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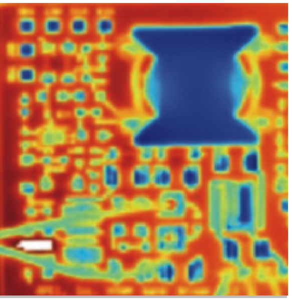
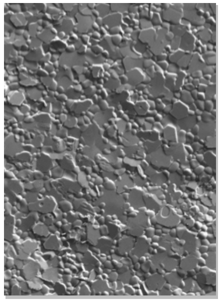
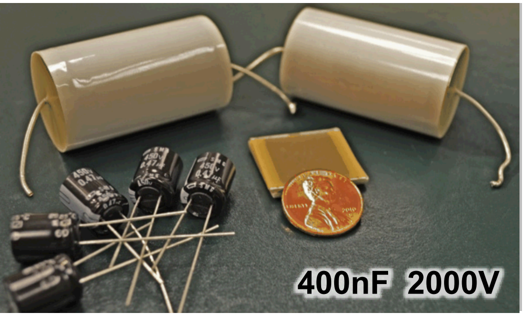






Processing of $Bi(Zn_{1/2}Ti_{1/2})O_3$-$BaTiO_3$ dielectrics for reliable high field operation

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

Geoff Brennecka, Harlan Brown-Shaklee and Mia Blea

Sandia National Laboratories

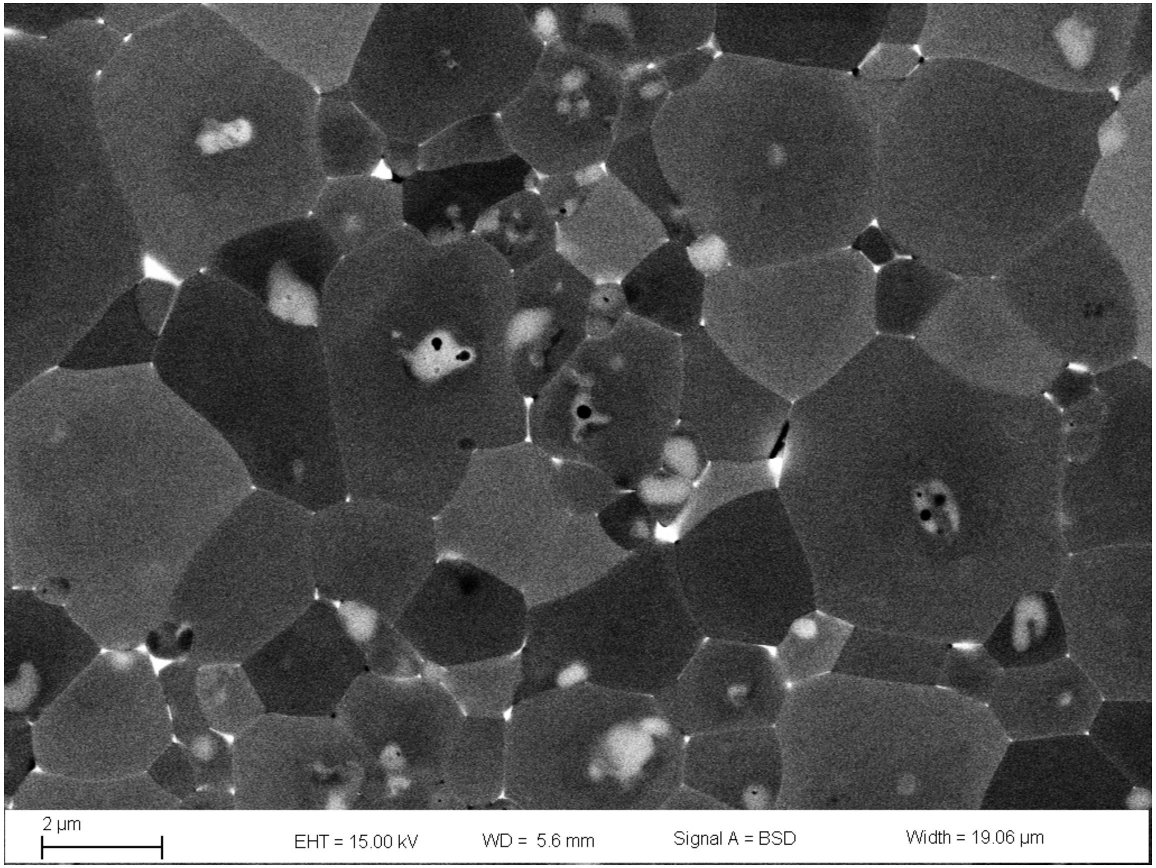
Natthaphon Raengethon and David Cann

Oregon State University

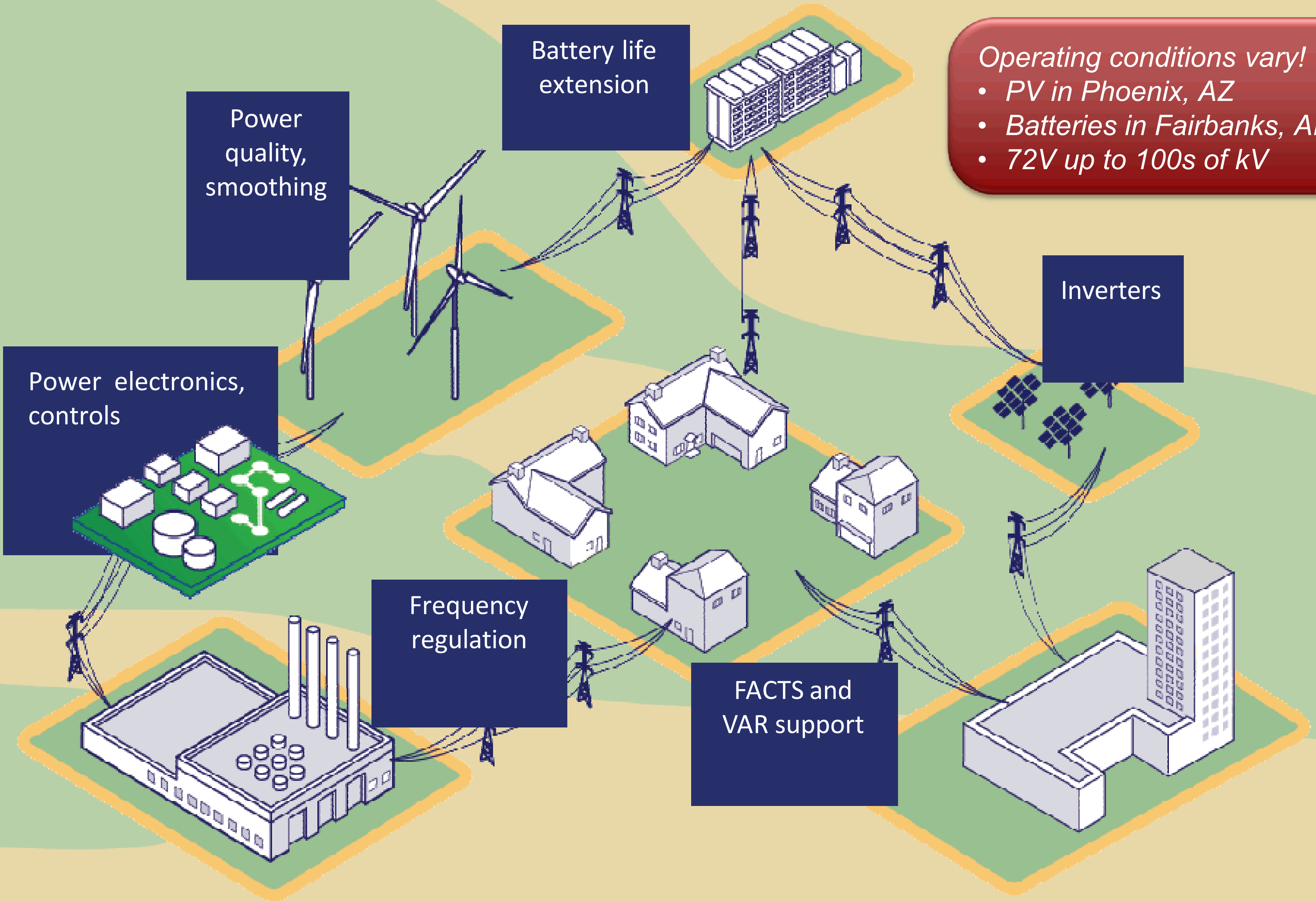
The authors gratefully acknowledge the support of Dr. Imre Gyuk and the Department of Energy's Office of Electricity Delivery and Energy Reliability.

