Effects of dopant on depoling temperature in modified \( \text{BiScO}_3 - \text{PtTiO}_3 \)
Introduction

• Piezoelectrics for high temperature applications
  – Fuel/gas modulation, ultrasonic drilling, etc.
• Tolerance factor \( t \) acts as guide for selection of non-PT member
• BiScO\(_3\) – PbTiO\(_3\):
  – \( T_c \): 450°C, \( d_{33} \): 460 pm/V for morphotropic phase boundary (MPB) composition


– A-site modification: La, Ba
– B-site modification: Ga, Mn, Zr, Zn\(_{0.5}\)Ti\(_{0.5}\), Nb, etc.
– DC conductivity, tan\( \delta \), \( d_{33} \), \( T_c \), \( T_d \), etc.
A different metric

- Curie temperature ($T_c$) doesn’t tell whole story
- Many piezoelectric materials depole before $T_c$
- Why do they depole? Domain rotation, phase transitions, inhomogeneities
- Dope to change depoling temperature


Dopant effects on depoling temperature in BS-PT
Compositions

• Previous success with aliovalent Zr\textsubscript{Sc} and compensated Zn\textsubscript{0.5}Zr\textsubscript{0.5} on Sc
  – 2\% Zr\textsubscript{Sc} increases T\textsubscript{d} by 20\textdegree C for 37BS – 63PT, with a decrease in T\textsubscript{c}
• Compositions chosen from rhombohedral and tetragonal regions around MPB
• Aliovalent Zn\textsubscript{Sc} chosen for high ferroelectric activity; hybridizes similarly to Ti
• Conventional solid state processing
  – Calcine: 3hrs @ 750\textdegree C
  – Sinter: 1hr @ 1100\textdegree C

Zr\textsubscript{Sc} doping – Sehirlioglu et al., J. Am. Cer. Soc., 2010
Zn\textsubscript{0.5}Zr\textsubscript{0.5} doping – Kowalski et al, J. Am. Cer. Soc., 2013
X-ray Diffraction Comparison

- BSPT62: Shifting rhombohedral/tetragonal ratio
- BSPT64: Increasing c/a ratio (1.011 to 1.013) with Zn addition
- ★: \( \text{Pb}_x \text{Bi}_{(1-x)} \text{O} \) phase
Optical Microscopy

- Density: > 96%; dense structures with low porosity
- Grain Size: tends to increase with Zn addition
- Size distribution: possible promotion of abnormal grain growth with Zn addition
- $\text{Pb}_x\text{Bi}_{(1-x)}\text{O}$ observed in clusters at grain boundaries
Weak Field Measurements

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High Field Measurements

- Poled at 100°C under 40kV/cm for 30 min.
- BSPT62: Increased $E_c$, $P_r$ with Zn addition
- Assymetric hysteresis
  - Doesn’t fully depole upon switching; Possible pinning from defects
Phase angle (θ) – BSPT58

- Phase angle: 100Hz to 3MHz
- Width in phase angle peak related to coupling coefficients
Phase angle ($\theta$) – BSPT58

- Phase angle: 100Hz to 3MHz
- Width in phase angle peak related to coupling coefficients
Phase angle ($\theta$) – BSPT

The diagram shows the phase angle ($\theta$) versus temperature ($T$) for different BSPT samples (BSPT58, BSPT60, BSPT62, BSPT64, BSPT66). The color scale indicates the dopant effects on depoling temperature in BS-PT (200). The inset graphs display the corresponding 2D plots for each sample, highlighting the frequency distribution of the 2θ peaks.
Phase angle (θ) - Transitions

- $T_c$
- $T_{d_{\text{final}}}$
- $T_{d_{\text{onset}}}$

Transition effects on depoling temperature in BS-PT (200)
Phase angle (θ) - Transitions

\[ \tau, \psi \]

Transitions

14 Dopant effects on depoling temperature in BS-PT (200)

\[ T_c, T_{d_{\text{final}}}, T_{d_{\text{onset}}} \]

Phase angle ($\theta$) - Comparison

Dopant effects on depoling temperature in BS-PT
Phase angle ($\theta$) - Transitions

Dopant effects on depoling temperature in BS-PT
Zn_{0.5}Zr_{0.5} for Sc

- BZZ2: 60PbTiO_3 – 40Bi[0.9375Sc,0.0625(Zn_{0.5}Zr_{0.5})]O_3
- BZZ5: 62.5PbTiO_3 – 37.5Bi[0.933Sc,0.066(Zn_{0.5}Zr_{0.5})]O_3

Zn_{0.5}Zr_{0.5} doping – Kowalski et al, J. Am. Cer. Soc., 2013
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Zn$_{0.5}$Zr$_{0.5}$ doping – Kowalski et al, J. Am. Cer. Soc., 2013
Conclusions

- We looked at the effects of dopants on $T_d$ and relevant properties.
- ZnSc increases $T_d$, $\tan \phi$, and relevant properties, also slightly enhancing electromechanical properties.
- Zn$^{0.5}$Zr$^{0.5}$ increases electromechanical properties.
- Structure-specific trend behavior for Zn$^{\infty}$.
- Combine with other aliovalent dopants to tailor properties further.
- We looked at the effects of Zn$^{\infty}$ on $T_d$ and relevant properties.

Dopant effects on depoling temperature in Bi-Sn-PT
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