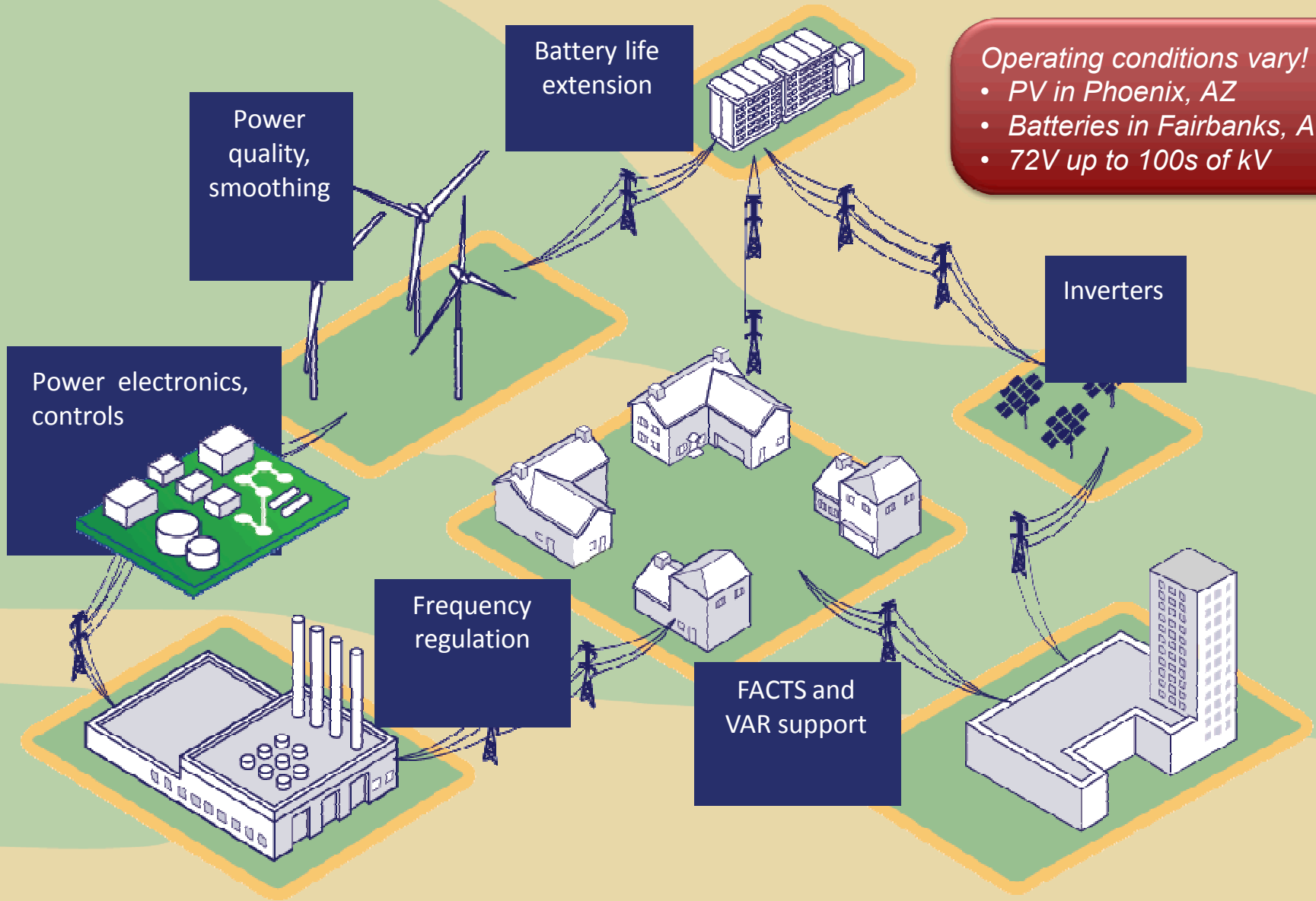
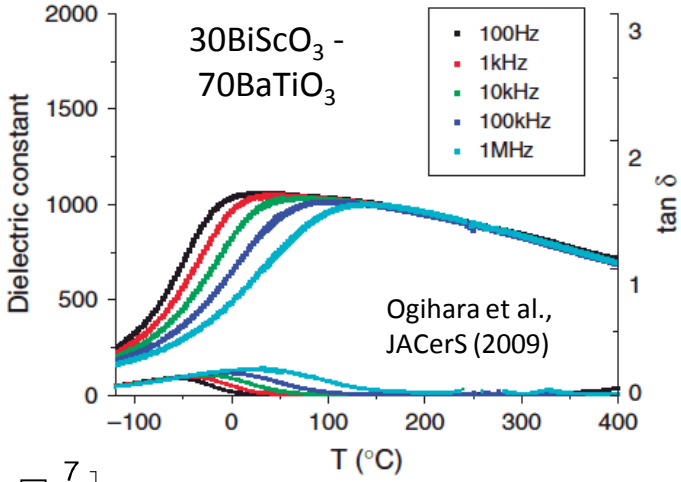
  - Adrian Wagner
  - Mark Rodriguez
  - John Borchardt
  - Greg Lyons
  - Jim Klarkowski

