Room-Temperature Fabrication of Dielectric Ceramics

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Abstract

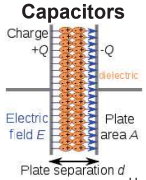
Conventional ceramic processing techniques use high-temperature sintering to achieve high degrees of densification in ceramic compacts; however, this process uses a significant amount of energy. Room-temperature fabrication (RTF) of ceramic materials presents a promising energy-efficient alternative, which effectively eliminates the need to use a furnace. It also allows for cofiring of materials with lower sintering temperatures; however, the multiphase composition and hygroscopic nature of pellets produced using this method make fabricating functional ceramics a challenge. Our goal is to fabricate capacitors with properties comparable to those produced via conventional techniques. Composite pellets composed of the dielectric $PbZr_xTi_{1-x}O_3$ (PZT) and $Ba_{1-x}Sr_xTiO_3$ (BST) perovskite ceramics and Li_2MoO_4 binder will be synthesized via RTF. The volume fraction of binder material and ceramic particle size distribution and composition will be varied to minimize porosity and optimize relative permittivity, which will be measured using an LCR meter at temperatures ranging from -60 – 150°C.

Dielectrics

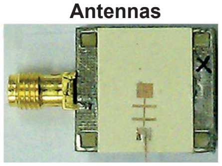
- A dielectric material exhibits appreciable electrical polarization upon exposure to an external electric field
- Dielectrics are useful for a variety of applications:

Computer Memory

Capacitors



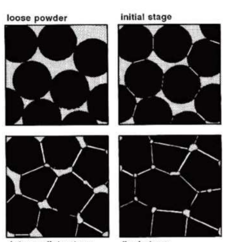
Antennas



Hong Le et al. *Chin. Phys. B.* **2015**, *24*, 127704.

Room Temperature Fabrication (RTF)

- Conventional sintering (>1000 °C) can result in low porosity and good electrical properties
- RTF reduces furnace energy consumption and allows for cofiring of materials with lower sintering temperatures
- Lower density and Li_2MoO_4 phase result in lower relative permittivity



Rivera. *Advances in Ceramics*; InTech, 2011; pp. 136

Aims

RTF fabrication of PZT- and BST-Li_2MoO_4 composites with low porosity and high relative permittivity.

Methods

Figure 1. Stoichiometric PbO, ZrO_2, TiO_2 powders were milled. **A.** Mill pot with milling media. **B.** Rotary mill.

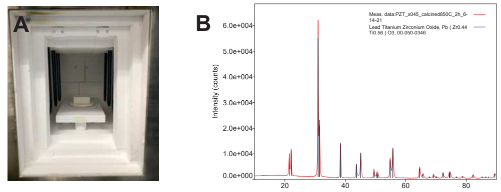


Figure 2. Powders were calcined at 850°C to produce phase-pure PZT. **A.** Covered crucible in box furnace. **B.** XRD pattern of $PbZr_{0.5}Ti_{0.5}O_3$ (red) with reported peak locations of $PbZr_{0.44}Ti_{0.56}O_3$ for verification (blue).

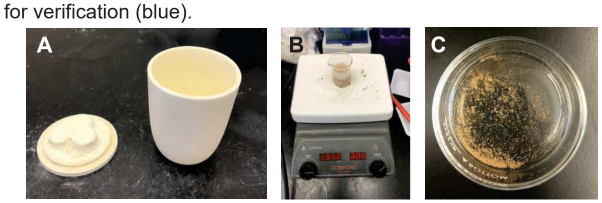


Figure 3. Calcined and milled powder was sintered at 1150°C in an inverted crucible and then coated with Li_2MoO_4. **A.** Powder pressed into pellets and coated with sacrificial powder. **B.** Coating procedure. **C.** Coated PZT.

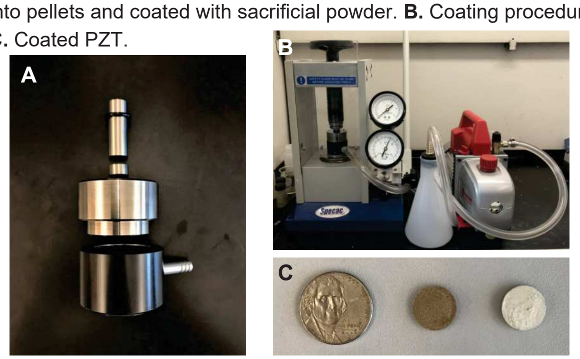


Figure 4. Coated powder was pressed with aqueous Li_2MoO_4 at 650 MPa under vacuum. **A.** Vacuum die. **B.** Uniaxial pellet press with vacuum pump. **C.** Pellet and silver-coated pellet relative to a nickel (from right to left).

Results

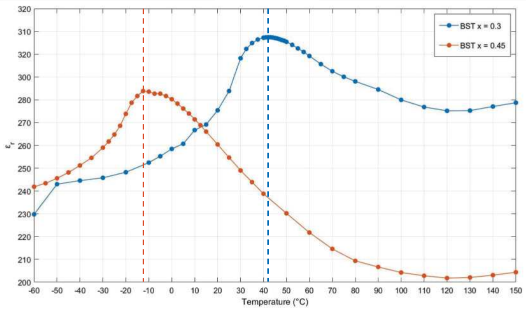


Figure 5. Dielectric properties of BST composites as a function of temperature at 1 kHz while cooling. In both cases, the Curie temperature (T_C) is indicated by a vertical dashed line.

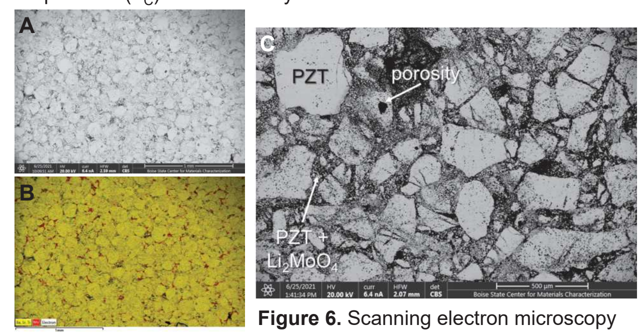


Figure 6. Scanning electron microscopy images of ceramic composites. **A.** Backscattered electron image of $Ba_{0.5}Sr_{0.5}TiO_3$ pellet. **B.** Phase mapping by EDS analysis of the same location, with yellow corresponding to BST, red to Li_2MoO_4, and black to porosity. **C.** Backscattered electron image of $PbZr_{0.5}Ti_{0.5}O_3$ pellet, with phases labelled.

Future Work

- Obtain electrical measurements across PZT compositions.
- Change binder material (Li_2MoO_4) to material with higher dielectric constant (V_2O_5, Rochelle salt).
- Vary coating procedure according to Nelo *et al.* 2019.
- Apply RTF method to doped PZT compositions (e.g., with isovalent additives to lower T_C and increase permittivity).

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