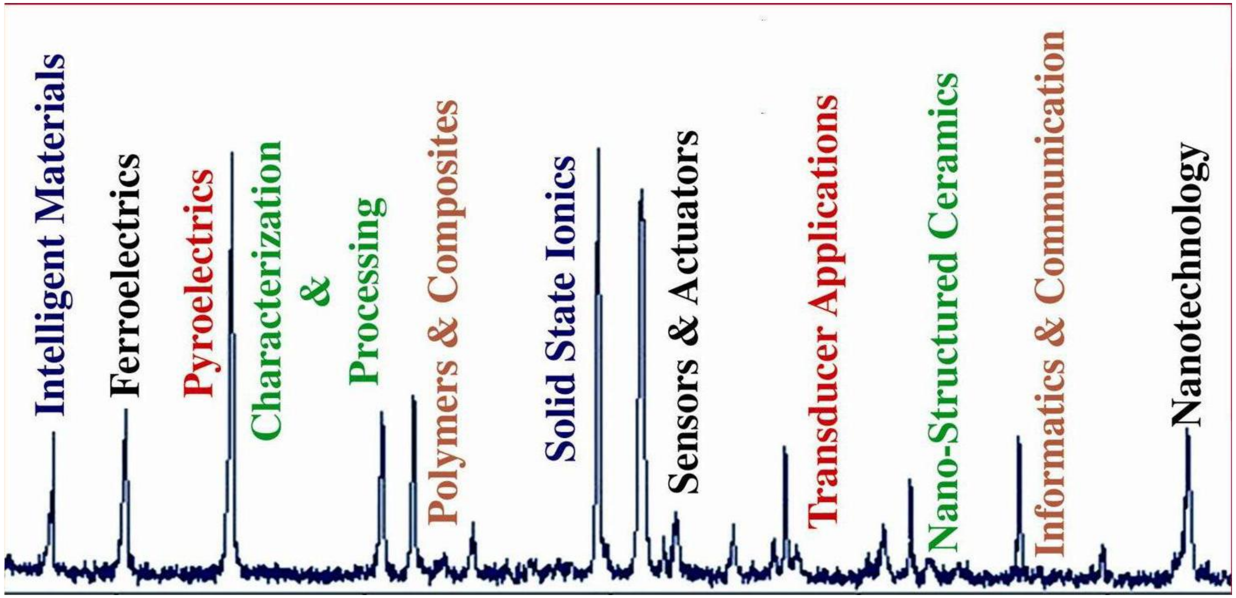

Dielectric and Ferroelectric properties of Ag modified lead free 0.94[KNN]-0.06[LS] Ceramics

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Outlines

1. **General Electroceramics.**

2. **Different Ferroelectric Material Properties.**

3. **Applications of Ferroelectric Materials.**

4. **Synthesis of Lead Free KNN by Microwave Process.**

5. **Comparison with CS and MWS of KNN System.**

6. **Conclusions.**

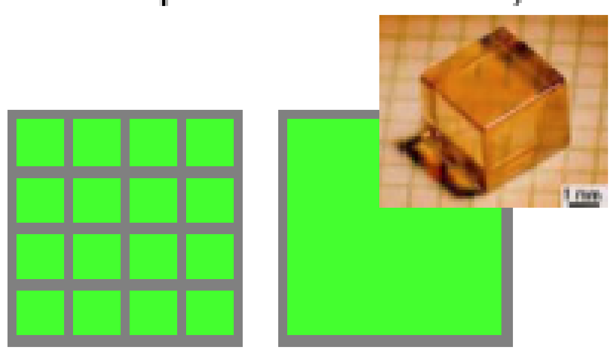
ELECTROCERAMICS – STRATEGIC MATERIALS IN THE QUEST TO SOLVE THE ENERGY CRISIS

Electro-ceramics, combining stability (thermal, chemical), functional versatility and low cost, represent the key materials candidates in many of the proposed renewable energy solutions including solar photovoltaics, fuel cells/electrolyzers, high energy density batteries, and thermoelectrics.

Ceramics
: derived from *keramos* :
Greek word for potter's clay or ware made from clay and fired. ('pottery')

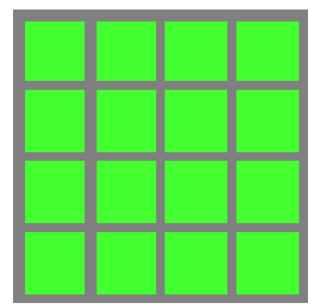
Ceramics
(Old concept)
: Pottery

Ceramics
(Current, wide concept)
: all inorganic nonmetallic materials
(single crystal + polycrystalline materials + amorphous materials)



Difficult to fabricate
Expensive

Ceramics
(Current, narrow concept)
: polycrystalline nonmetallic materials that acquire their mechanical strength through a firing or sintering process.



Easy to fabricate
Economic

Electroceramics

-Ceramics conductor
Heating element
Varistor
Thermistor
Ionic conductor
Humidity Sensor
Gas Sensor
Superconductor