Acknowledgements

- This work would not have been possible without:
  - Alice Kilgo
  - Bonnie McKenzie
  - Joe Michael
  - Ping Lu
  - Kevin Ring (NM Tech)
  - Yu Hong Jeon (OSU)
  - Adrian Casias
  - Adrian Wagner
  - Mark Rodriguez
  - John Borchardt
  - Greg Lyons
  - Jim Klarkowski



Capacitor Needs for Grid Storage



Battery life extension

Power quality, smoothing

Power electronics, controls

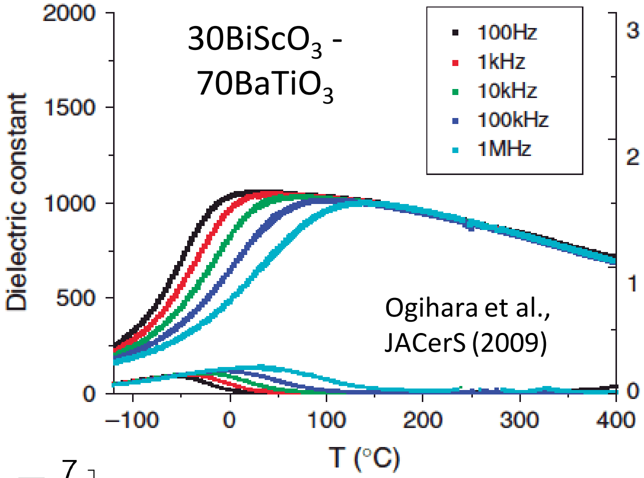
Frequency regulation

FACTS and VAR support

Inverters

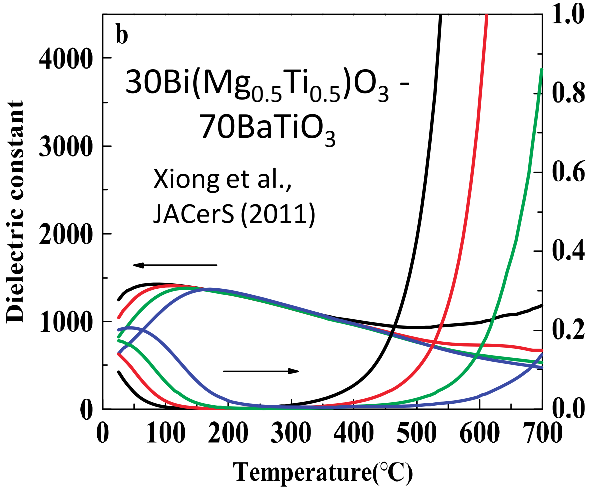
Operating conditions vary!
- *PV in Phoenix, AZ*
- *Batteries in Fairbanks, AK*
- *72V up to 100s of kV*

Bi-modified $BaTiO_3$ Relaxors



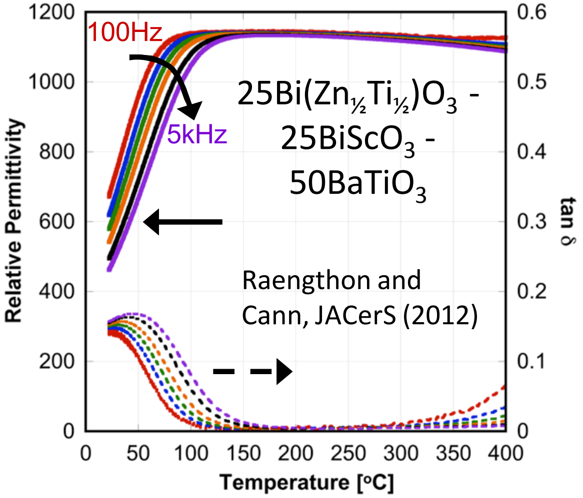
$30BiScO_3$ - $70BaTiO_3$

Ogihara et al., JACerS (2009)



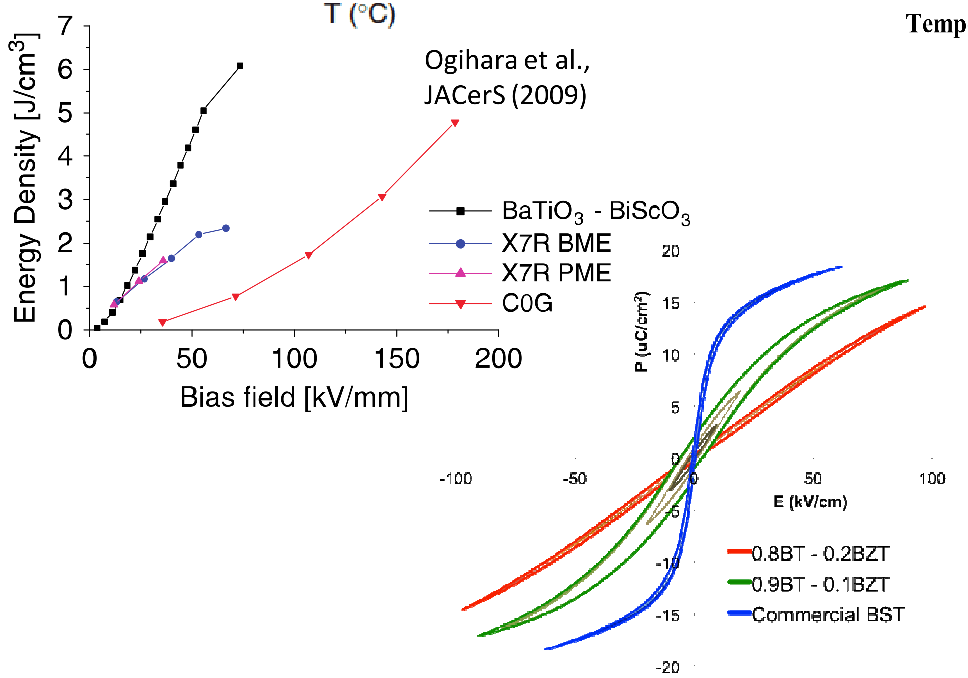
$30Bi(Mg_{0.5}Ti_{0.5})O_3$ - $70BaTiO_3$

Xiong et al., JACerS (2011)



$25Bi(Zn_{½}Ti_{½})O_3$ - $25BiScO_3$ - $50BaTiO_3$

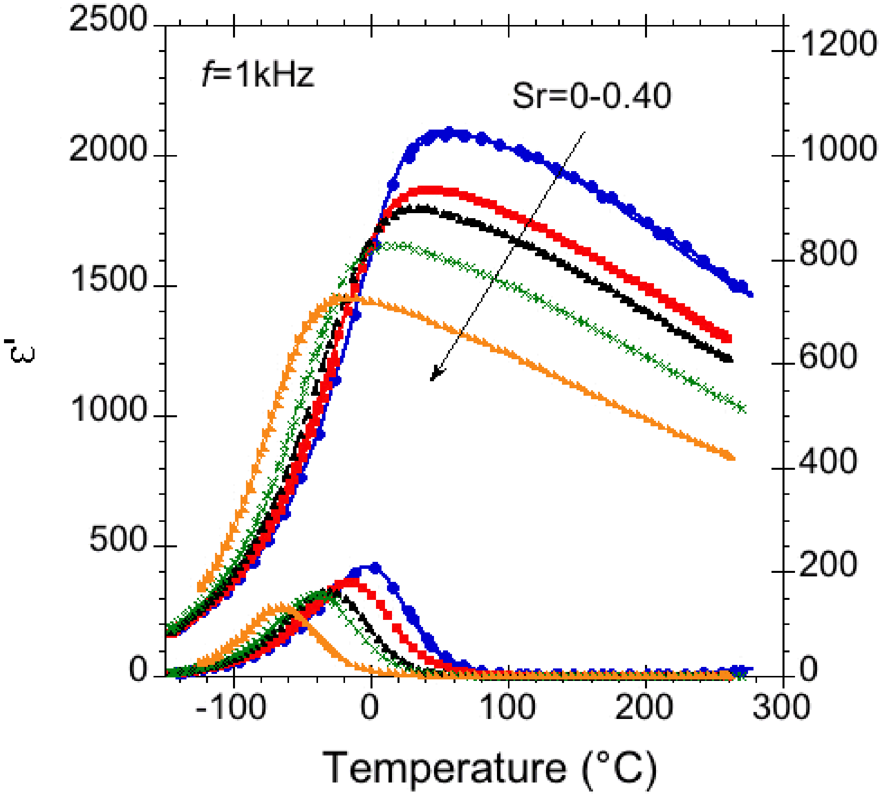
Raengthon and Cann, JACerS (2012)

