State Committee of Science RA

Synthesis of $0.77BiFeO_3$-$0.33BaTiO_3$-0.001Mn Solid Solution ceramics As Promising Materials For Accelerator Applications

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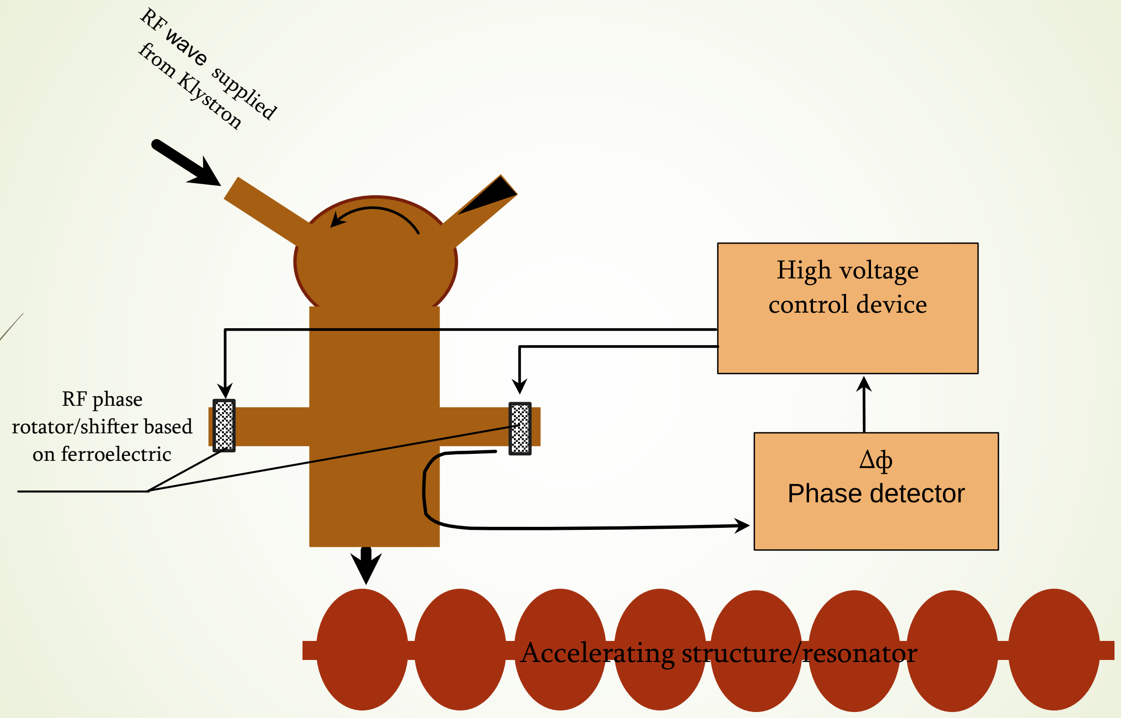
Topics

- Fast Switching Ferroelectric Materials for Accelerator Applications
- Ferroelectric and Multiferoic materials
- Self-propagating High-temperature Synthesis (SHS)
- SHS of $0.77BiFeO_3$-$0.33BaTiO_3$ Solid Solution