-Dielectrics and Insulators
Multilayer Ceramic Capacitor
Electrical Insulator

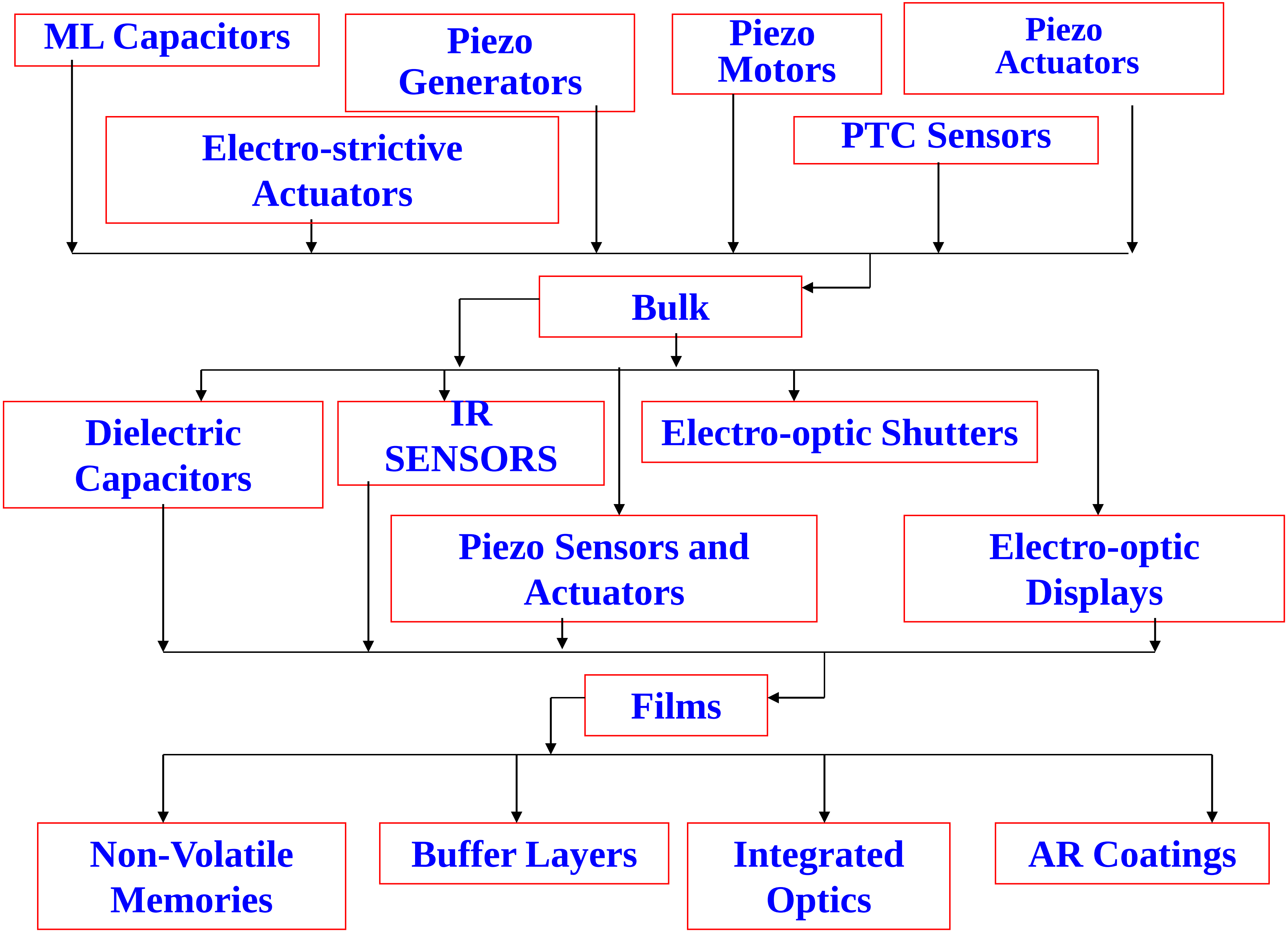
Electroceramics
: Ceramic materials and devices using electronic properties.

-Piezoelectric ceramics
Ultrasonic transducer
Water level sensor
Proximity sensor
PZT