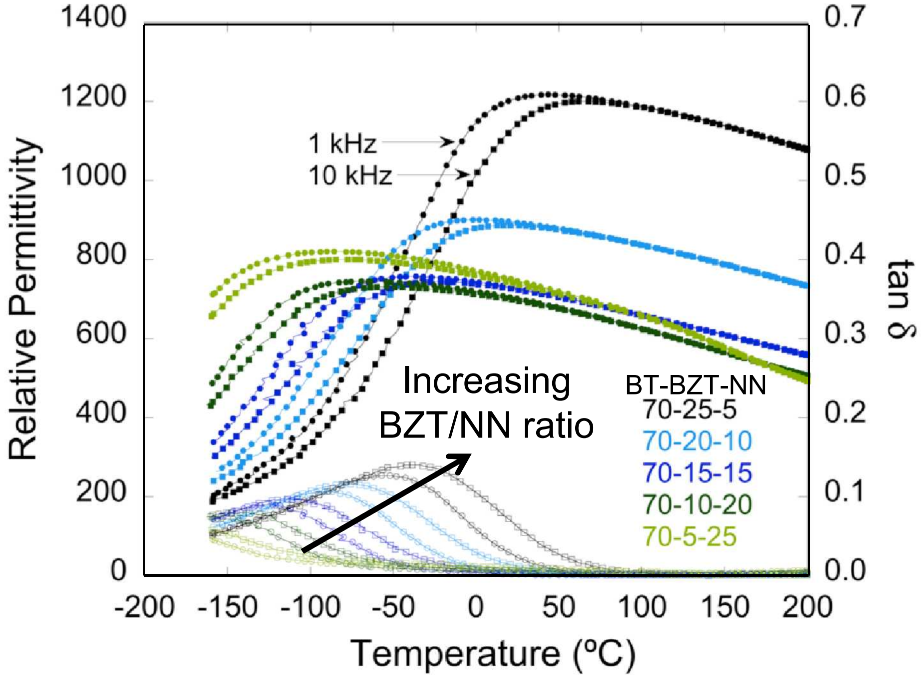


Ogihara et al., JACerS (2009)

- ‘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}



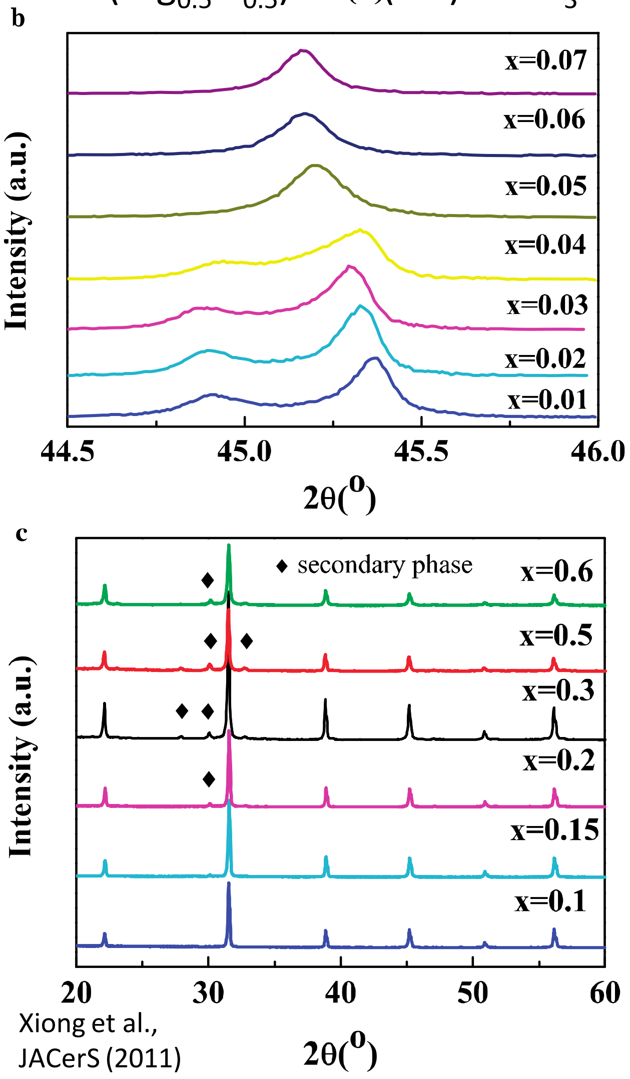


- $NaNbO_3$, $SrTiO_3$, $BaZrO_3$, La_{Bi}^{x}, etc. shift T_{max} down
- $BiScO_3$, $PbTiO_3$ and others shift T_{max} up

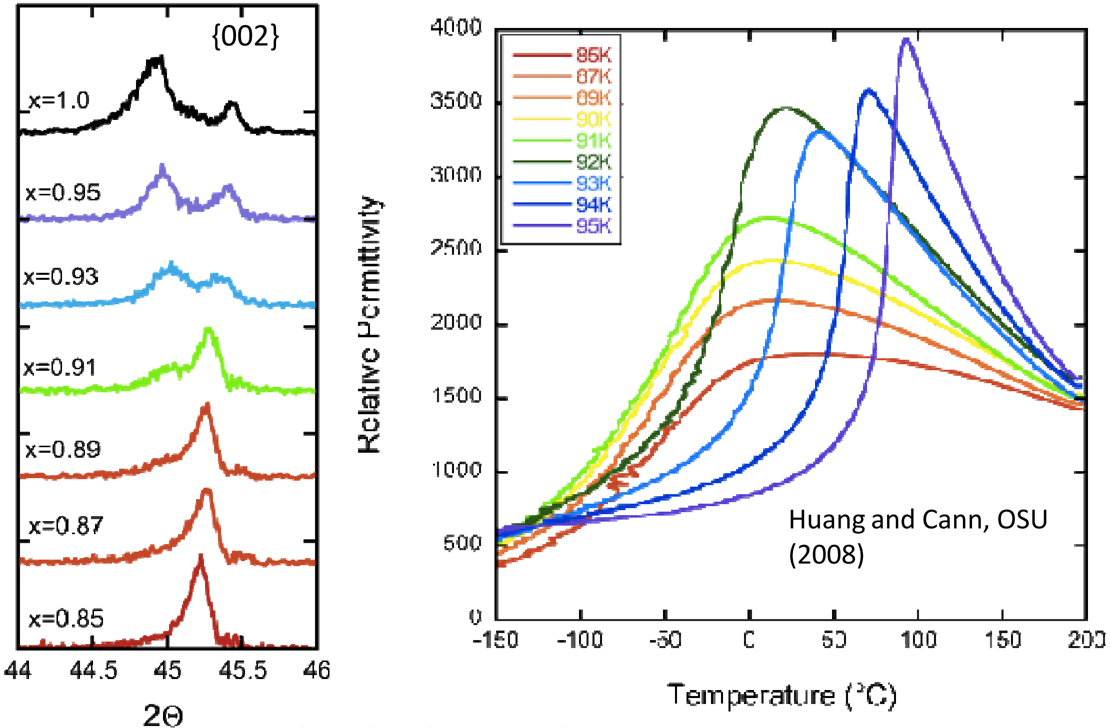
Diffraction Studies are Limited

- 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…

$xBi(Mg_{0.5}Ti_{0.5})O3(-)(1\text{-}x)BaTiO_3$



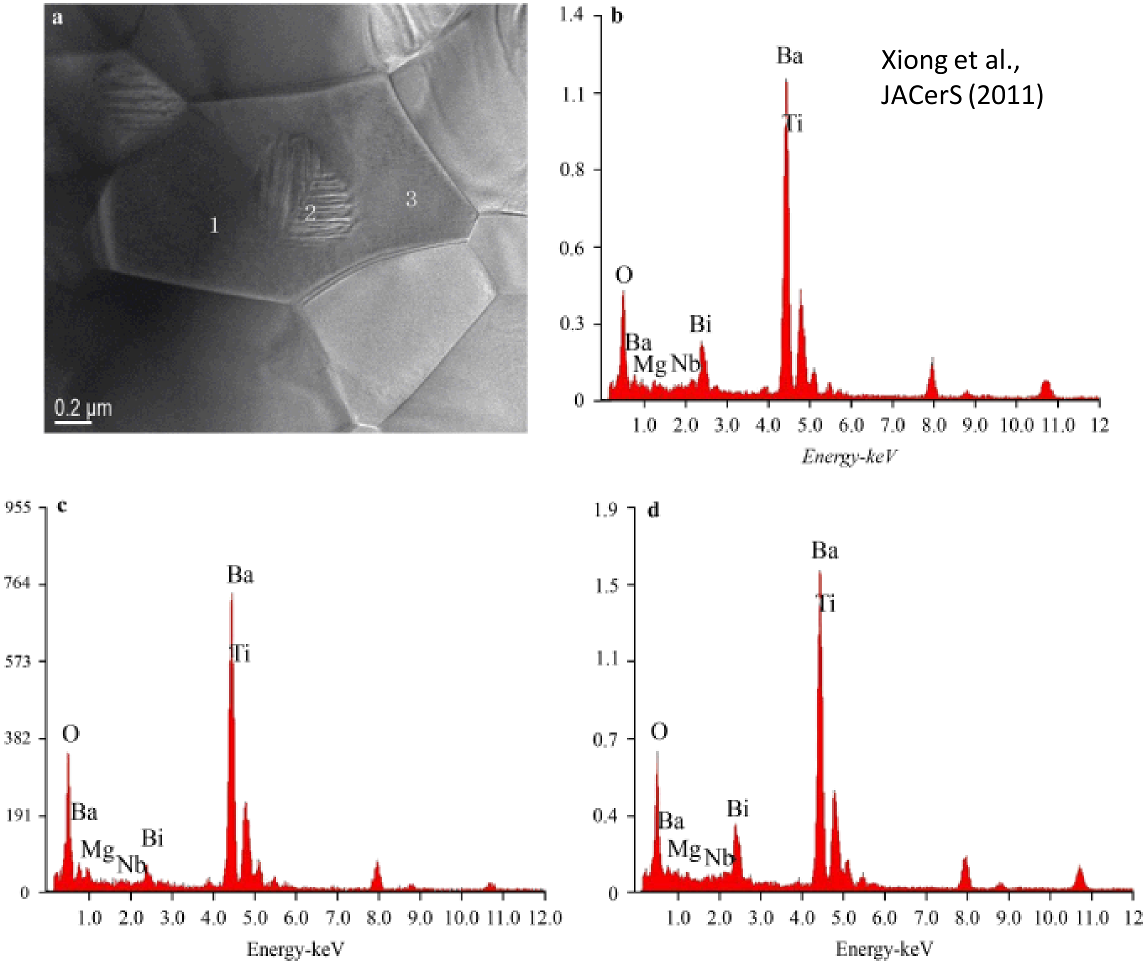
Xiong et al., JACerS (2011)