The Type Scheme of RF Phase Rotator/Shifter

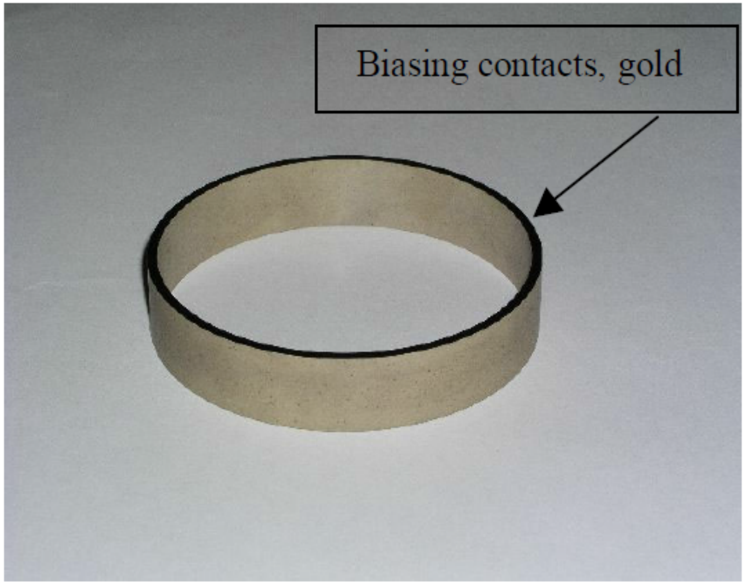


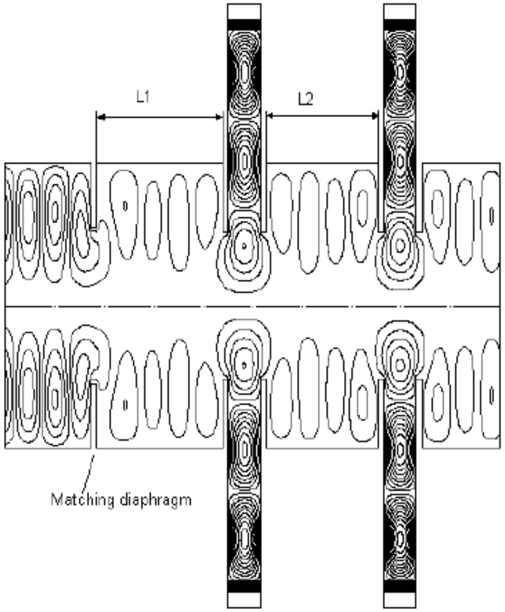
✓ The ferroelectric-based high power RF shifter is 1-2 times quicker than the usual ferrite or mechanical regulators.

Prototype BST(M) Ferroelectric Ring Sample and Conceptual Layout of the Switch

The ring diameter is 110 mm, thickness is 2.8 mm. The 2 um thick gold biasing contact deposited on the ring edge.

The operating mode of the cavities is TE_{031}





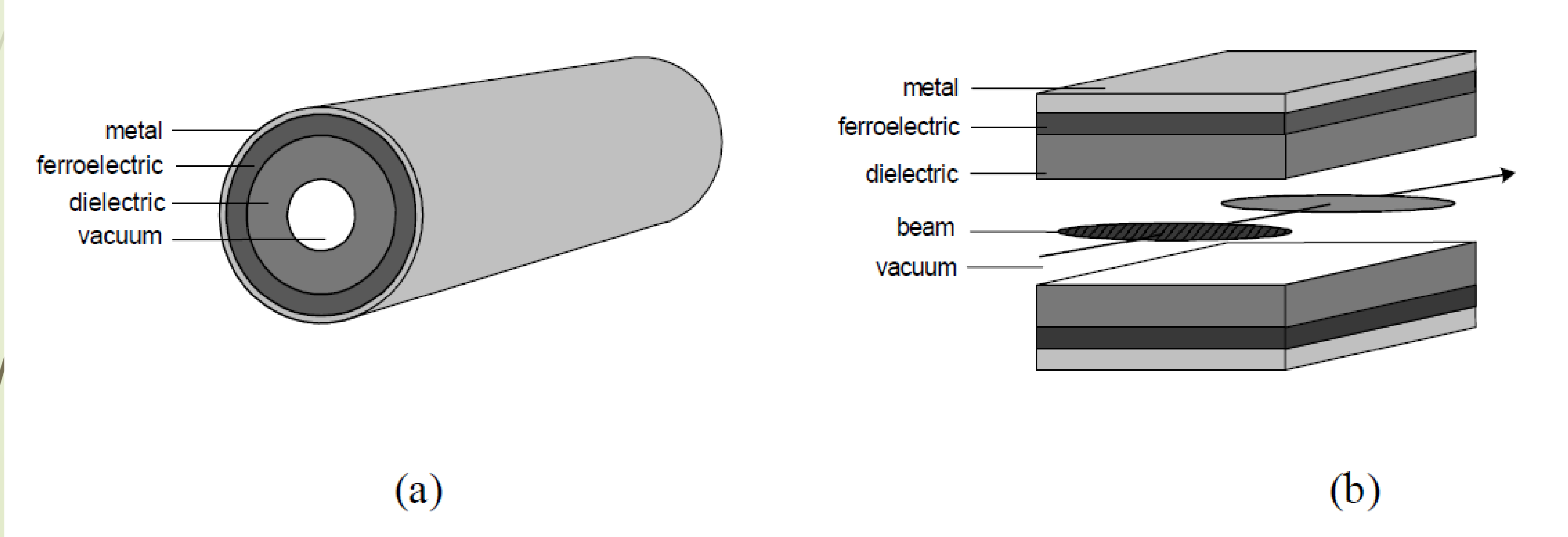
A. Kanareykin, E. Nenasheva, V. Yakovlev & et al.

Properties of $Ba_xSr_{1-x}TiO_3$ (x=1; 0.5; 0.4)

Dielectric constant at 10 GHz	400…500
Dielectric loss at 3-11 GHz	0.0021…0.0068
High electric breakdown strengths	100…200 kV/cm
Bias electric field	20…50 kV/cm
Tunability factor at 50 kV/cm	1.15 – 1.20
Leakage current density at a field intensity of 2×10^5 V cm^{-1}	10^{-11} … 10^{-10} A cm^{-2}

Basic Designs of Tunable Dielectric Loaded Accelerating Structures

(a): Cylindrical geometry, with ferroelectric outer layer and ceramic inner layer. The thickness of the ferroelectric layer is 1/10 of the ceramic thickness. (b): Tunable planar structure geometry.