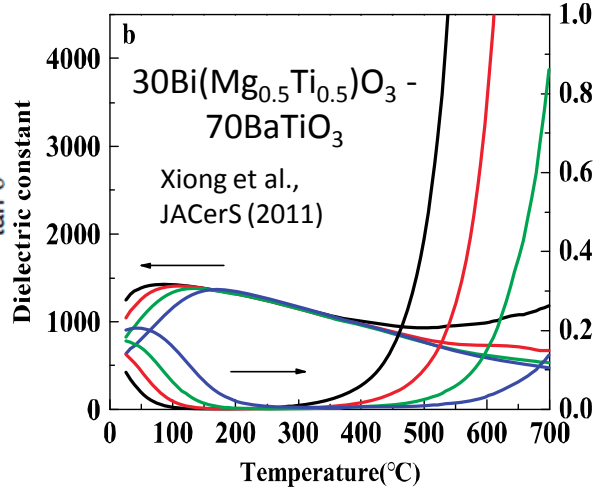
Capacitor Needs for Grid Storage

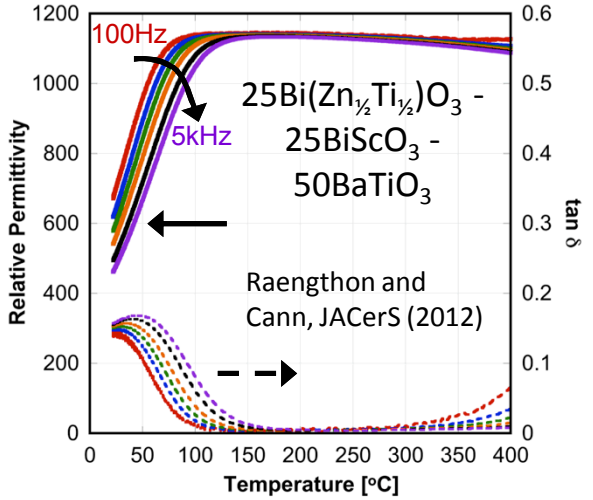


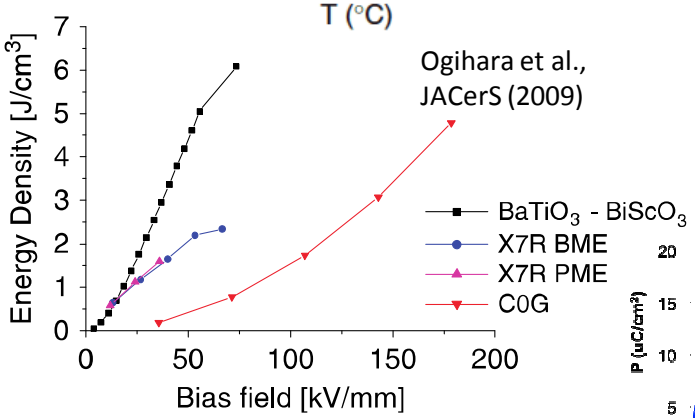
Operating conditions vary!
- *PV in Phoenix, AZ*
- *Batteries in Fairbanks, AK*
- *72V up to 100s of kV*

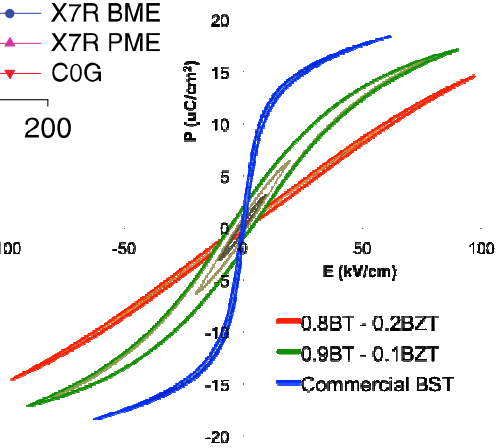
Bi-modified $BaTiO_3$ Relaxors





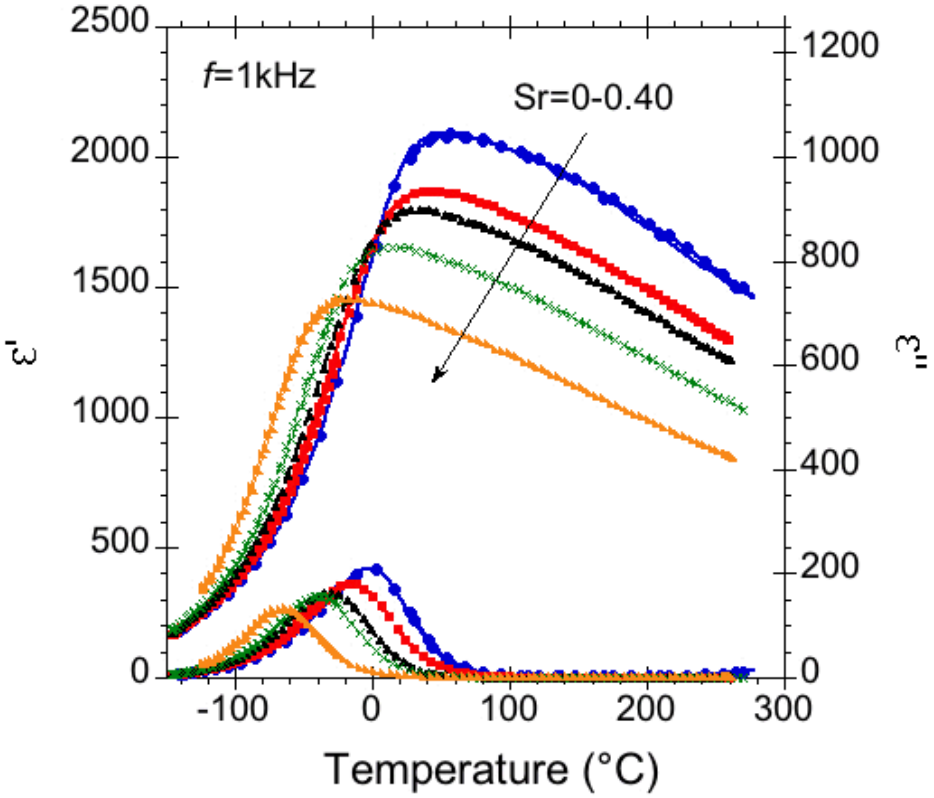


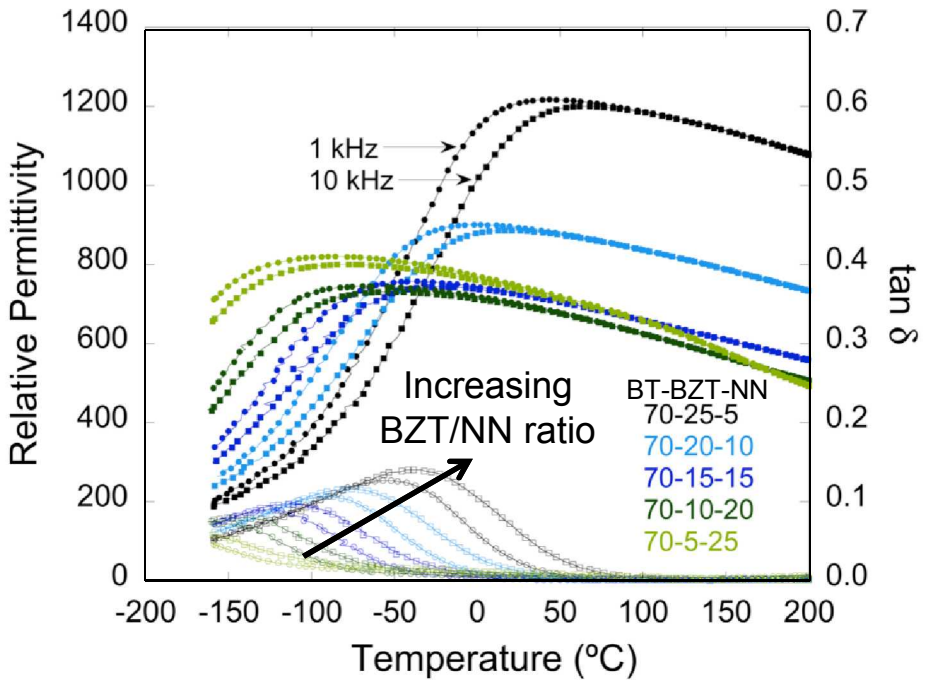




- 'Weakly-coupled relaxors'
- $BaTiO_3$ +
  - $Bi(Zn_{0.5}Ti_{0.5})O_3$
  - $Bi(Mg_{0.5}Ti_{0.5})O_3$
  - $BiScO_3$
  - …
- Voltage stable, moderately-high permittivity above relaxor transition