-Pyroelectric ceramics
PZT
Temperature sensor

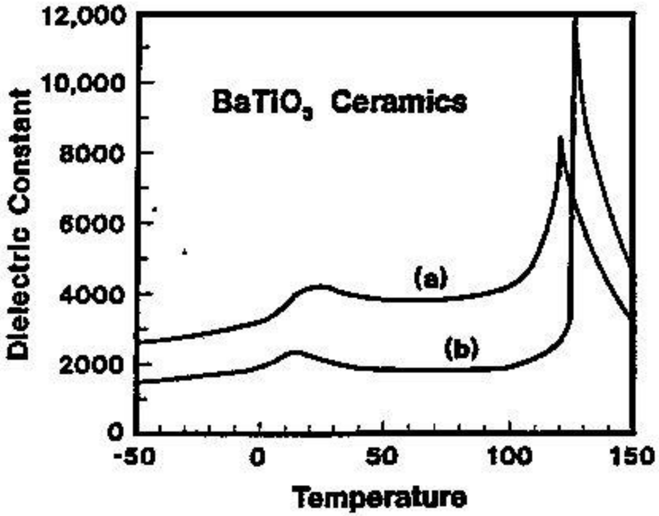
Electro-optic ceramics
- PLZT

-Magnetic ceramics
ferrite

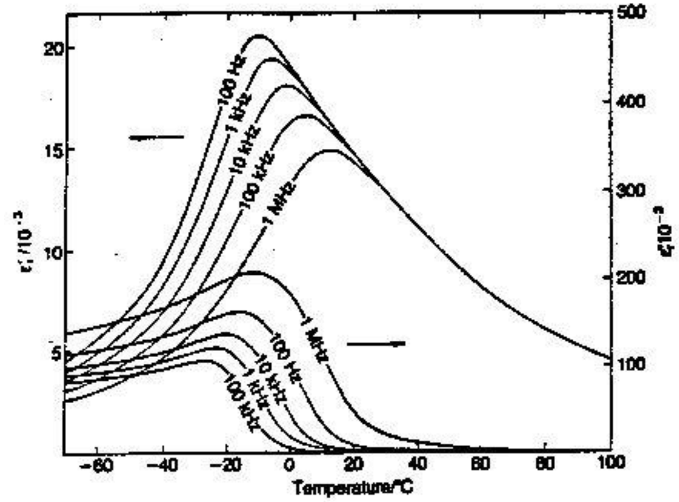


Application of Bulk and Thin Ferroelectric Materials

Dielectric Properties

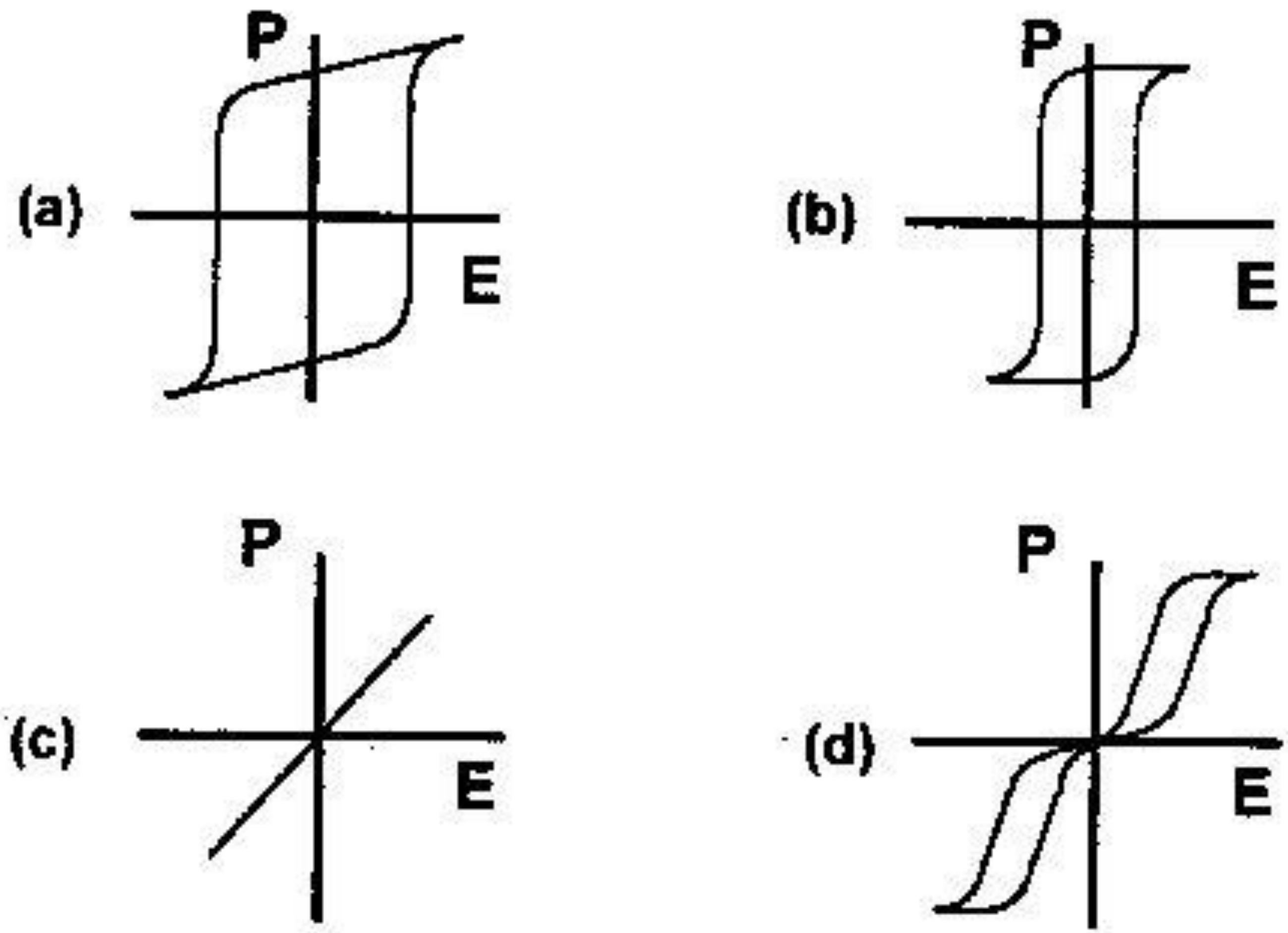


Variation of the dielectric properties of BTwith temperature (a) 1 micro m grain size & (b) 50 micro m grain size.



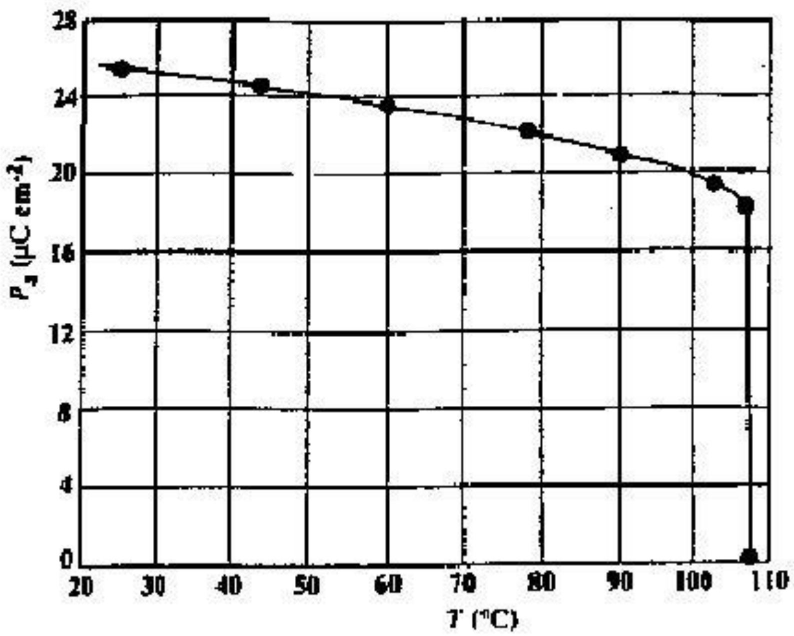
Variation of the dielectric properties of PMN with temperature.

POLARIZATION VERSUS ELECTRIC FIELD HYSTERESIS LOOP



(a) FT (b) FR (c) FC and (d) AF regions of the PLZT phase diagram.

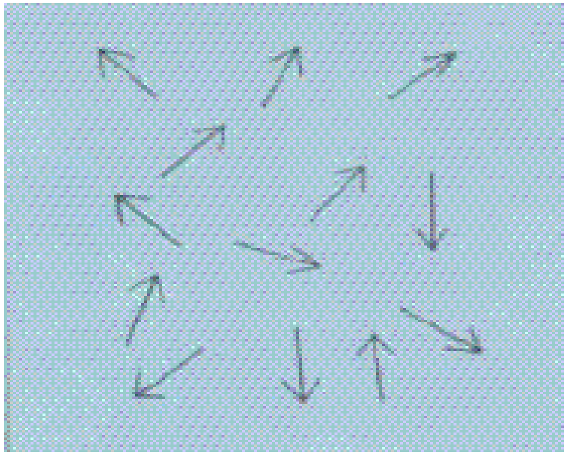
Pyro-electric Effect



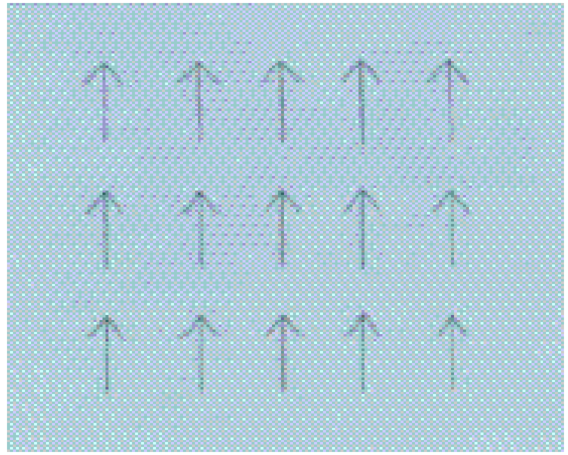
"Uniform Change in Temperature Produces Charges on the Face of the Materials"