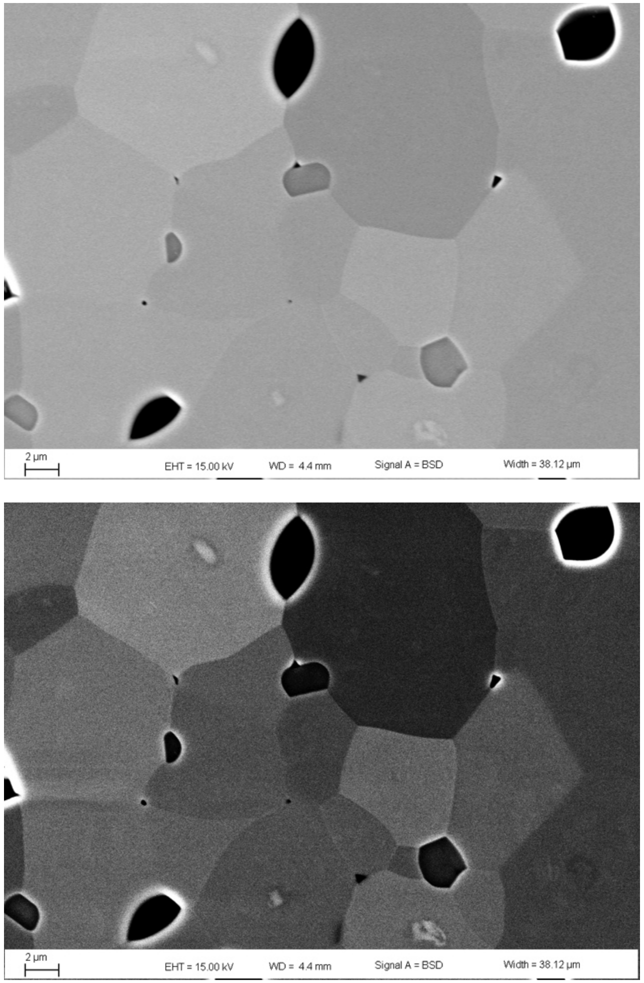
Huang and Cann, OSU (2008)

$(1\text{-}x)Bi(Zn_{½}Ti_{½})O_3 – xBaTiO_3$

BT-BZT: Modifications can Shift T_{max}

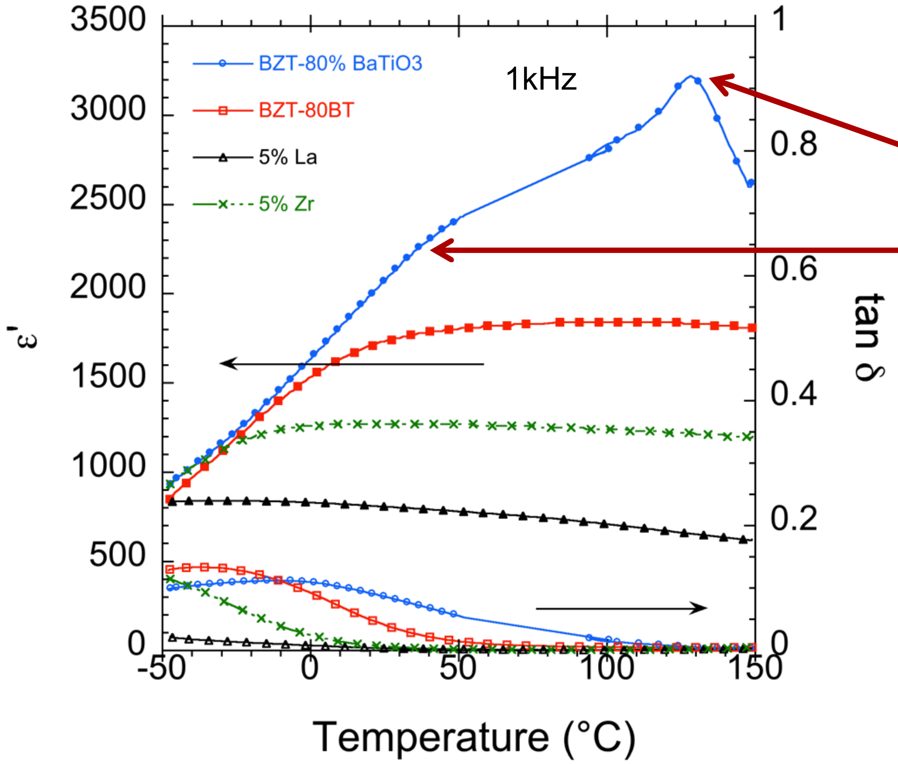


Xiong et al., JACerS (2011)

