# Multiferroic cobalt ferrite barium titanate core-shell nanoparticles prepared by organosol method


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## Abstract


We have successfully synthesized $CoFe_2O_4/BaTiO_3$ (CFO-BTO) core-shell nanoparticles, where cobalt iron oxide nanoparticles are cores and barium titanate forms a shell, using an new organosol crystallization technique. The weight fraction of the ferroelectric and the ferromagnetic phase was 80% and 20%, respectively. The nanopowders were sintered to form a ceramic composite. The crystalline phases were confirmed by x-ray diffraction. Electron microscopy was used to study the specimen's structure and morphology. The saturation magnetization and polarization and the remanent magnetization and polarization were extracted from magnetization and polarization hysteresis loops. The composite exhibits the converse magnetoelectric effect, which was measured using a modified SQUID ac susceptometer. The value of the converse magnetoelectric coefficient $\alpha_c$ for the ceramic sample reaches $4.4 \cdot 10^{-12}$ s·m$^{-1}$ at magnetic field $\mu_0 H_{dc}$ = 0.15 T and T=284 K. We proved that the co-precipitation method and organosol method can be combined to form CFO-BTO composite.

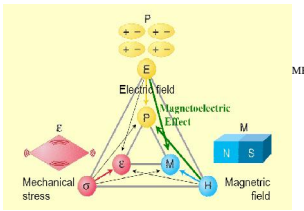

## Background

-The coupling between magnetic and electric order parameters result in the magnetoelectric (ME) effect.

-Single phase multiferroic are rare and have a low magnetoelectric coefficient at lower temperature.

- Barium titanate cobalt ferrite composite has a high magnetoelectric effect at toom temperature.

- Applications: memories, magnetoelectric sensors




$$\text{ME effect} = \frac{\text{electrical}}{\text{mechanical}} \times \frac{\text{mechanical}}{\text{magnetic}}$$

Piezoelectric effect of FE component

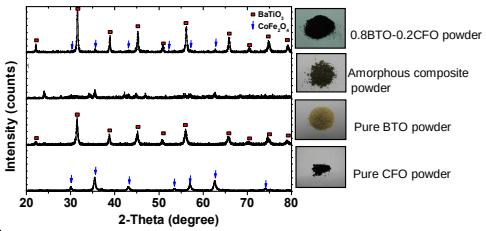
Magnetostrictive effect of FM component

*N. A. Spaldin & M. Fiebig, Science 2005*

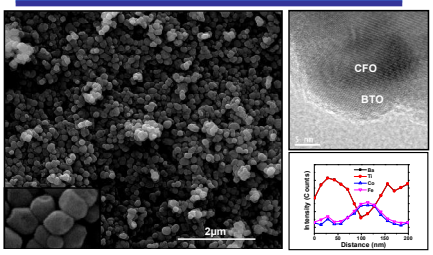
## Motivation

- To synthesize cobalt iron oxide-barium titanate core-shell nanoparticles using new organosol method
- To investigate the ferromagnetic and ferroelectric properties of the composites.
- To explore the mangetoelectric properties of the composites.

## XRD Analysis




## SEM and TEM Analysis

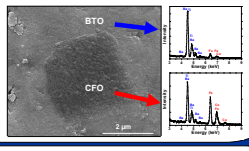



Composite powder calcined at 750 °C for 15 minutes

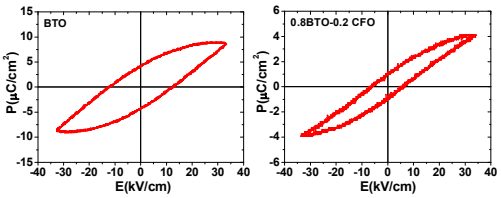
-The particles are homogeneous and spherical in ist shape.