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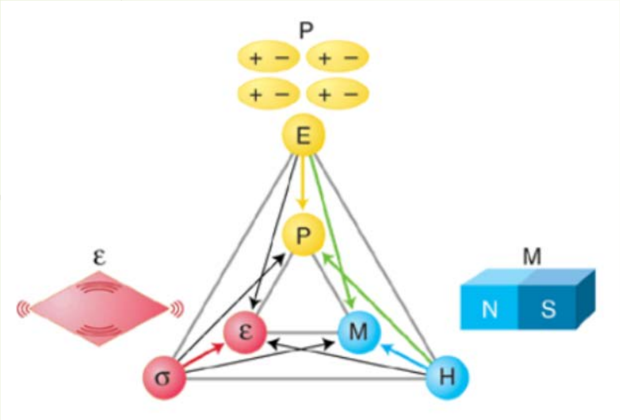
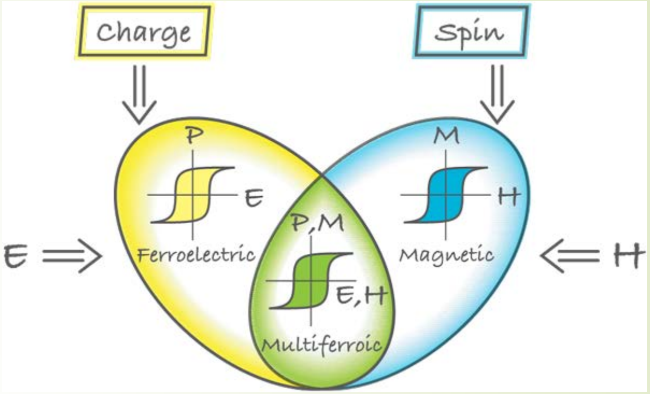
Ferroelectric and multiferoic