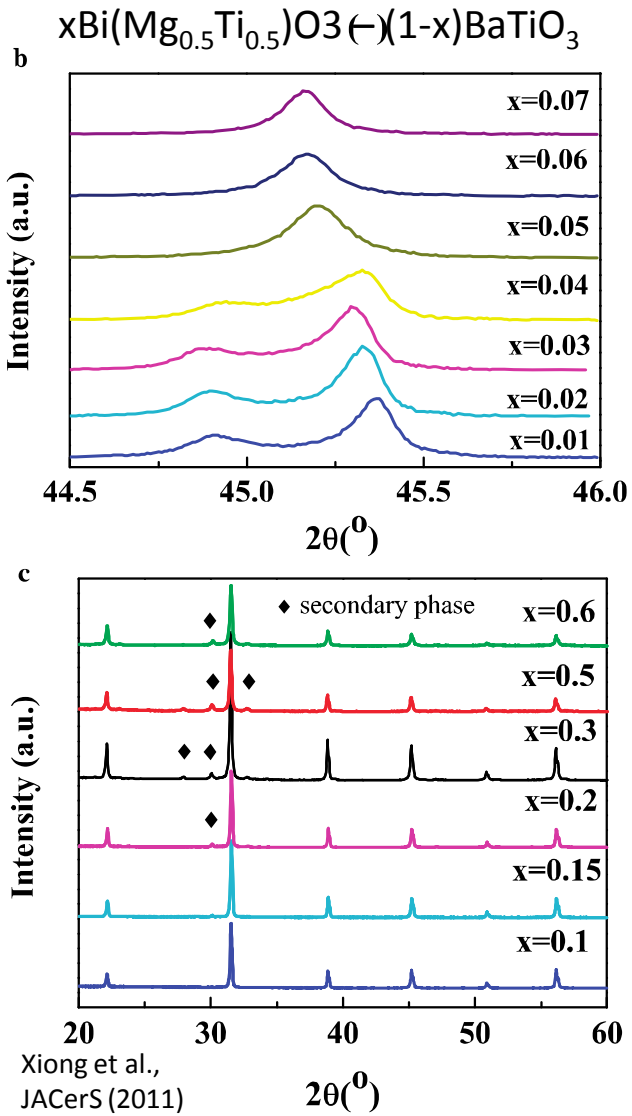
BT-BZT: Modifications can Shift T_{max}



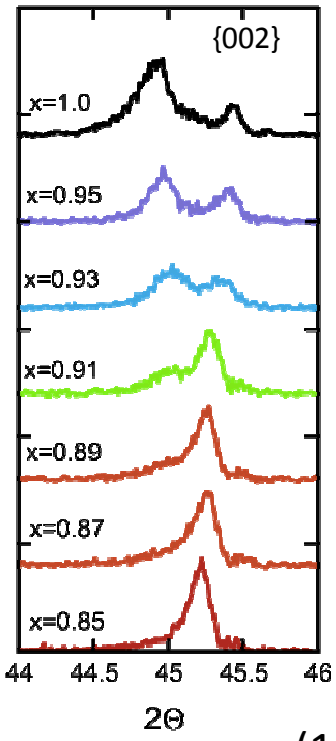


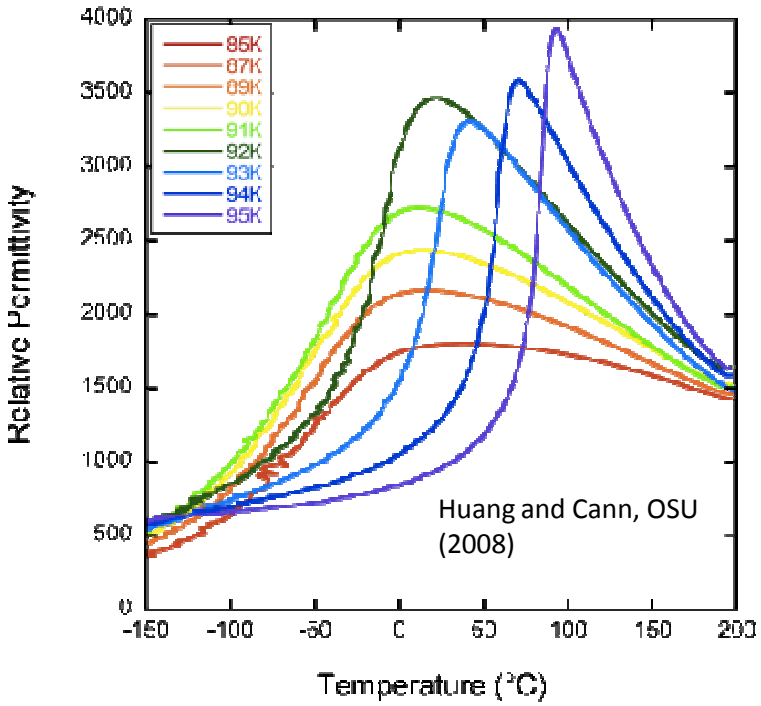
- $NaNbO_3$, $SrTiO_3$, $BaZrO_3$, La_{Bi}^{x}, etc. shift T_{max} down
- $BiScO_3$, $PbTiO_3$ and others shift T_{max} up

Diffraction Studies are Limited



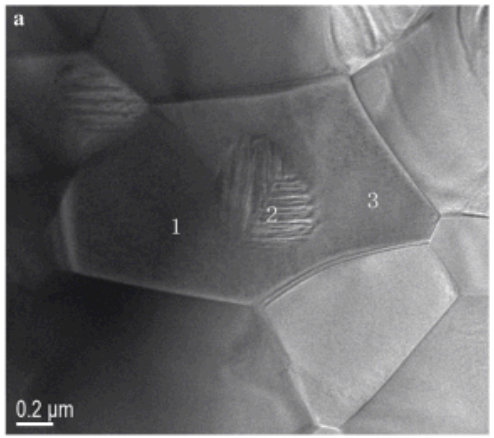
- Pure $Bi(Zn_{0.5}Ti_{0.5})O_3$ and $Bi(Mg_{0.5}Ti_{0.5})O_3$ end members unstable; additional phases observed for large substitutions
- Unusual behaviors suggest complexity…