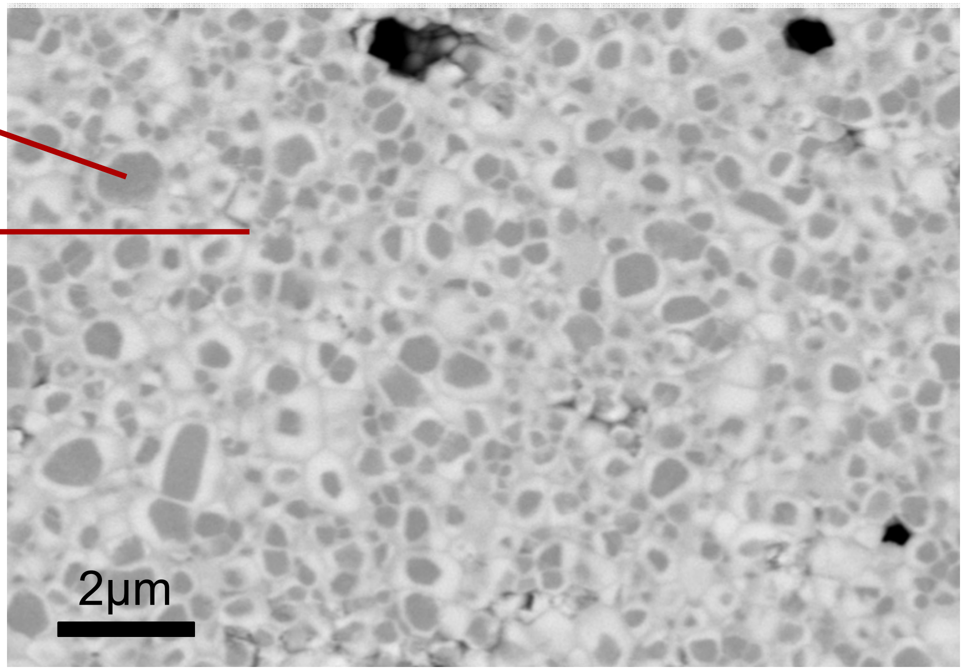


- Reminder: ‘single phase by XRD’ != homogeneous

BT-BZT: Modifications can Shift T_{max}



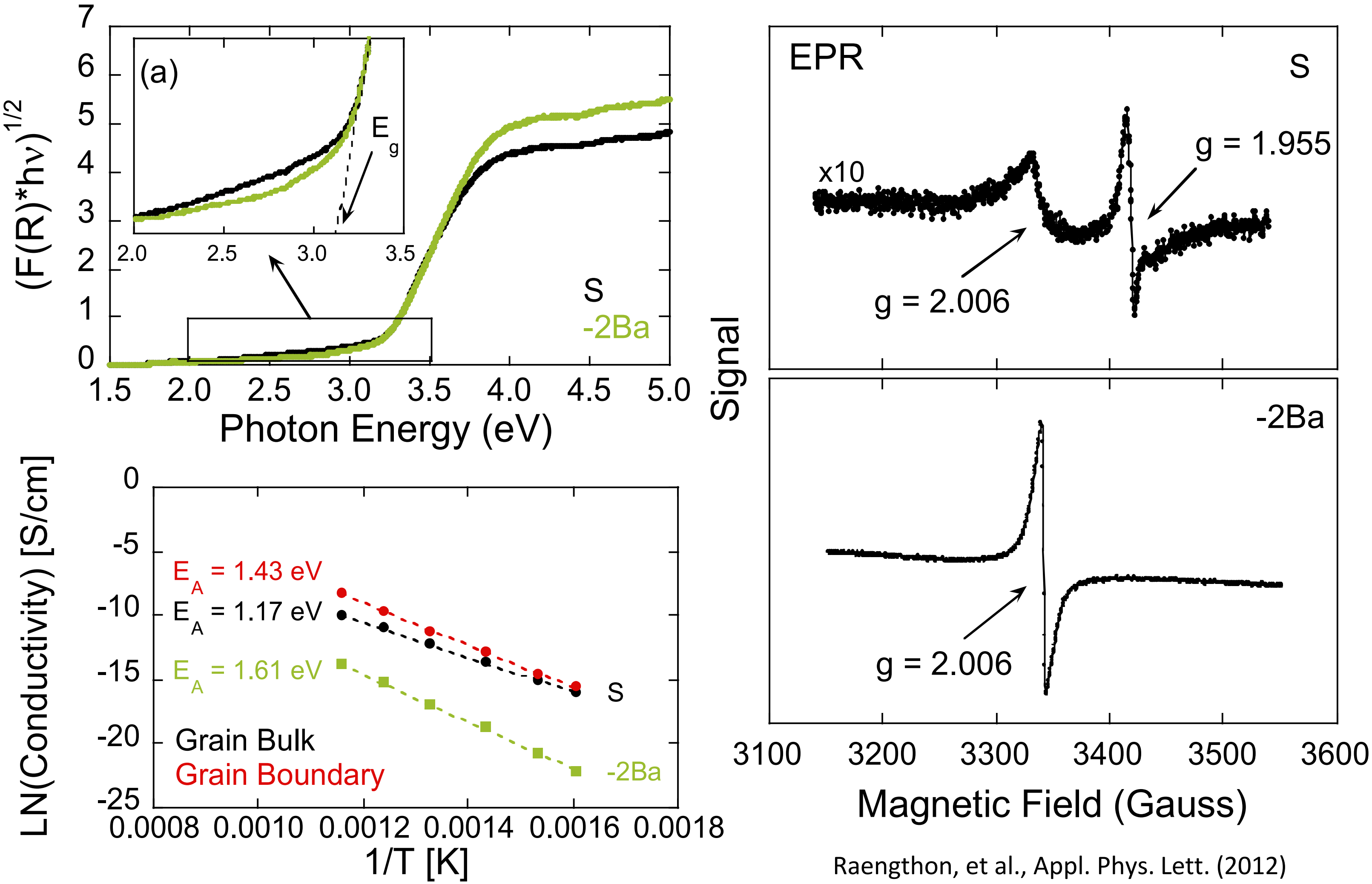
Intentionally fabricated $BaTiO_3$ core, Bi-rich shell



Core exhibits T_C ~125°C
Shell exhibits relaxor behavior

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

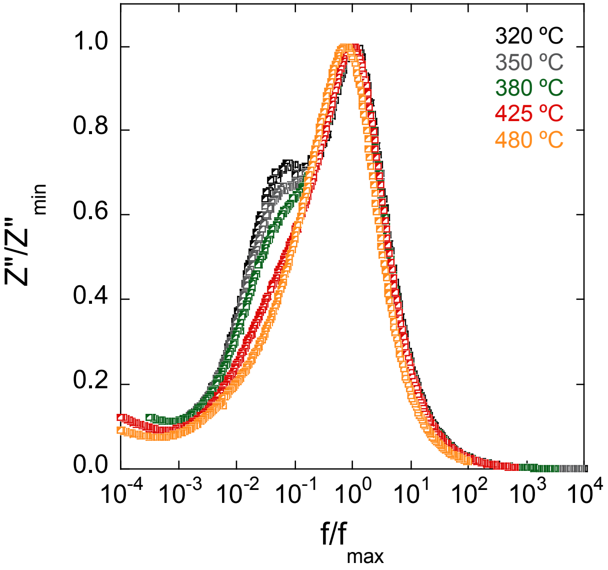
Defects: Optical & Electrical Info

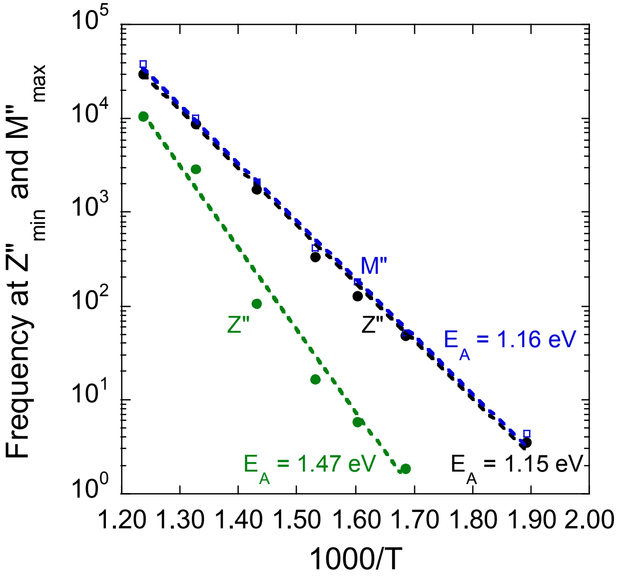


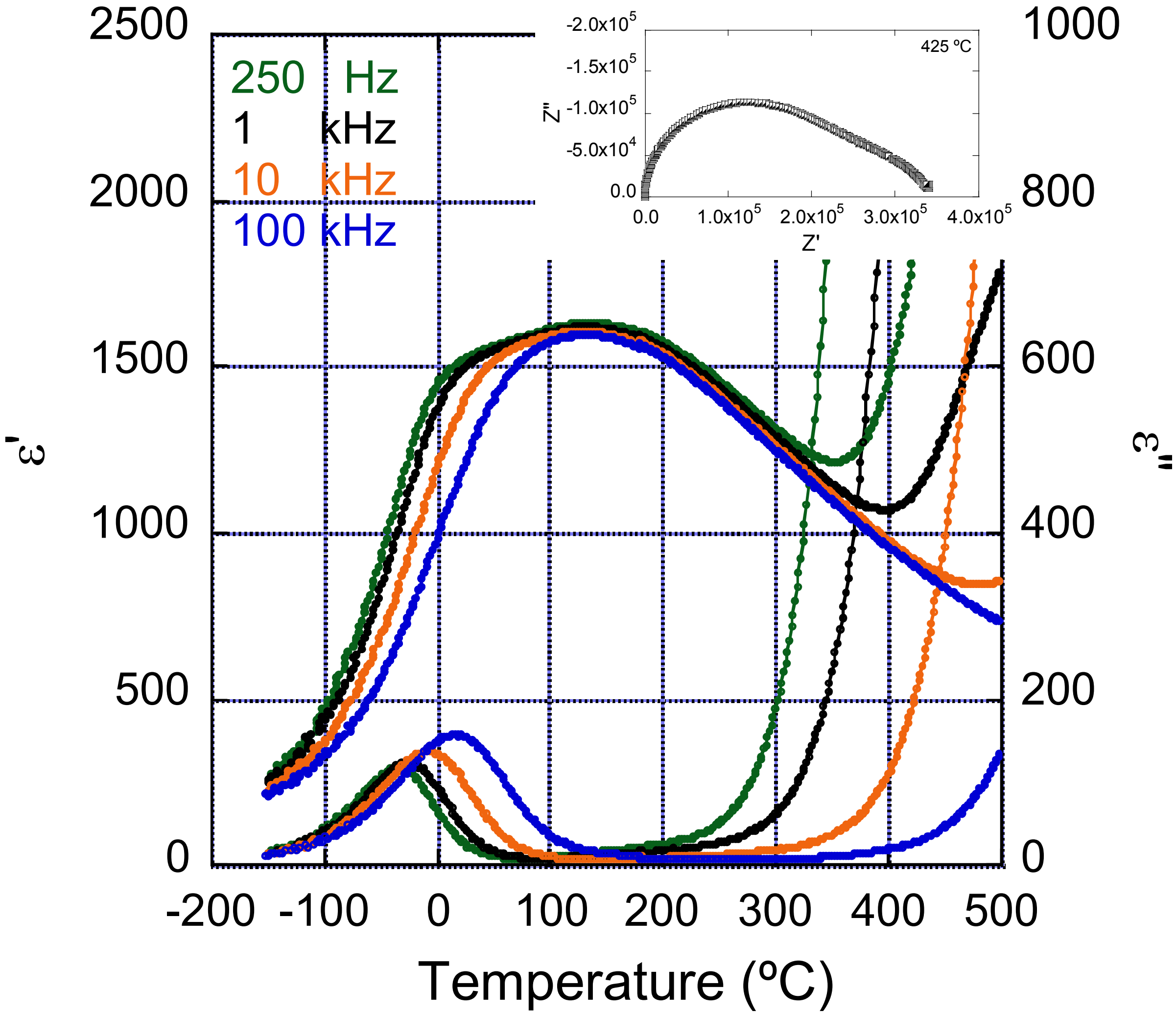
Raengthon, et al., Appl. Phys. Lett. (2012)