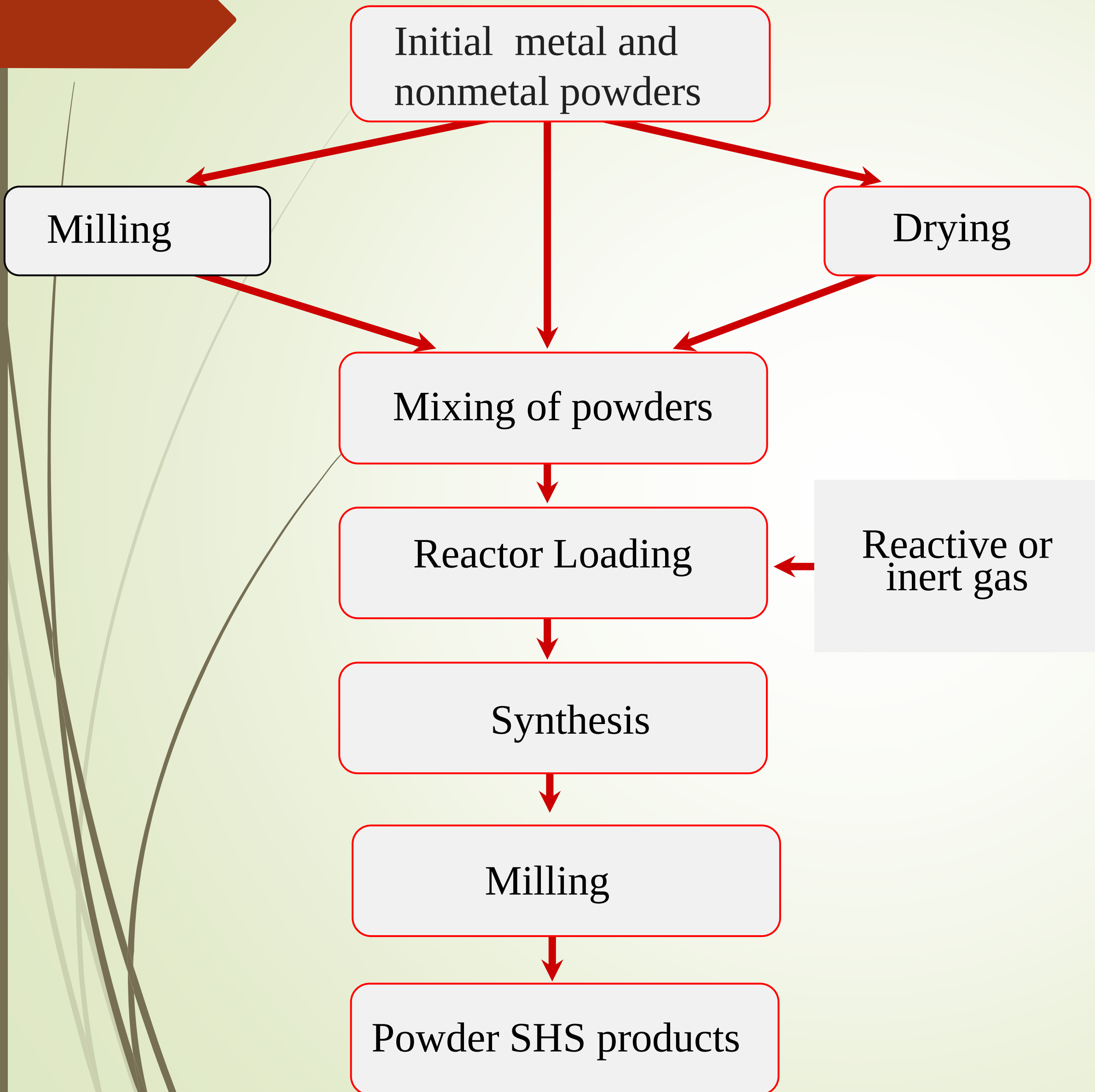




- Ferroic: P, M or ε are spontaneously formed to produce ferroelectricity, ferromagnetism or ferroelasticity;
- Multiferroic: Multiferroics are defined as materials with at least two of the forms of primary ferroic order in the same phase. Multiferroics combine the properties of ferroelectrics and magnets.