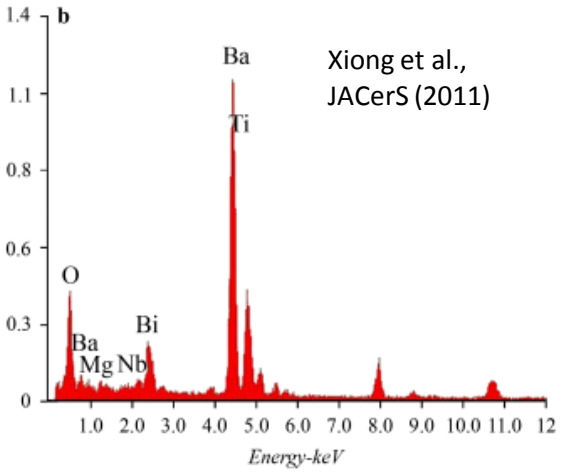




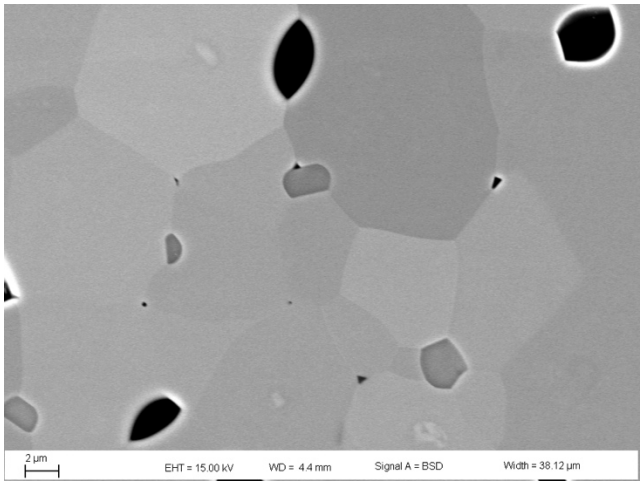
$(1-x)Bi(Zn_{½}Ti_{½})O_3 –xBaTiO_3$

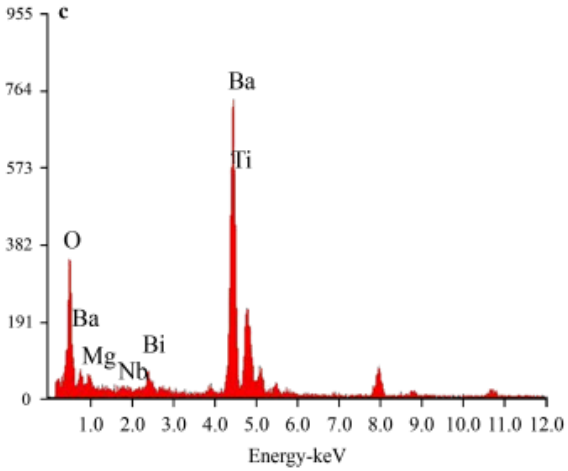
BT-BZT: Modifications can Shift T_{max}

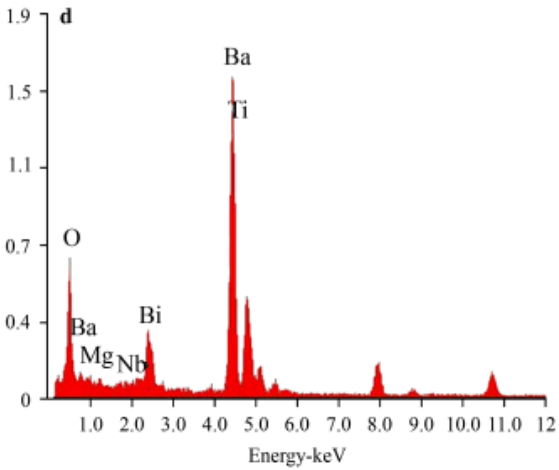


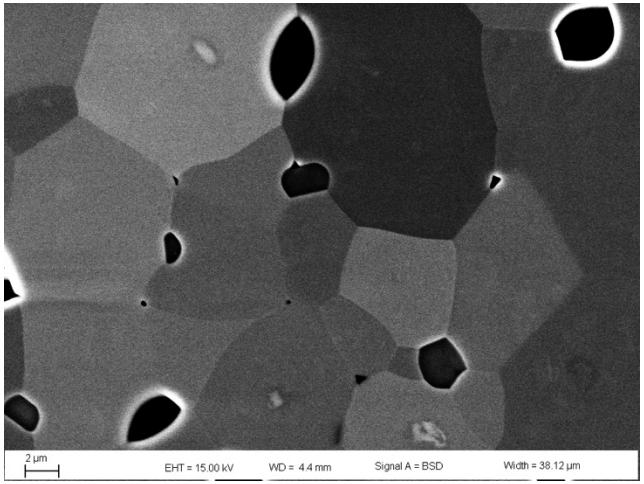


Xiong et al., JACerS (2011)