$$P_I = (I/A).\ (dt/dT)$$

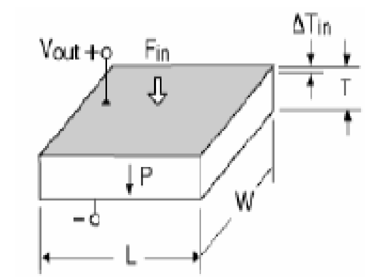
Piezoelectric Effect



Piezoelectric ceramic - before polarization



Piezoelectric ceramic - after polarization

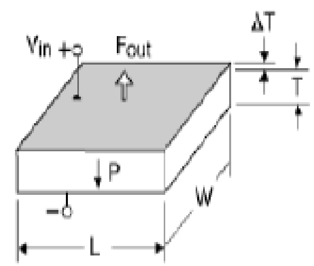


Mechanical Signal In

Voltage Out

Direct Piezoelectric Effect:

$$D = (d)\, T,$$



Converse Piezoelectric Effect:

$$S = (d)\, E,$$

Voltage In

Mechanical Signal Out

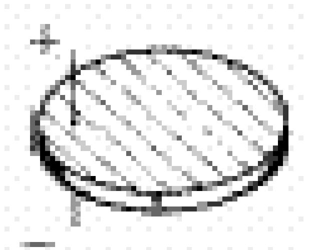
d: Piezoelectric Coefficient

Piezoelectric Coefficients:

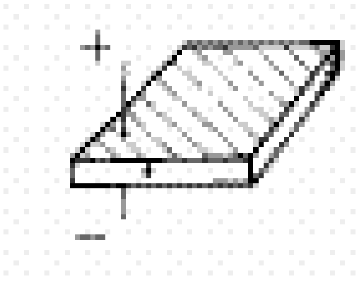
d_{33}, d_{31} =Piezoelectric Charge Coefficients