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

Nominally Stoichiometric, Acceptor

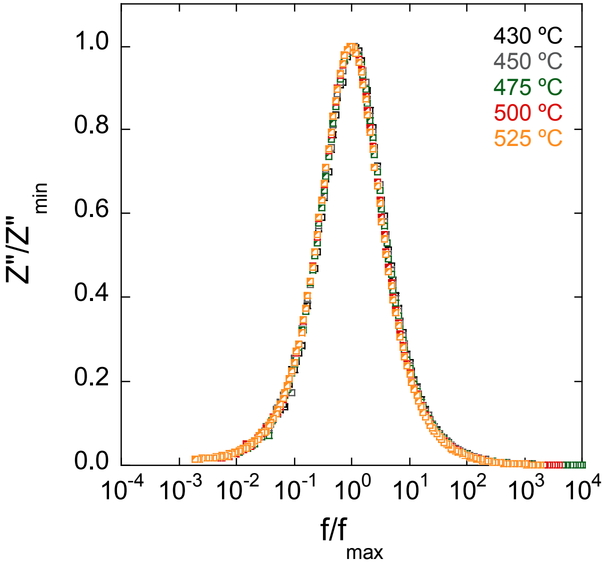


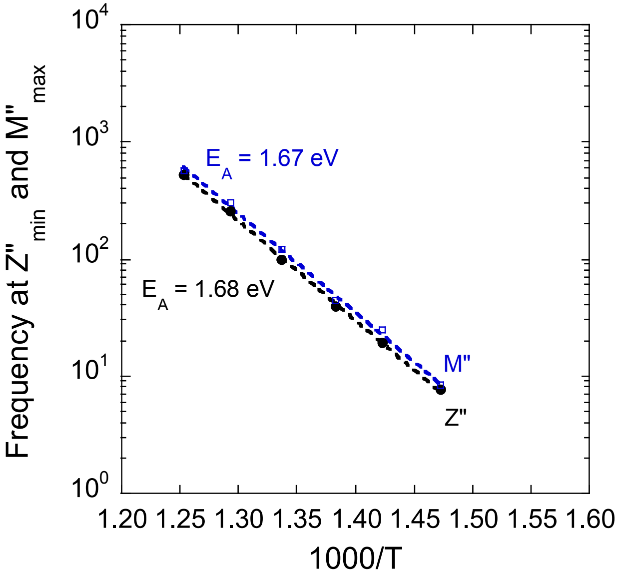


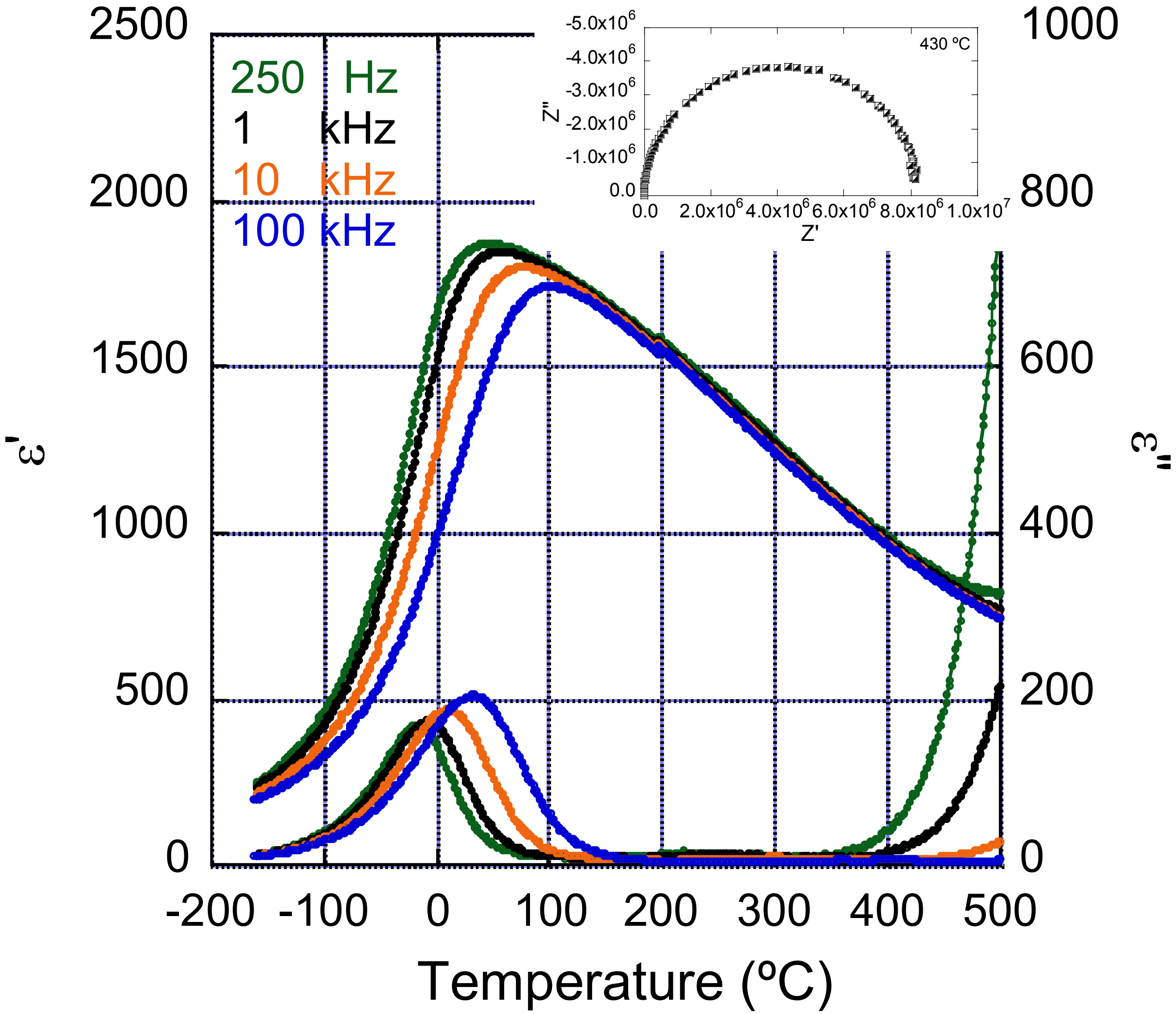


- (Nominally) stoichiometric and acceptor-doped samples are ‘electrically heterogeneous’