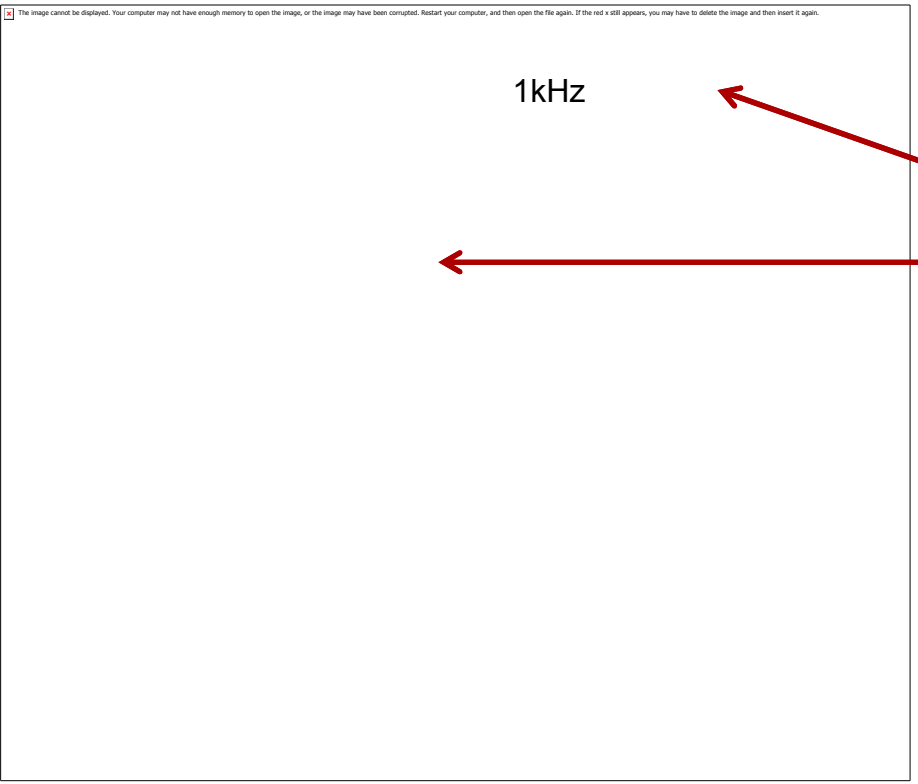




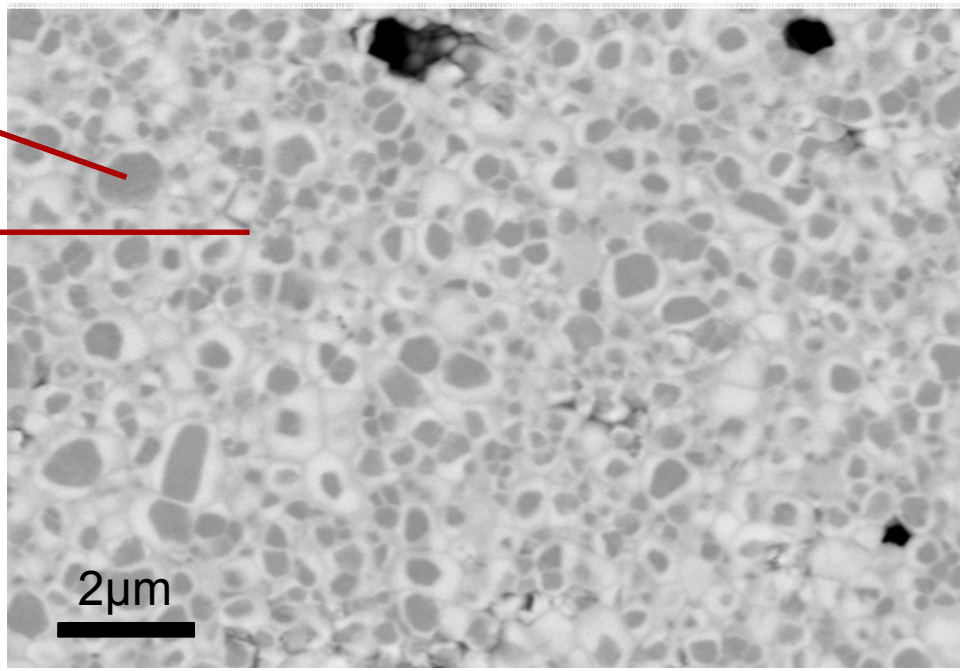


- Reminder: ‘single phase by XRD’ != homogeneous

BT-BZT: Modifications can Shift T_{max}



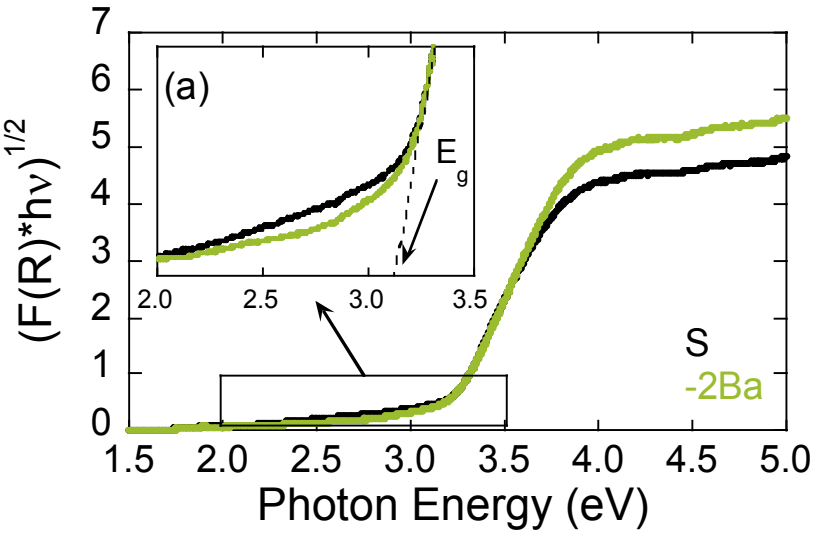
Intentionally fabricated $BaTiO_3$ core, Bi-rich shell

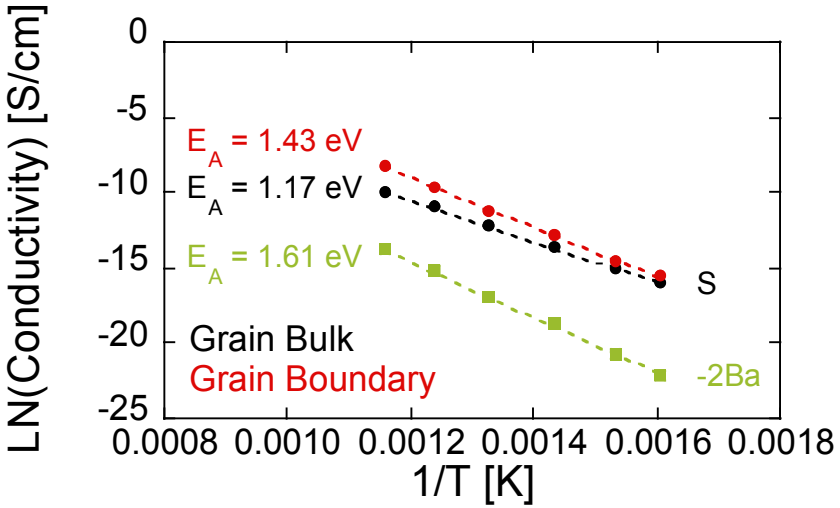


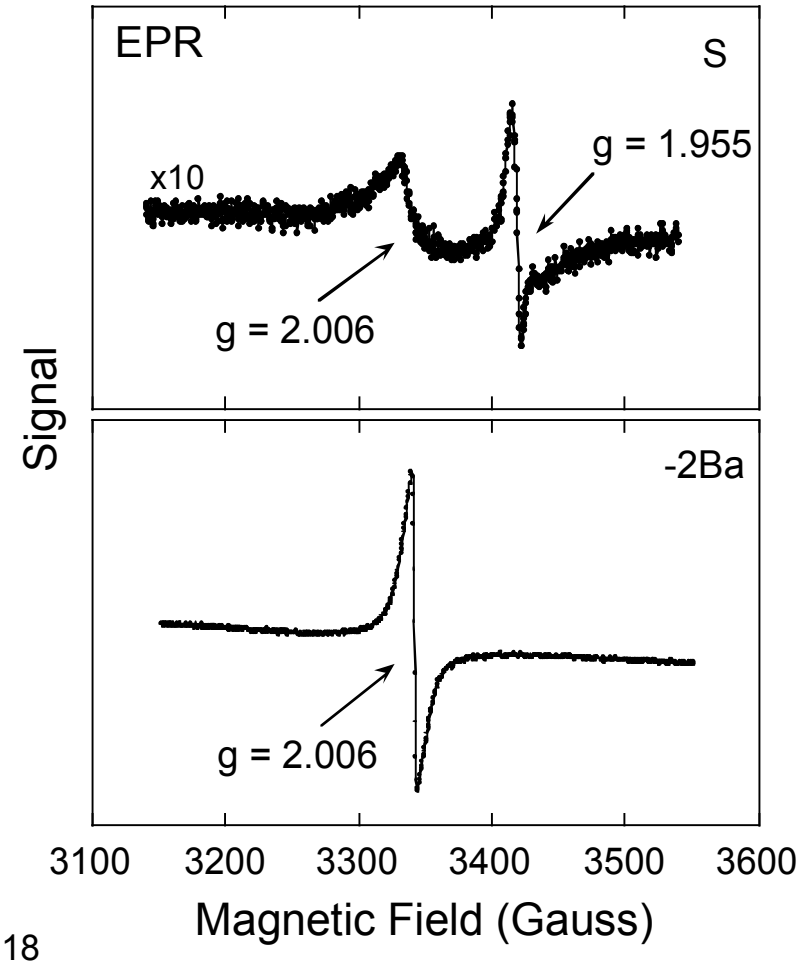
Core exhibits T_C ~125°C
Shell exhibits relaxor behavior