d_h = Hydrostatic Piezoelectric Coefficient

K_P= Planar Coupling Coefficient

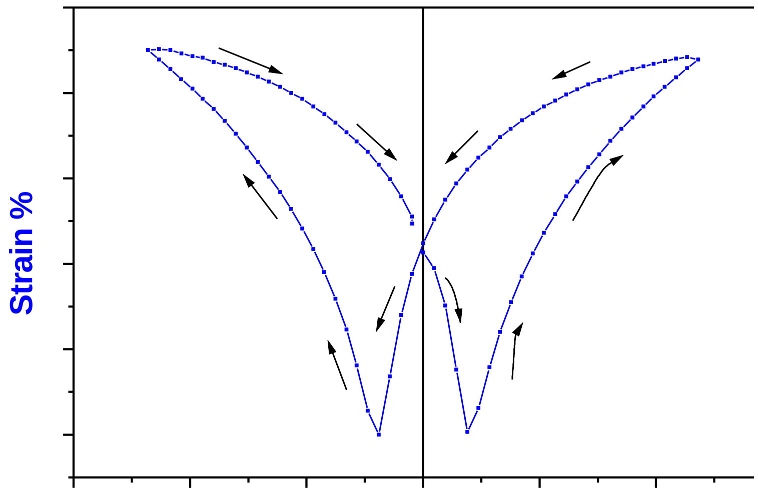


K_t= Thickness Coupling Coefficient

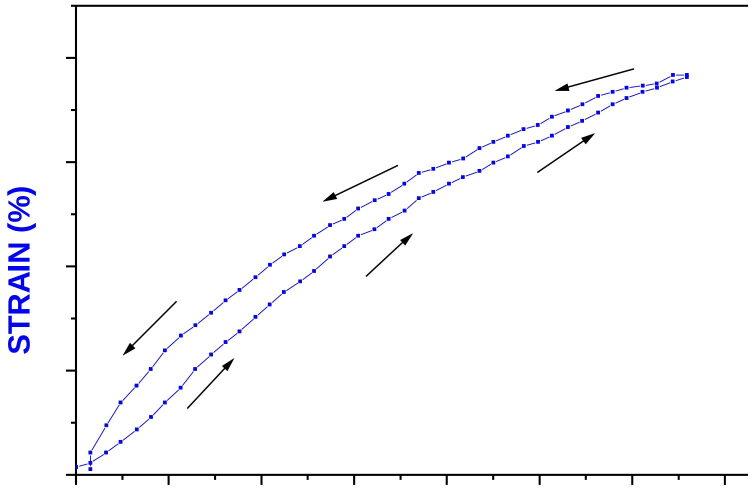


g_{33}, g_{31}=Piezoelectric Voltage Coefficients

Piezoelectric Behavior



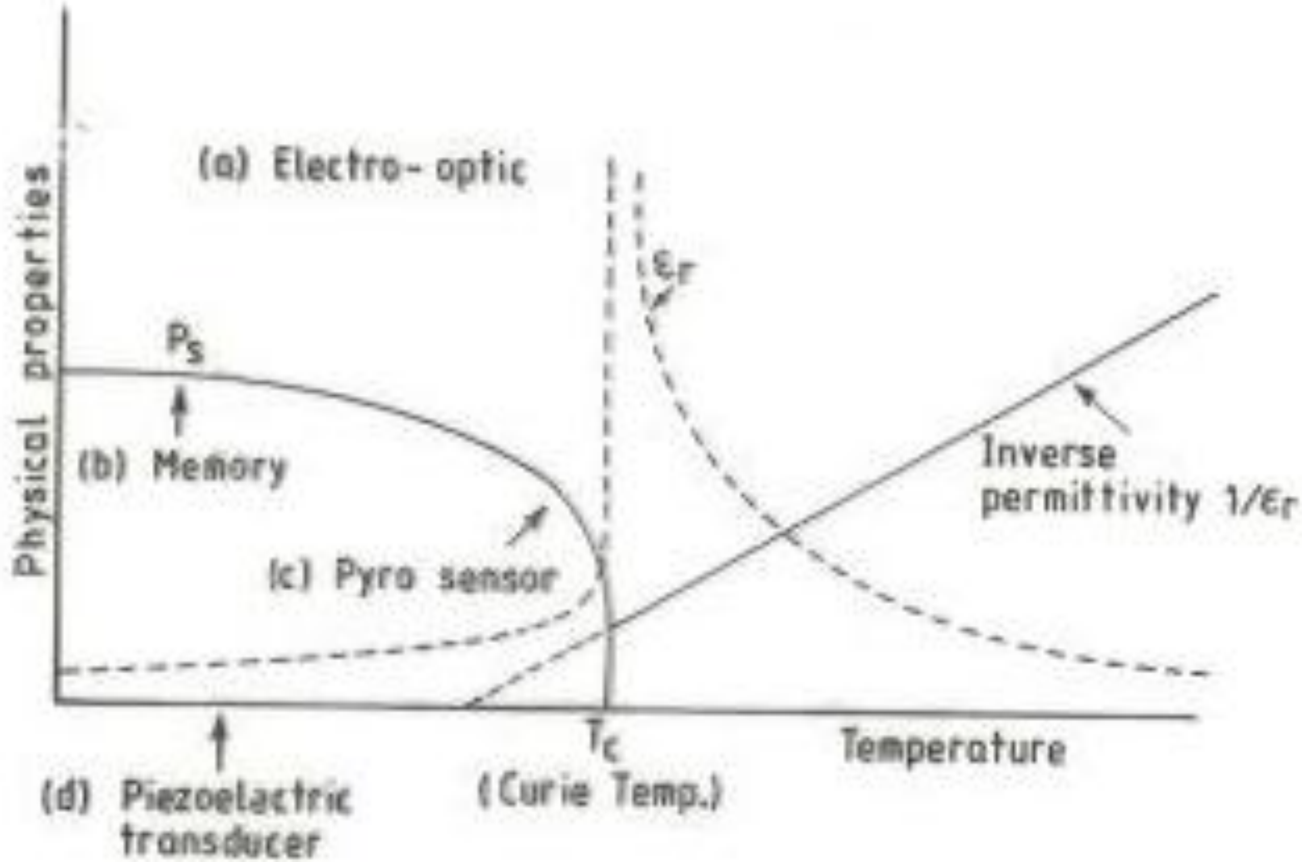
(S-E) Behavior Under Bipolar Field



(S-E) Behavior Under Unipolar Field