In the ideal case, the magnetization of a ferromagnet in a magnetic field displays the usual hysteresis (blue), and ferroelectrics have a similar response to an electric field (yellow). $0.77BiFeO_3$-$0.33BaTiO_3$ are simultaneously ferromagnetic and ferroelectric, there is a magnetic response to an electric field.

SHS Powder Production Technology



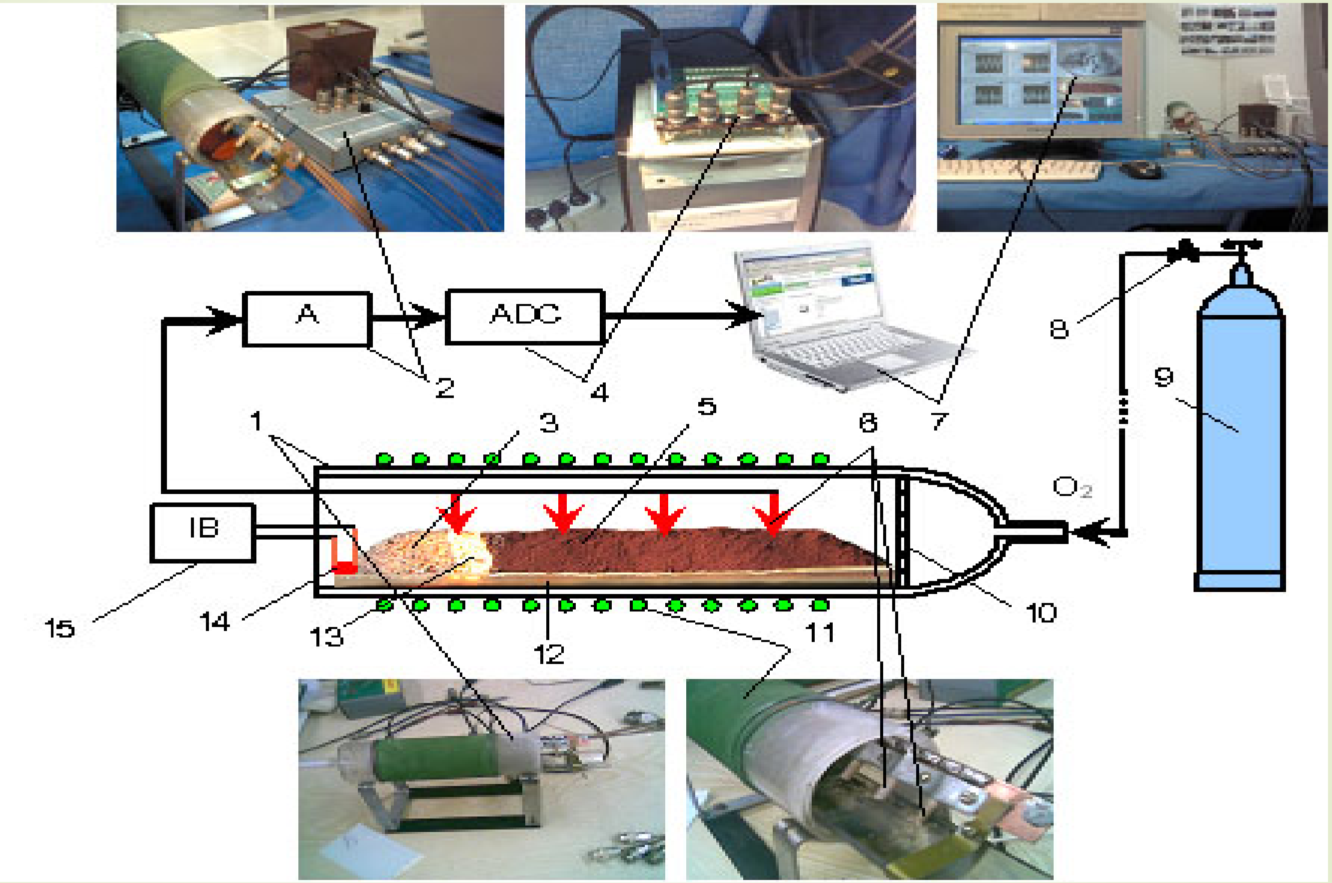
The technological scheme ofpowder production includes the following operations:

- preparation of a green mixture;
- milling, drying of components;
- mixing;
- filling of a reactor with a green mixture and gases;
- synthesis after a short–time thermal initiation;
- subsequent processing of synthesized products;
- milling, drying.

SHS Technological Types are Characterized by the Following Features:

- low energy consumption (in most cases it is only necessary for initiating an SHS process);
- simple technological equipment, it has high productive capacity and safety;
- decreased number of technological stages in comparison with conventional technologies;
- feasibility of production lines adaptable to the production of different materials and items and amenable to mechanization and automation;

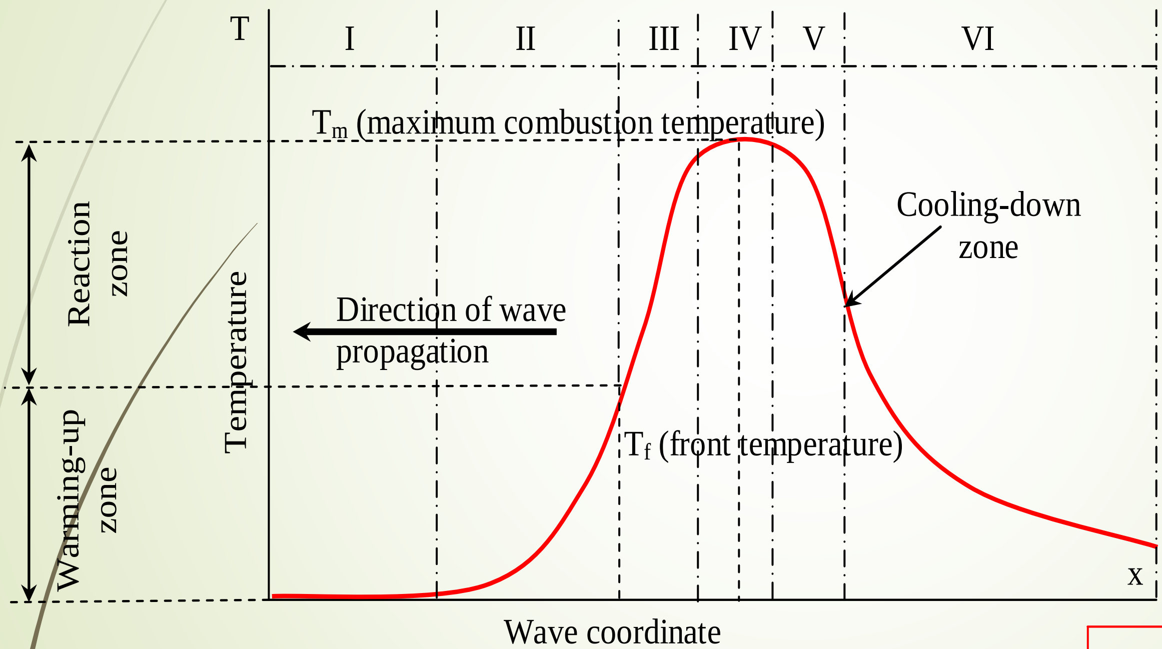
Experimental SHS Reactor

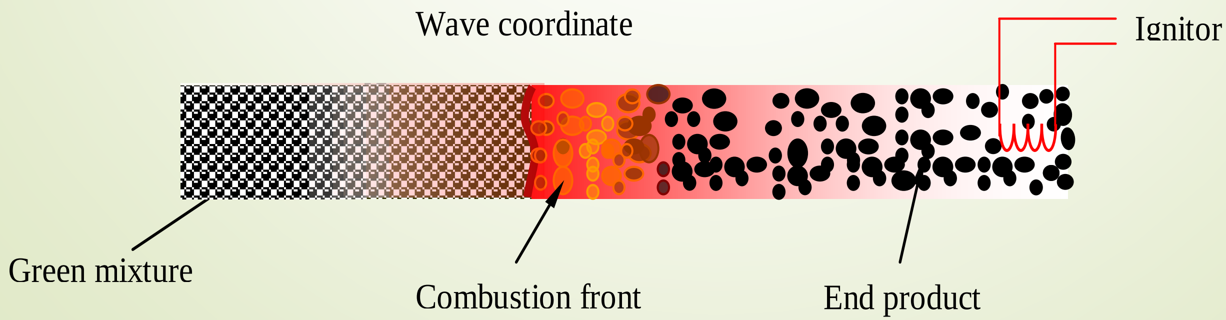


1. Quartz tube; 2. low noise amplifier; 3. end product; 4. analog-digital convertor; 5. green mixture; 6. thermocouples;
7. PC; 8. oxygen flow controller; 9. oxygen; 10. quartz mesh; 11. heater; 12. thermoresistant boat; 13. combustion front;
14. wolfram ignitor; 15. ignition block.

Temperature Distribution Along Combustion Front Propagation

I-green mixture; II-warming-up zone; III-metal oxidation zone; IV-active oxidation of metal and formation of the intermediated; V-zone of secondary chemical interactions between intermediates and formation of final product; VI-cooling-down zone.





The process of wave propagation is characterized by:

- Front propagation (burning) velocity.
- Maximum combustion temperature.
- Heating rate in the combustion front.
- Extent of phase/structure transformation.
- Stability limit (steady or unsteady wave propagation) .
- Pulsation frequency, hot spot velocity, etc. (in case of unsteady combustion).
- Extinction limit (no combustion even upon intense initiation).

The Synthesis were Done According to the Following Chemical Schemes

- $x\mathrm{BaO_2} + (1\text{-}k)\mathrm{TiO_2} + k\mathrm{Ti} + (1\text{-}x)\mathrm{SrCO_3} + \mathrm{O2} \rightarrow \mathrm{Ba_xSr_{1-x}TiO_3}$

- $[1\text{-}y][(1\text{-}x)(1/2\mathrm{Bi_2O_3}+(1\text{-}K)/2\mathrm{Fe_2O_3}+\mathrm{KFe})+x(\mathrm{BaO_2}+(1\text{-}k)\mathrm{TiO_2}+k\mathrm{Ti})]+y\mathrm{MnO_2}+\mathrm{O_2}=[1\text{-}y][(1\text{-}x)\mathrm{BiFeO_3}–x\mathrm{BaTiO_3}]\text{-}y\mathrm{Mn}$