- Reminder: 'single phase by XRD' != homogeneous

Defects: Optical & Electrical Info



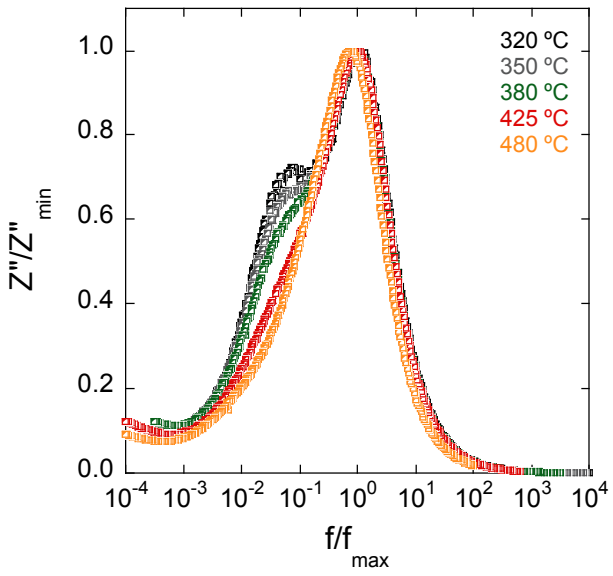


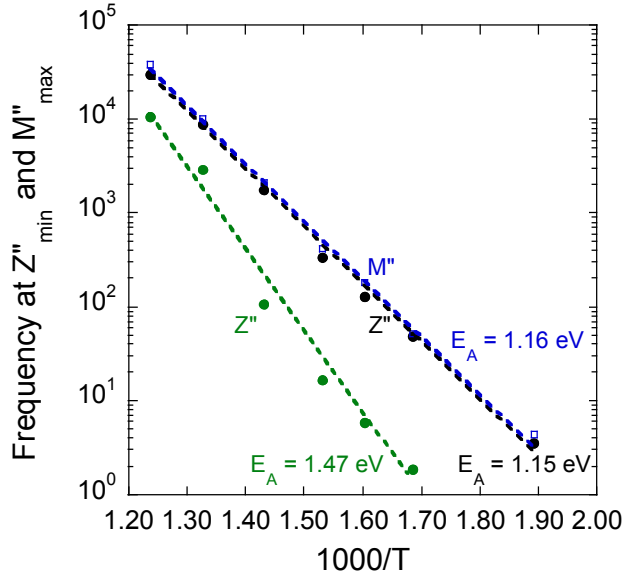


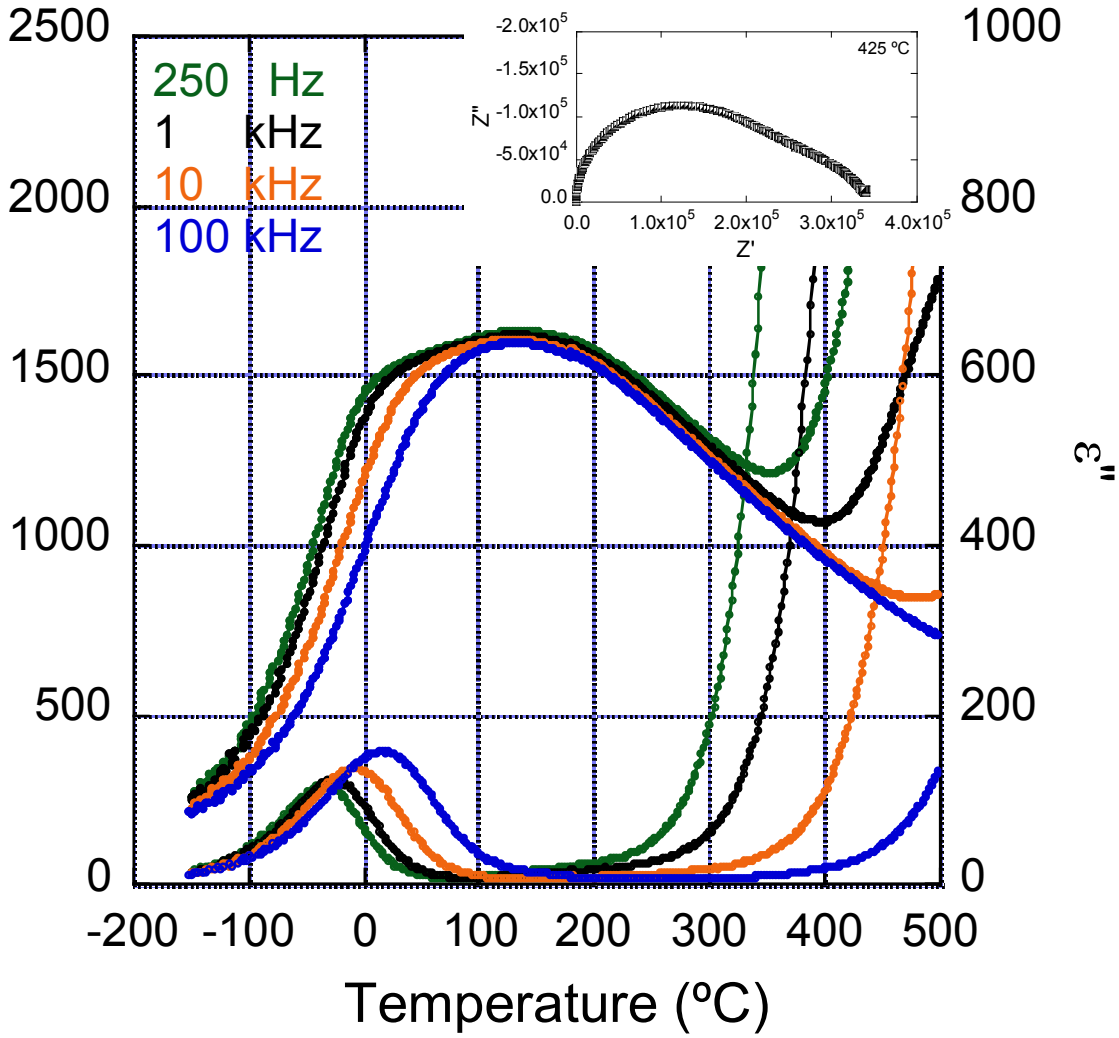
Raengthon, et al., Appl. Phys. Lett. (2012)