Strain Hysteresis %= (Hysteresis in Strain % at Half of the Maximum Electric Field/Strain% at the Maximum) $\times$100

Different Application Regions of Ferroelectric Materials



Why Lead-Free?

- Lower Acoustic Impedance.
- Suitability for Invasive Ultrasonic Applications.
- Higher Curie Temperature.
- Environmentally Friendly.

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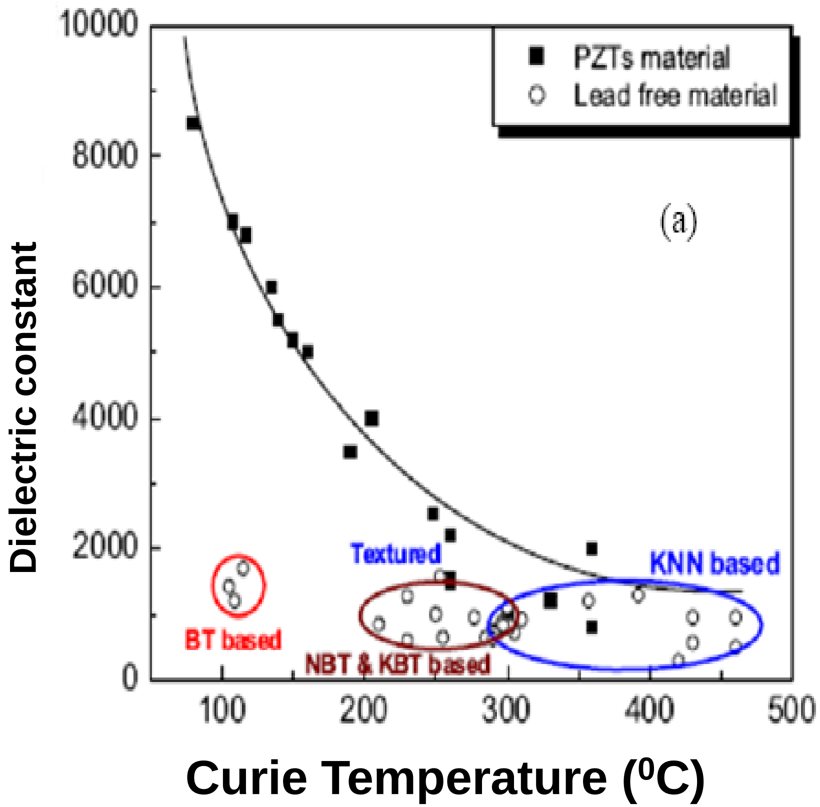
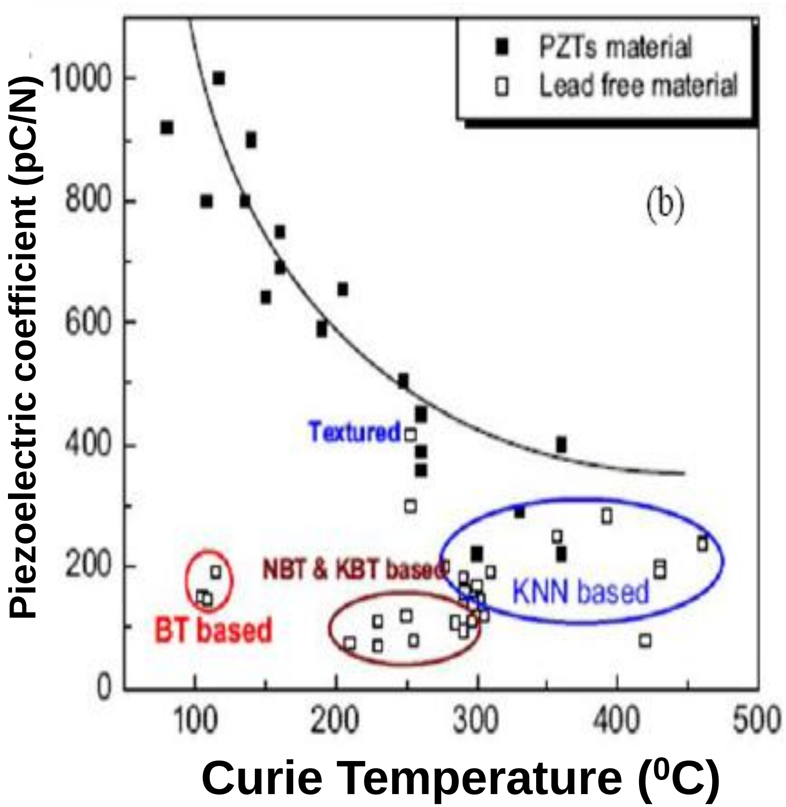
Why KNN System?