Self-propagating High-temperature Synthesis

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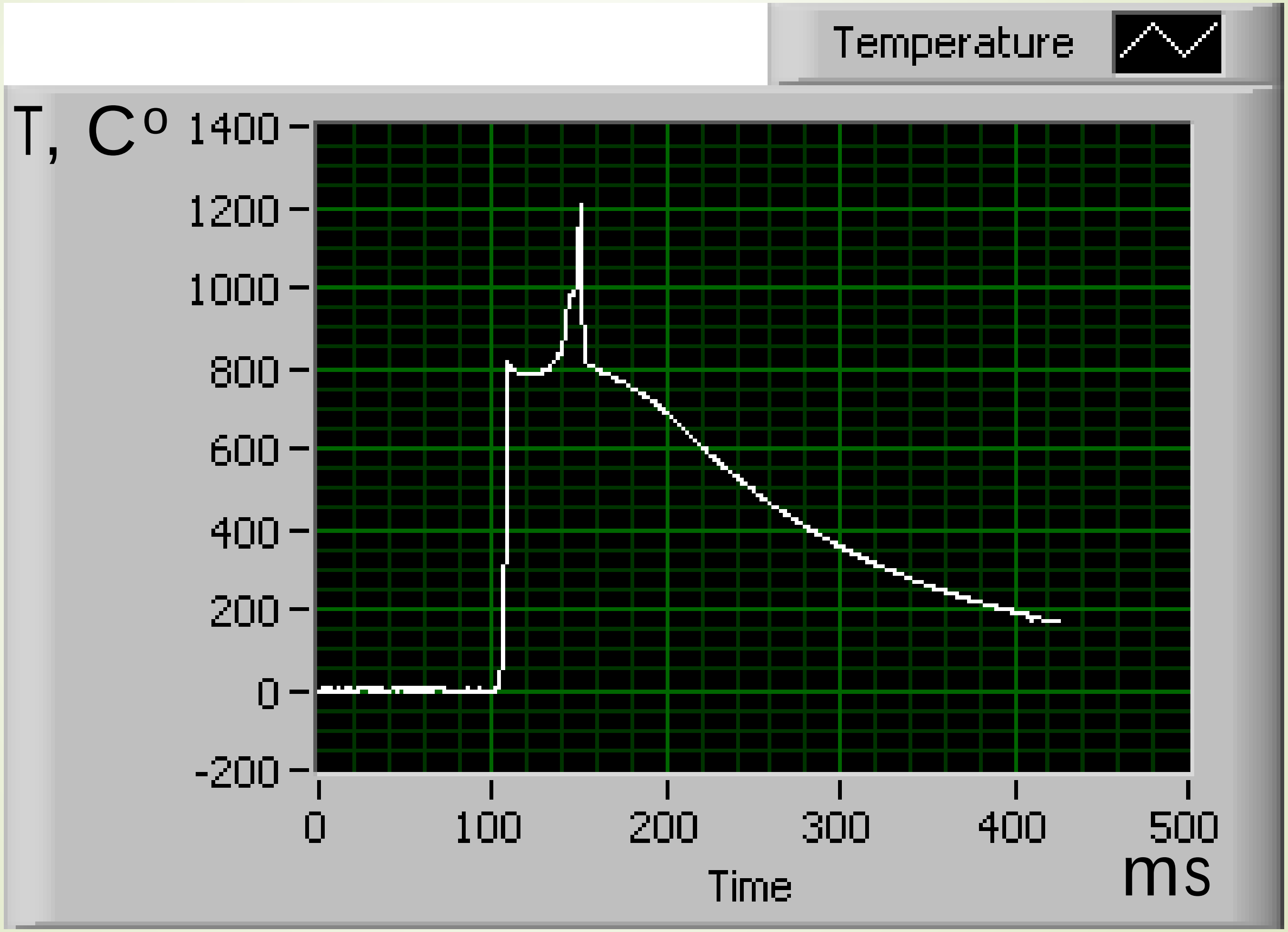
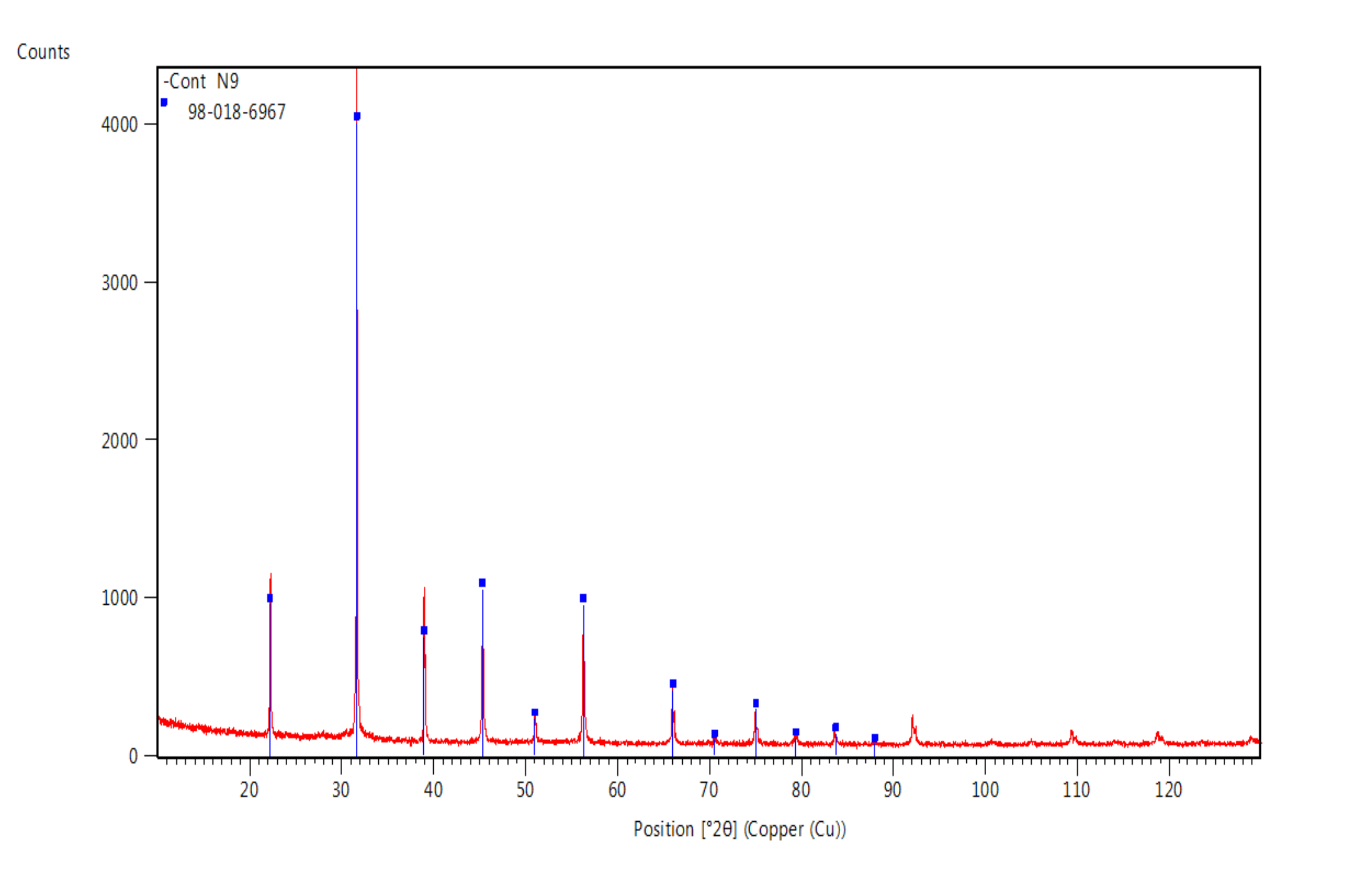
Temperature Dependence on Time