Donor-Doped

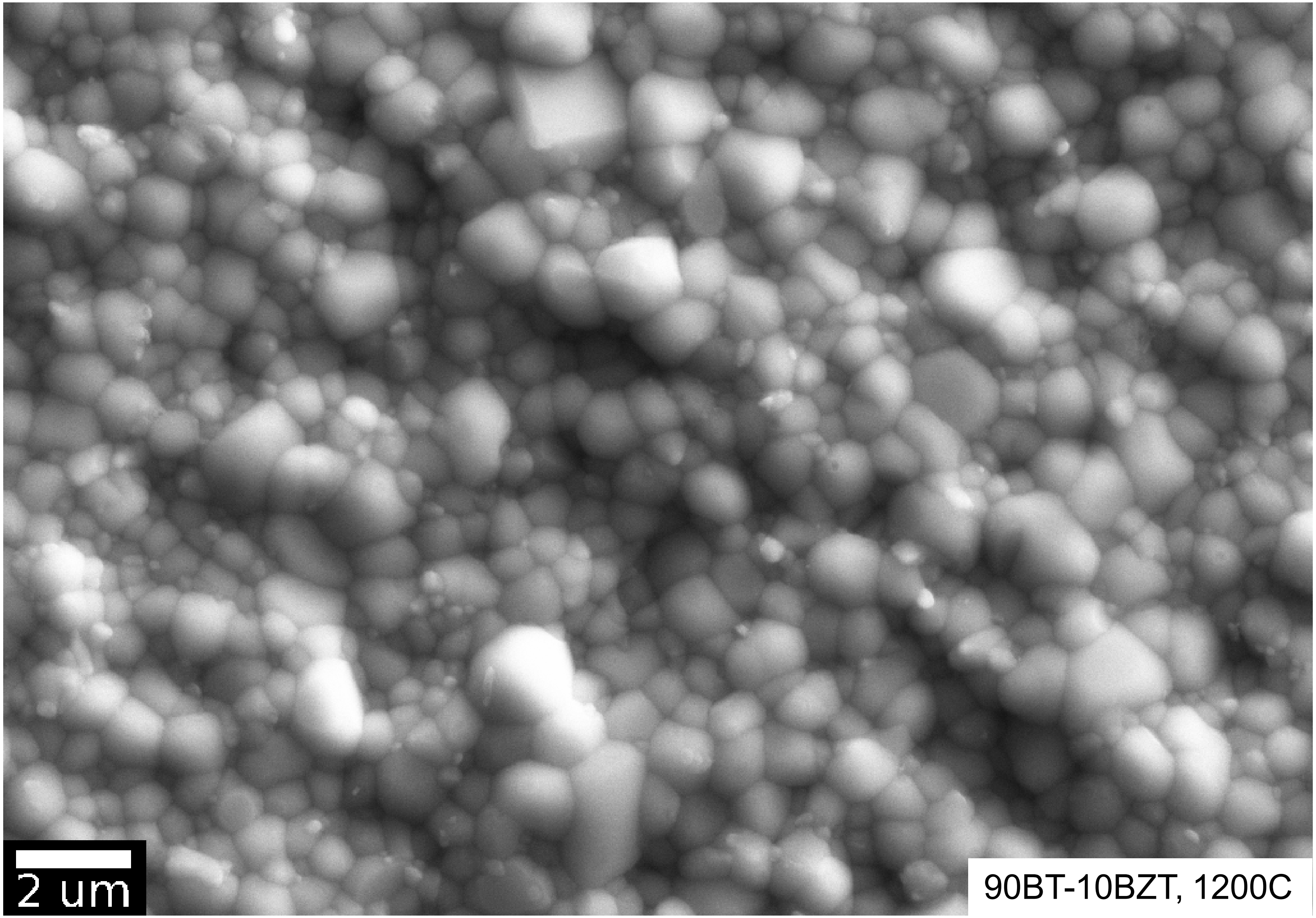






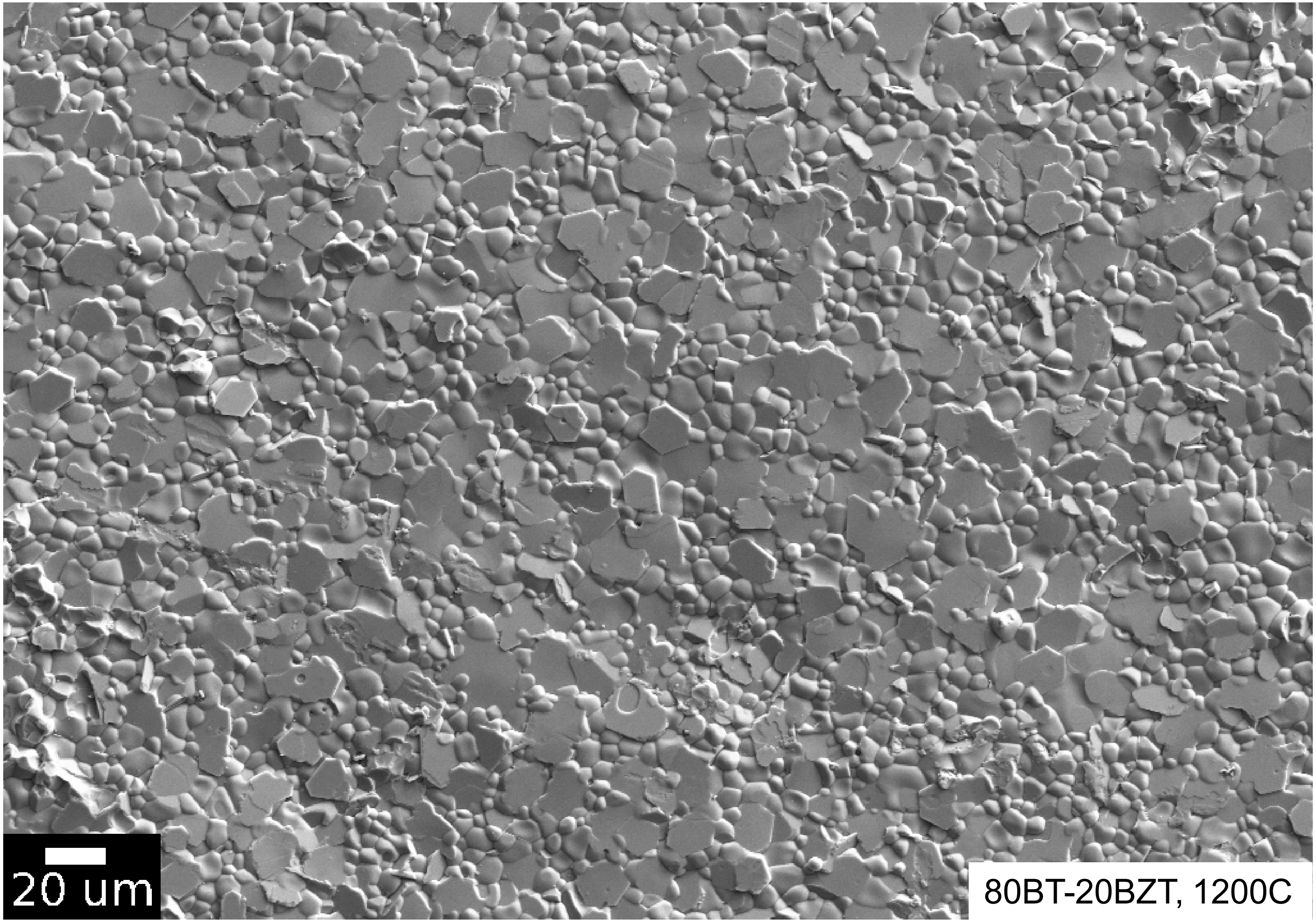
- Donor-doped samples are ‘electrically homogeneous’