✓This KNN System Possess a MPB Similar to PZT System.

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Synthesis Route

$0.94[(KN)_{0.98}Ag_{0.02}N]$-0.06[LS] Stoichiometric Composition

↓

Mixing in Distilled Water and Ball Milling 8hrs

↓

Grinding in a Mortar-Pestle

↓

Calcination, 850°C for 6 h and Grinding

↓

Green Pellets at 60MPa

↓

Conventional Sintering at 1080^{o}C /4 h & Microwave Sintering at 1050^{0}C/1 h

↓

Polisihing and Electroding

Why Microwave Processing?

- Direct Heating Mechanism
- Heating Profile is from Inside to Outside
- Total Cycle Time is Less
- Cost Effective
- Small Grain Size with Dense and Uniform Morphology.
- Better Ferroelectric Properties.

Advantages of Microwave Sintering

- **Microwave Sintering (MWS) is Superior to Conventional Sintering (CS) due to Its Unique Characteristics Such as :**
- **Rapid Heating**
- **Enhanced Densification Rate**
- **Improved Microstructure**
- **An Inverse Heating Profile**

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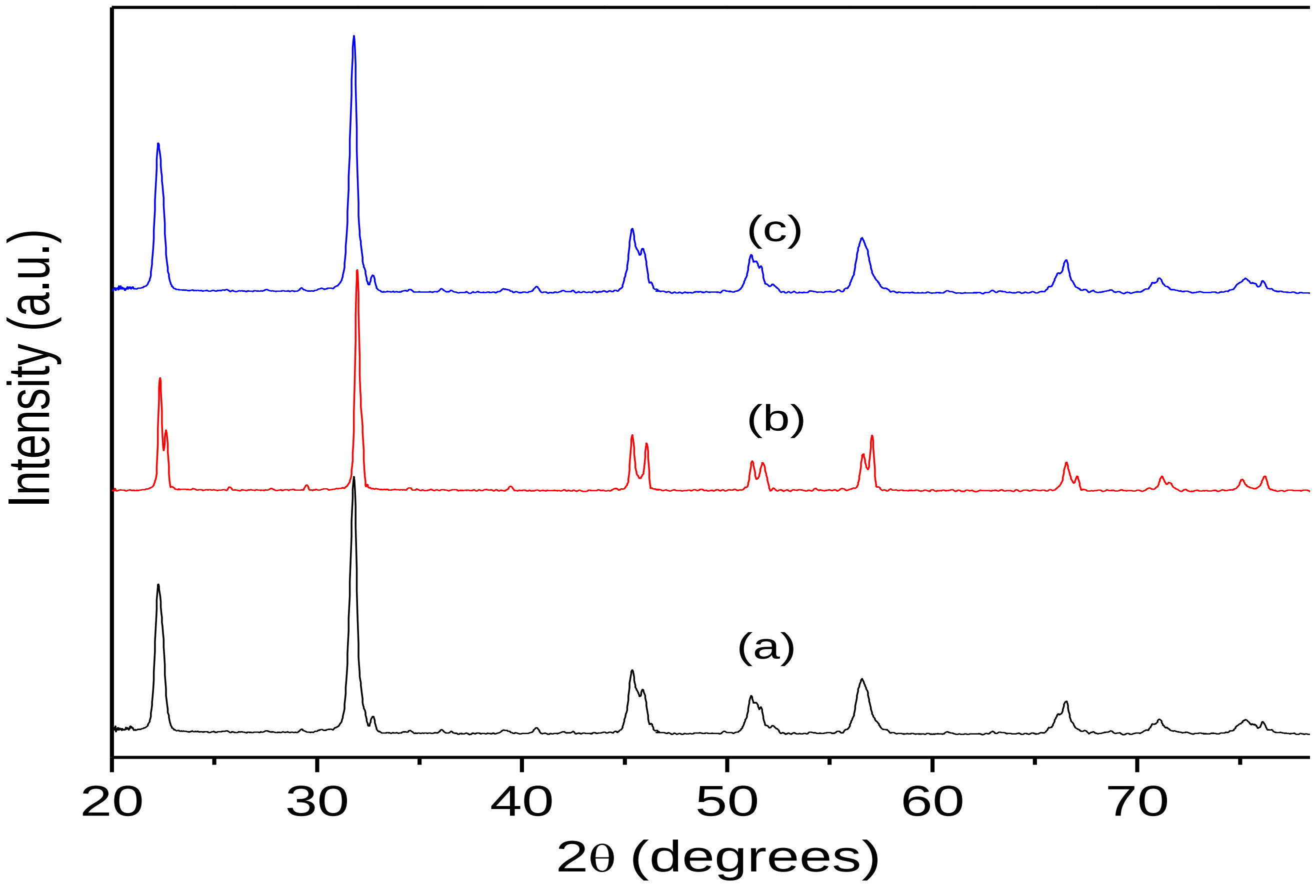
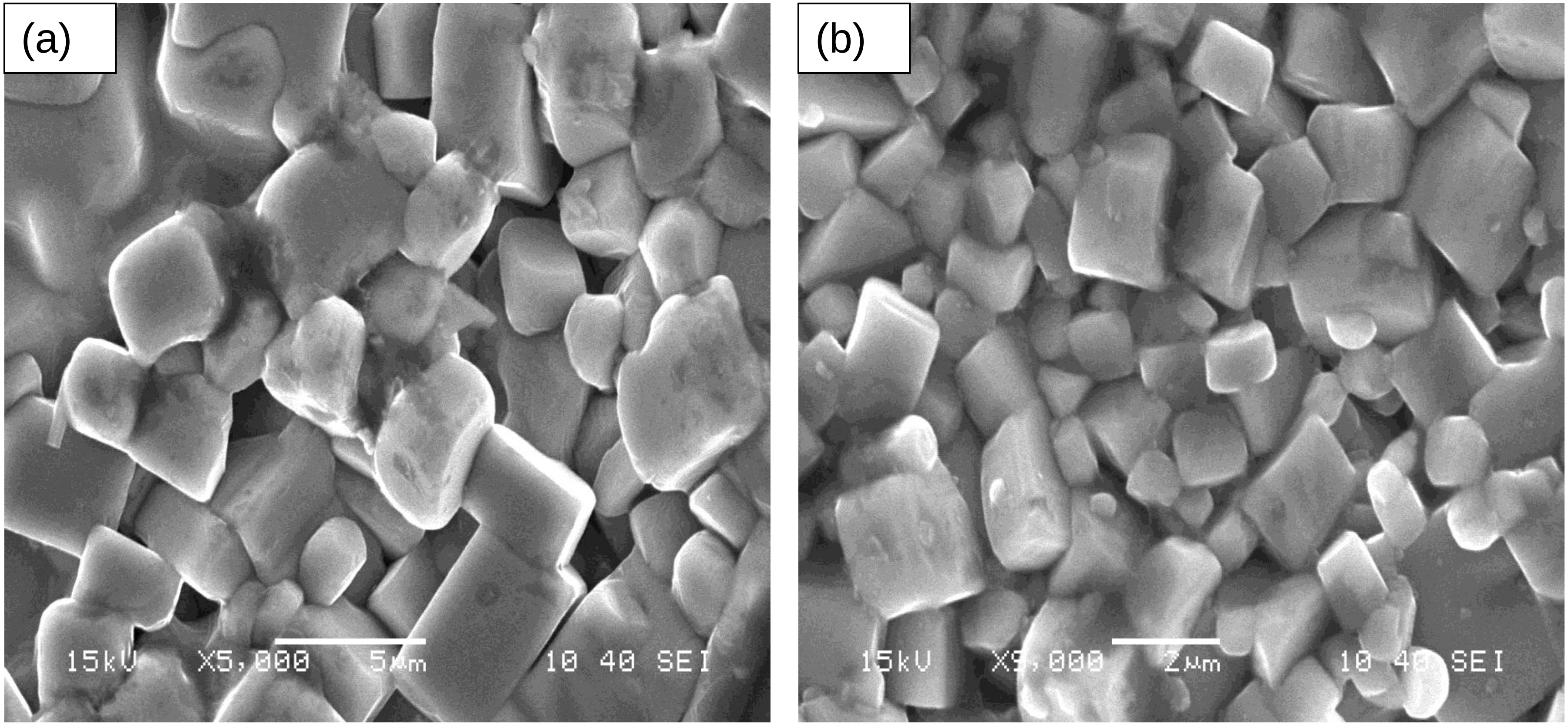
Results