X-Ray Pattern



- $0.77BiFeO_3$-$0.33BaTiO_3$-$0.001Mn$

Upcoming Tasks

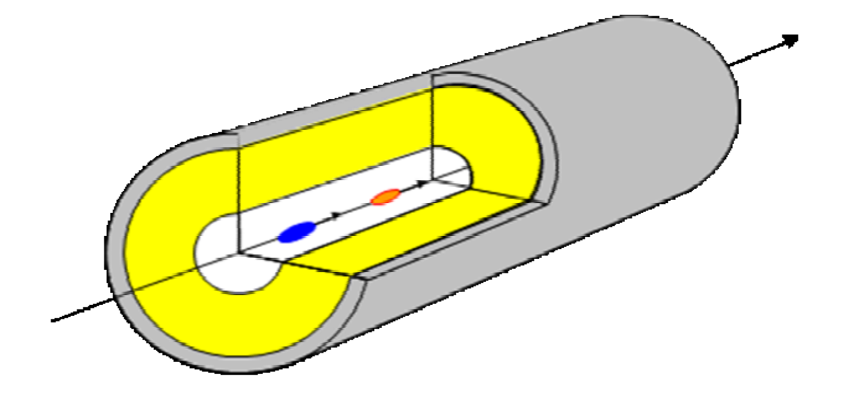
Making ceramic samples

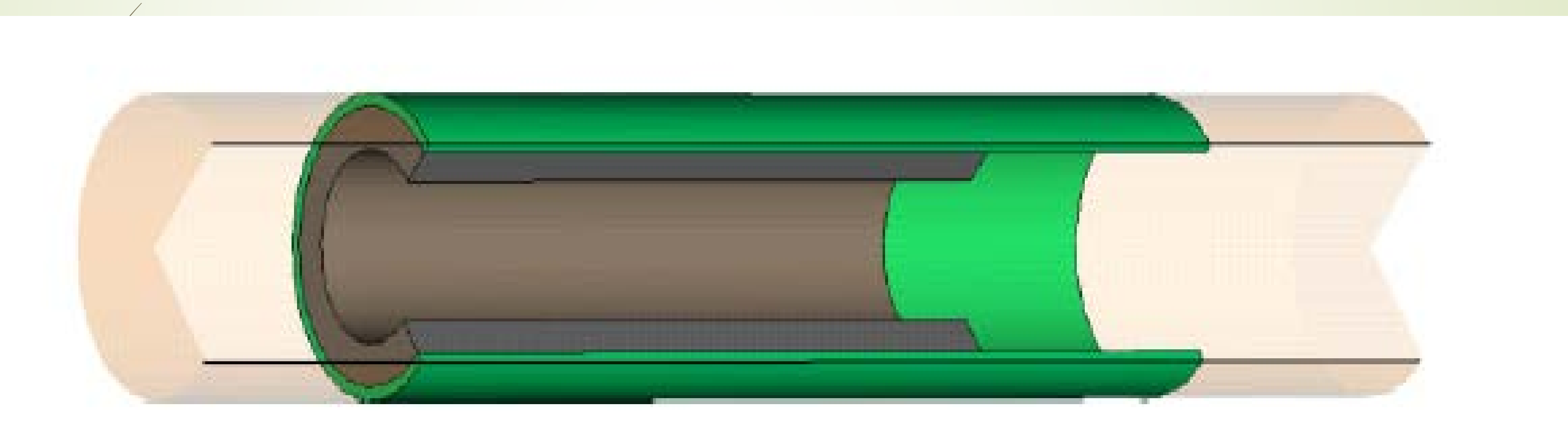
Putting electrodes on both sides

Investigation of dielectric properties

Optimization of technological steps

Future Plans





Inner dielectric diameter 30 mm, dielectric constant 3.8 (SiO_2) or 9 (Al_2O_3), thickness 2mm, length 12cm;
Outer dielectric: $0.77BiFeO_3$-$0.33BaTiO_3$-0.001Mn, dielectric constant 300…400, thickness 500 um, length 15cm;
Outermost layer: copper.

Thank You