- Defect studies suggest V_{Ba}'' – V_O^{oo} pairs are strong carrier traps

Nominally Stoichiometric, Acceptor

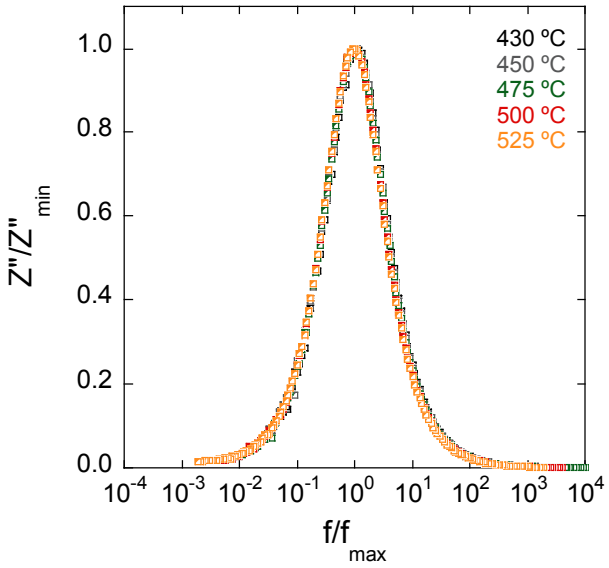


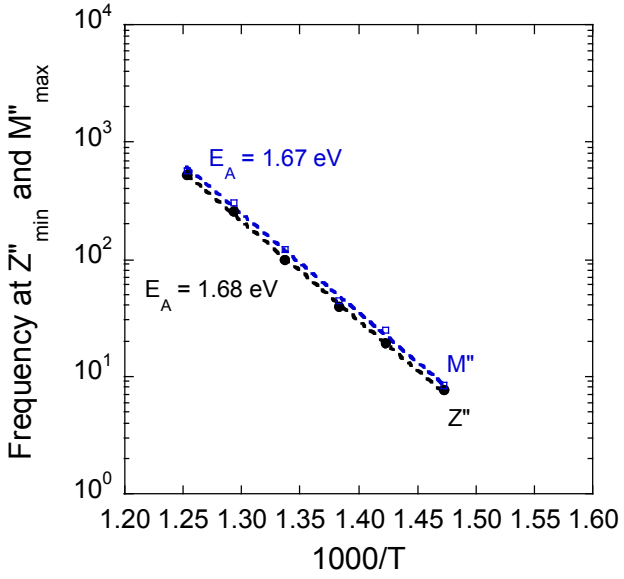


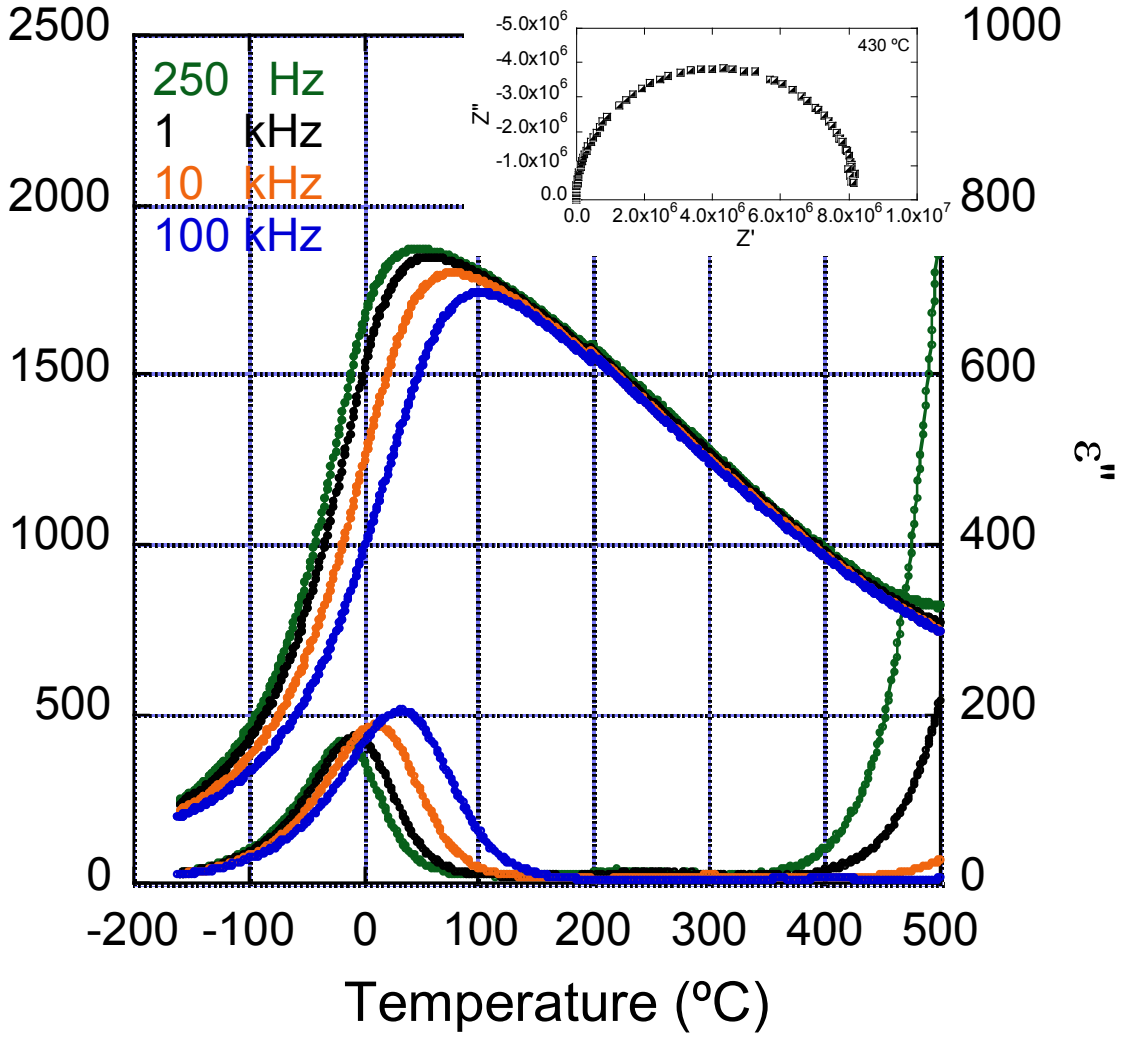


- (Nominally) stoichiometric and acceptor-doped samples are 'electrically heterogeneous'