XRD Patterns of KNAN-LS Samples (a) calcined at 850^0C (b) MWS at 1050^0C/1h and (c) CS at 1080^0C/4h



SEM Micrographs of (a) Conventional and (b) Microwave Sintered KNAN-LS Sample

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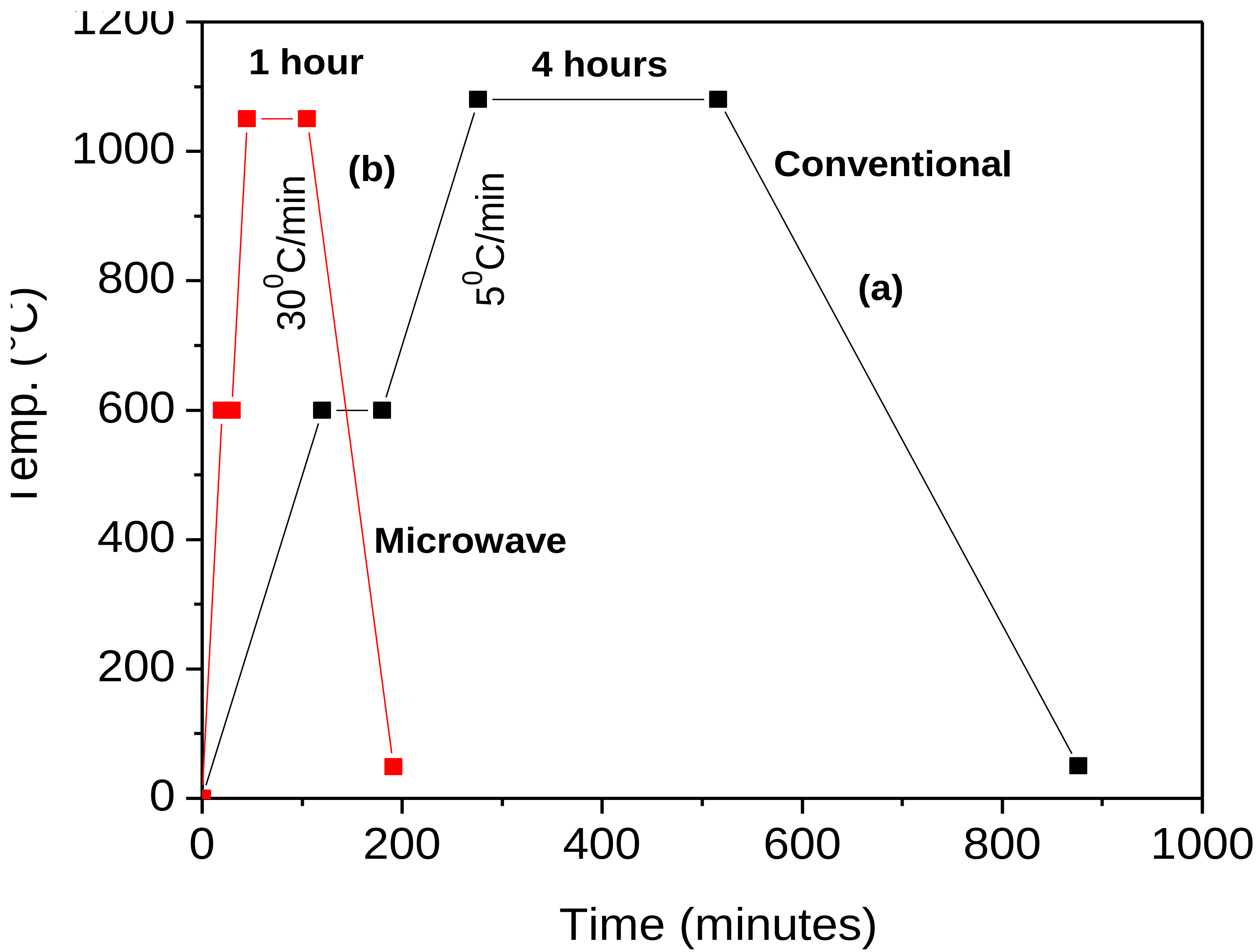
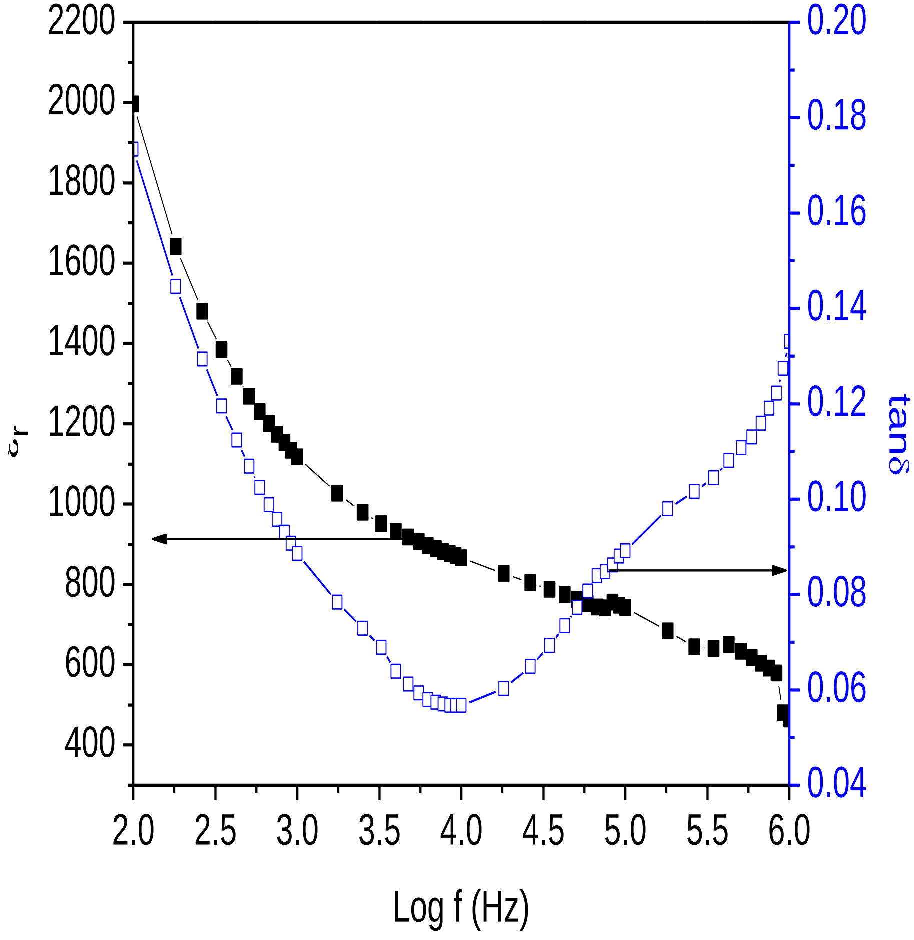
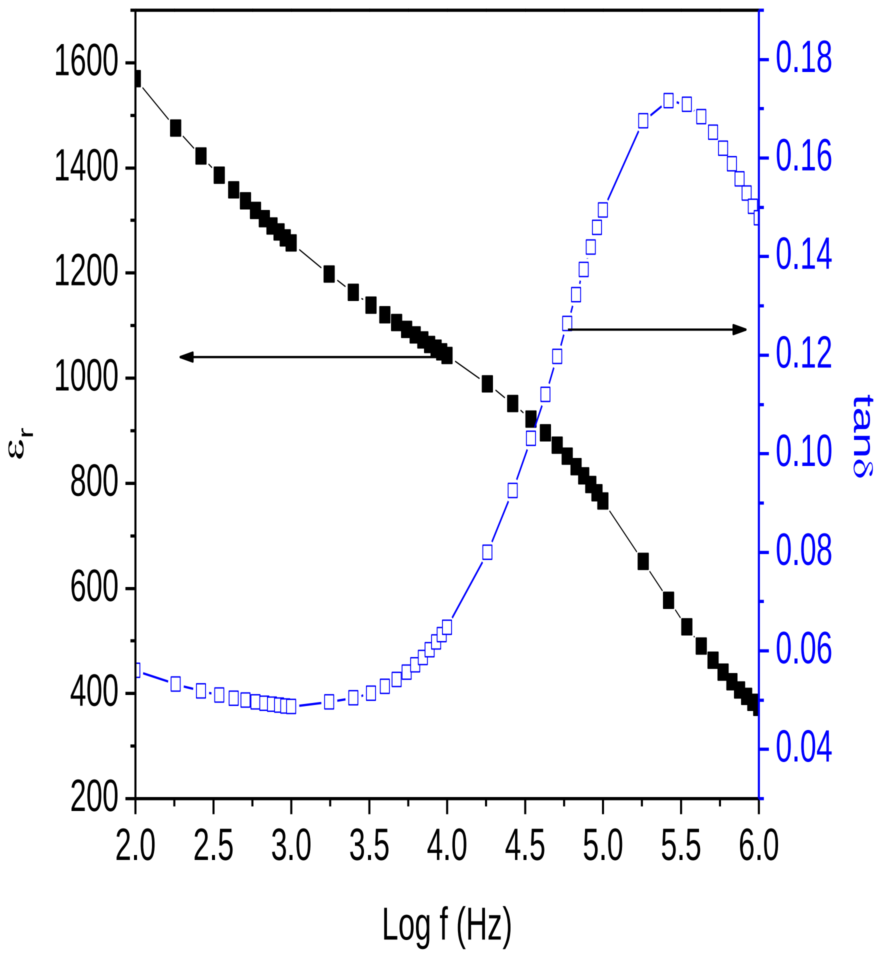


Time-Temp. Heating Profile of Conventional and Microwave Sintered Samples.





Frequency dependence of ε_r and tan**δ** of MWS and CS samples.

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Conclusions

- ✓Electroceramics: The Necessity of Present Day Technology.
- ✓ High K, Piezoelelctric, Pyroelectric & (P-E) Loop Properties Make Ferroelectric Material Important for Various Technological Applications.
- ✓ NKAN-LS Material was Synthesized in Pure Perovskite Phase by CS and MWS Techniques.
- ✓Better Micro-Structural and Dielectric Properties were Observed in Case of MWS Samples.
- ✓The Observed Finer and Uniform Grains in Case of MWS Sample is due to the Rapidity of Microwave Heating.

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Thank You!