Typical Microstructures



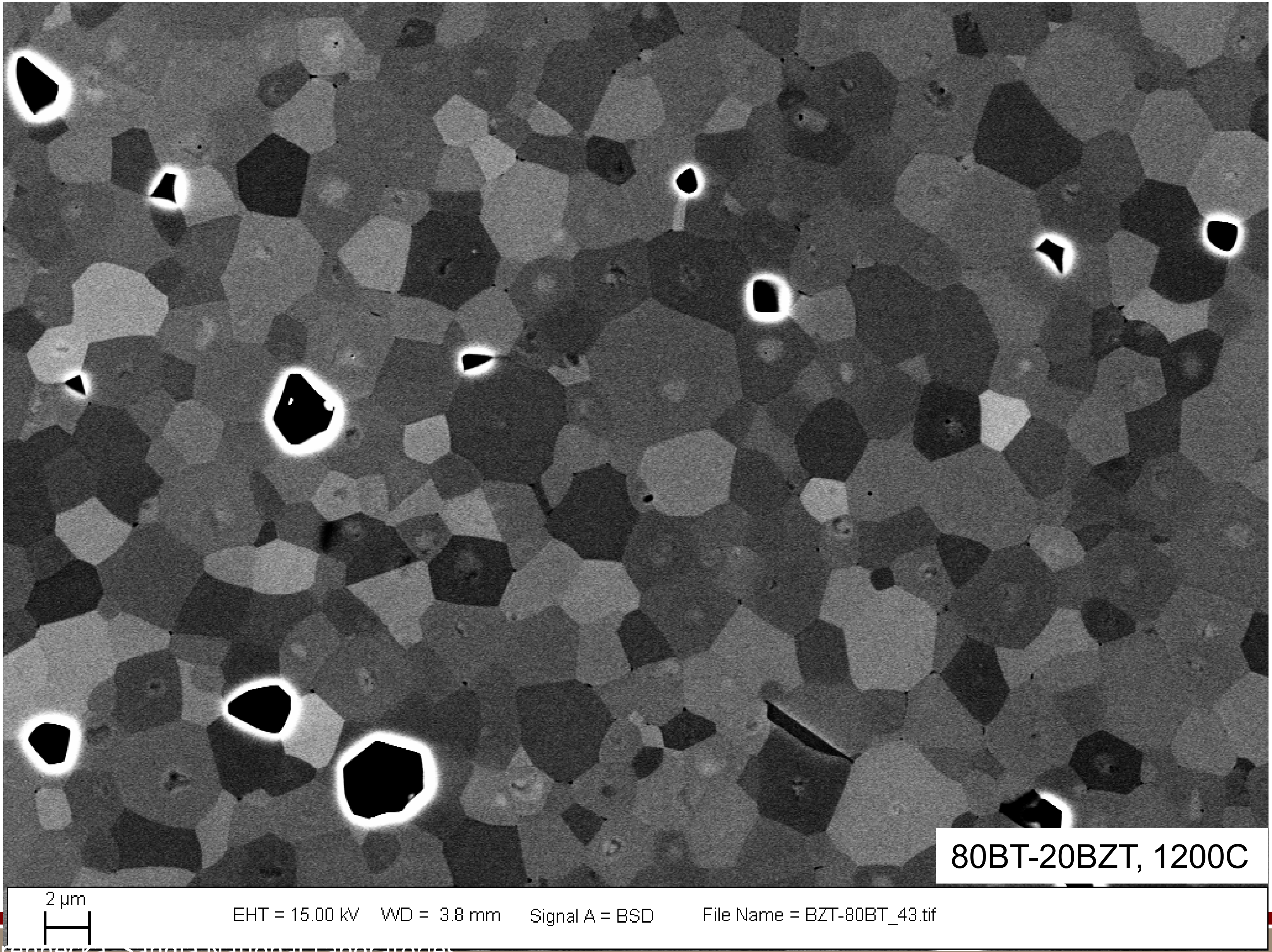
90BT-10BZT, 1200C

Typical Microstructures

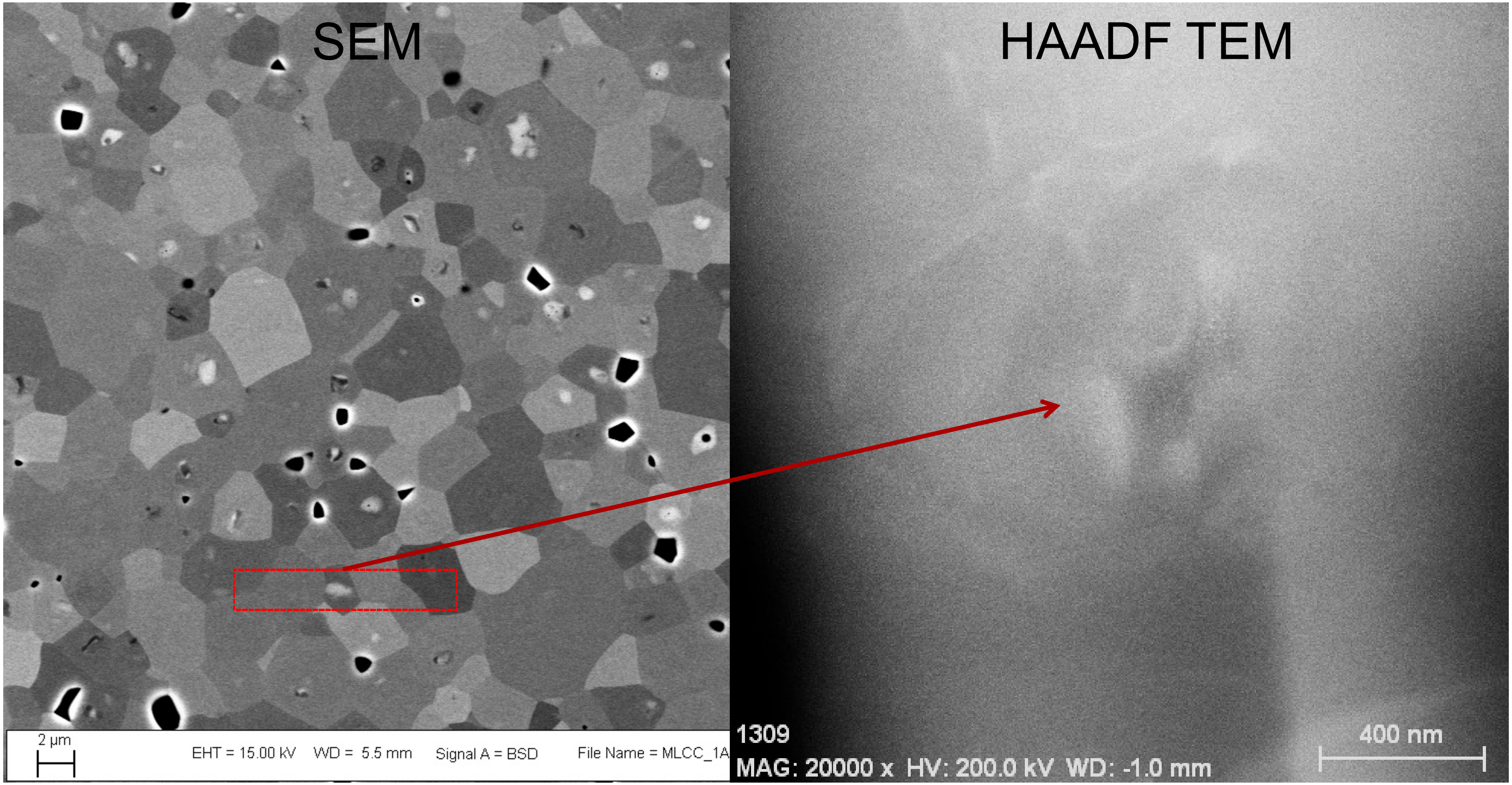


80BT-20BZT, 1200C

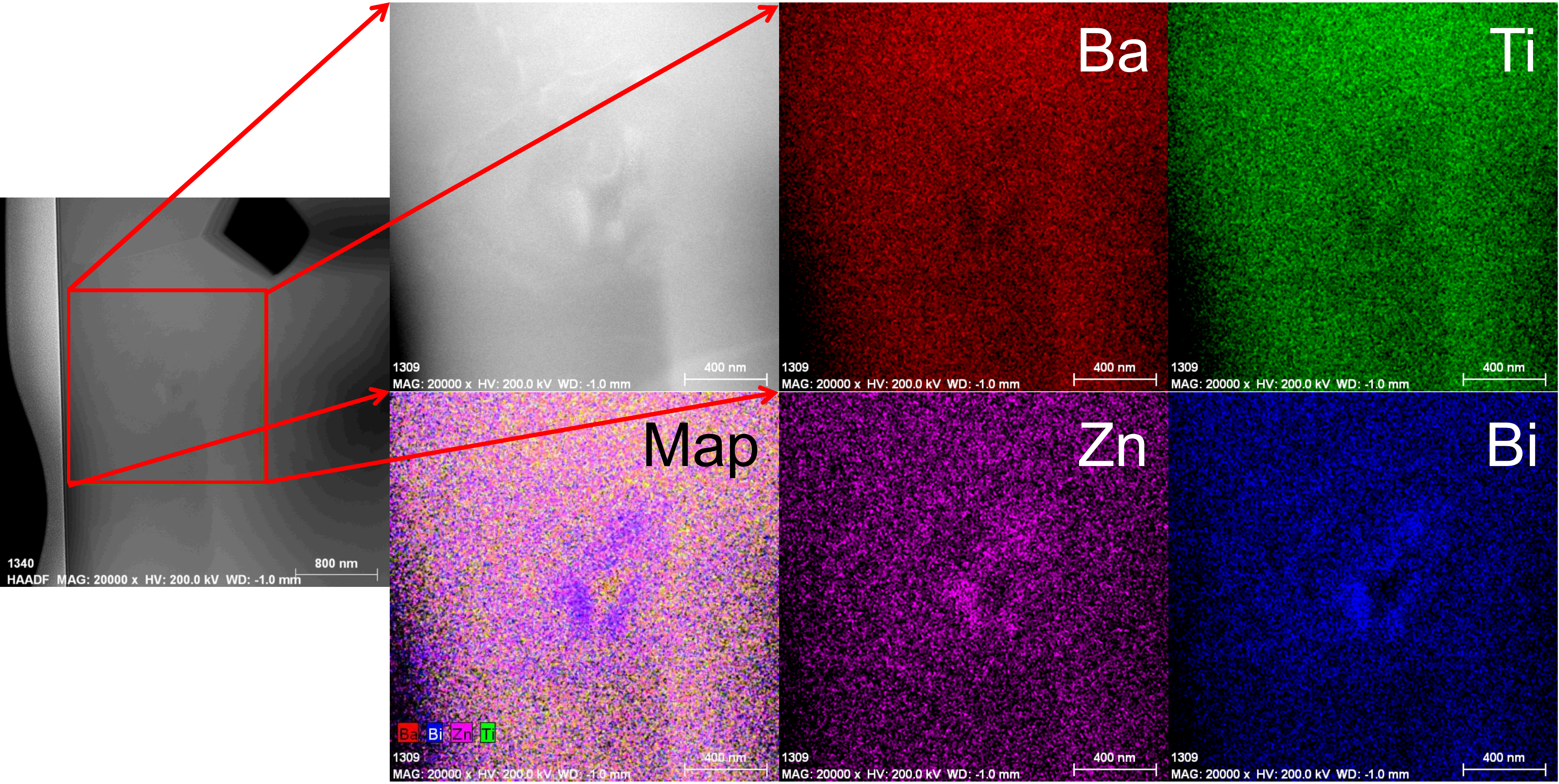
Typical Microstructures



Compositional Variation



Bi and Zn Variation



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!