Donor-Doped

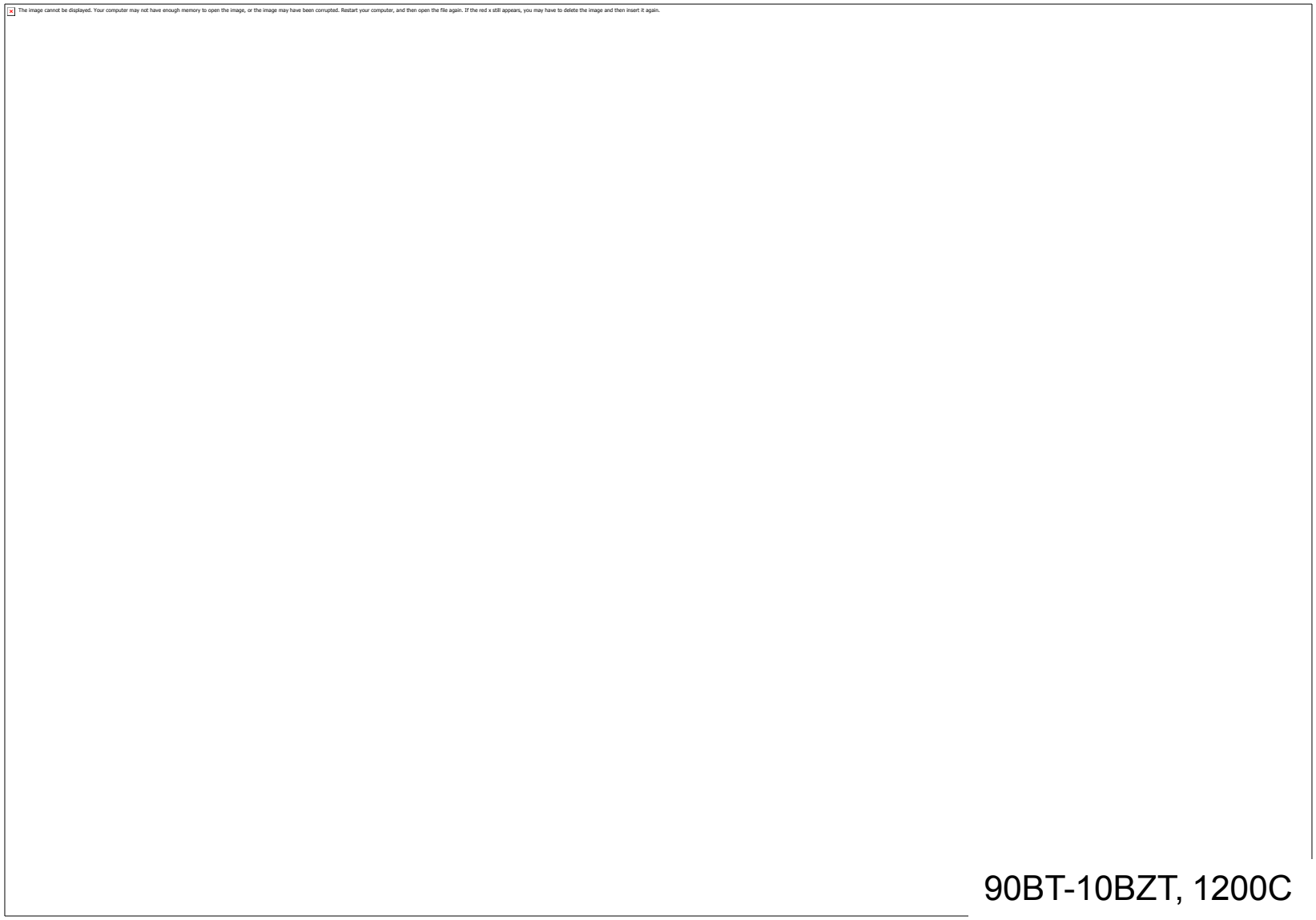






- Donor-doped samples are 'electrically homogeneous'

Typical Microstructures



90BT-10BZT, 1200C

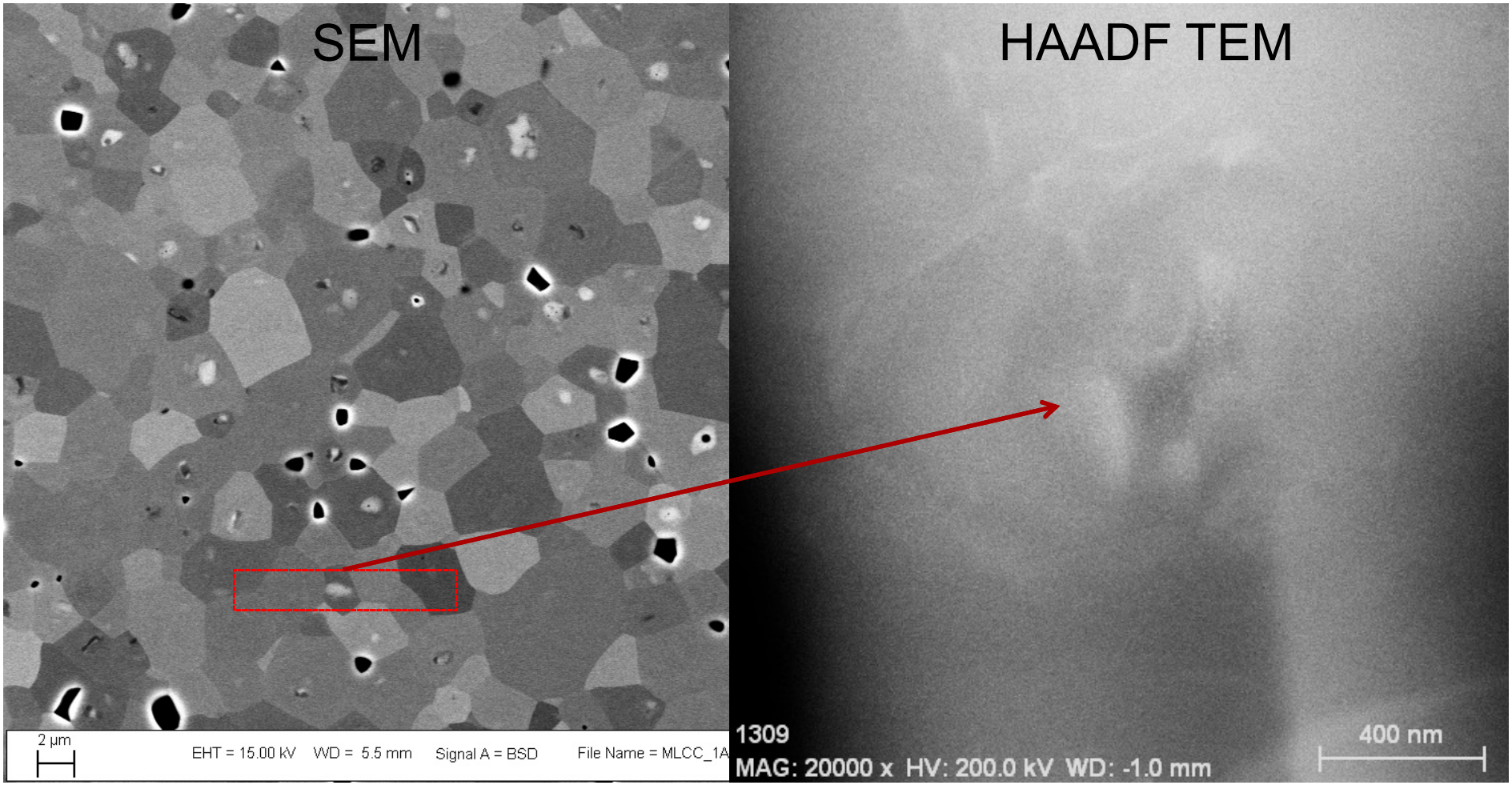
Typical Microstructures

80BT-20BZT, 1200C

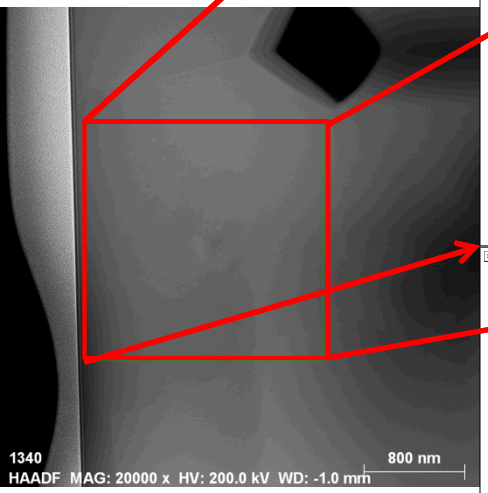
Typical Microstructures

80BT-20BZT, 1200C

Compositional Variation



Bi and Zn Variation



Map

Summary

- Electrical response(s) of weakly-coupled relaxor systems tied to multi-scale chemical heterogeneities

- Complex microscale chemical distributions appear to be (somewhat) independent of relaxor behavior, but likely contribute strongly to high-field electrical behavior

- Reminder: no single view (or characterization technique) provides the complete picture!