- Particles diameter 112±18 nm

-CFO regions in sintered ceramic are about 2 microns disributed in BTO matrix

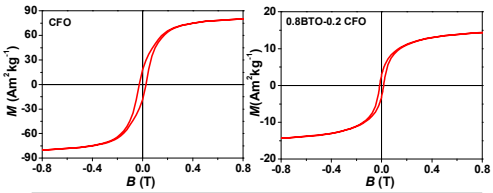



## Ferroelectric Properties



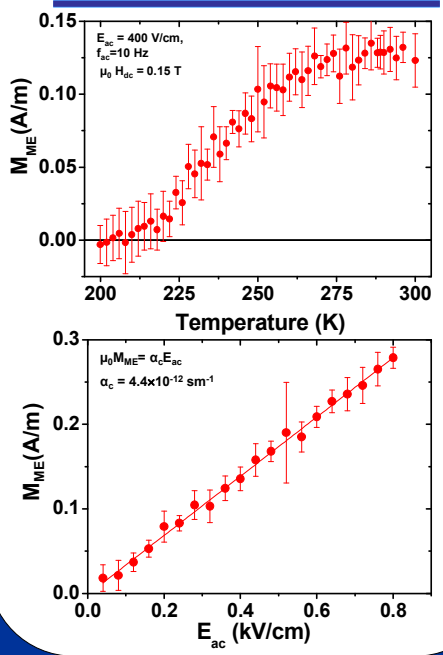

| Sample | $P_s$(μC/cm²) | $P_r$(μC/cm²) | $E_c$(kV/cm) |
|---|---|---|---|
| Pure BTO ceramic | 7.50 | 4.25 | 12.5 |
| BTO-CFO (80:20) ceramic | 4.00 | 0.82 | 6.0 |

## Ferromagnetic Properties

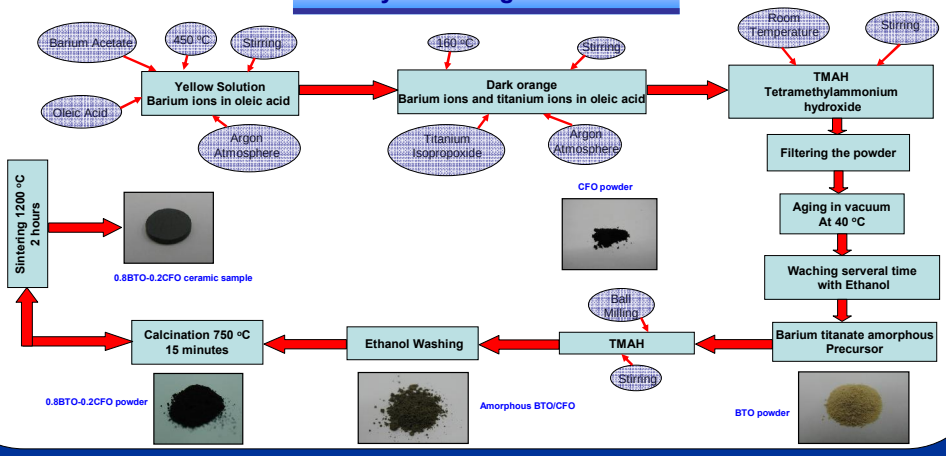



| Sample | $M_s$(Am²kg⁻¹) | $M_r$(Am²kg⁻¹) | $B_c$(T) |
|---|---|---|---|
| Pure CFO ceramic | 85.40 | 18.32 | 0.027 |
| BTO-CFO (80:20) ceramic | 15.00 | 3.01 | 0.160 |

## ME Measurements




## Synthesizing Method




## Conclusion

- The co-precipitation method and the organic method can be combined to form core-shell multiferroic nanoparticles $CoFe_2O_4$-$BaTiO_3$.
- This method can be used to synthesize other perovskite-ferrite multiferroic composites.
- The ceramic samples contain micron-size regions of cobalt ferrite distributed in barium titanate matrix due to a diffusion at high processing temperatures.
- The value $4.4 \times 10^{-12}$ sm$^{-1}$ of converse magnetoelectric coefficient for the ceramics contained 80%BTO and 20% CFO was obtained.
- The ME response decreases when temperature decreases and vanishes below 220 K.

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