Synthesis and Characterization of Multiferroic Ceramics

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Introduction

Multiferroic materials are those that exhibit both ferroelectric and ferromagnetic properties. When these properties are coupled they can apply to specific device applications such as multiple state memory elements, spintronics, and sensors.[1] My project incorporated doping Barium Titanate ($BaTiO_3$), an already known ferroelectric, with Iron in order to induce magnetic properties into the $BaTiO_3$ structure.

Procedure

Two samples were prepared with 10 m/o FeO added to $BaTiO_3$. TiFe System focused on doping Fe on a Ti site with the molecular formula $Ba(Fe_{0.1}Ti_{0.9})O_3$ and the BaFe System focused on doping Fe on a Ba site with the molecular formula $(Ba_{0.9}Fe_{0.1})TiO_3$. The two powder samples were ball milled for 50 hours to create mechanochemical activation in order to reduce the sintering temperature.[2] The two samples were dry pressed and sintered at 1100°C for 2 h. The apparent and theoretical densities were calculated and used to calculate the porosity of the samples. The porosities for TiFe and BaFe Systems were 10% and 30% respectively. The samples were then reground into a powder for XRD analysis, to determine if the material has a single phase, and VSM measurements, to determine the magnetization of the material. A pellet was kept solid and coated on the top and bottom with a silver adhesive in order for the material to conduct. A voltage was applied to the pellet and a polarization was obtained to determine the ferroelectric properties.

Results and Discussion

A single phase must be present in order to determine whether the magnetic and ferroelectric properties are coupled. Fig 1a displays XRD results of the samples compared to a $BaTiO_3$ standard. The matching peaks of the BaFe system with the standard depicts that the sample obtained a single phase. The TiFe system does not match with the standard, however, upon further analysis it appears that the TiFe results match with that of a hexagonal $BaTiO_3$ structure (Fig 1b). The systems displayed magnetic properties as revealed by the hysteresis loop of a soft magnetic, necessary for magetoelectric

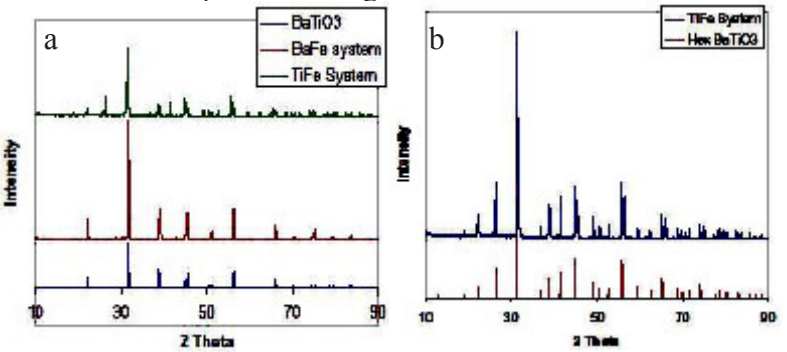

Figure 1 XRD results of a) TiFe and BaFe systems compared to $BaTiO_3$ standard. b) TiFe system compared to hexagonal $BaTiO_3$.

applications. The saturation levels for the TiFe and BaFe systems were 0.36767 emu/g and 0.22937 emu/g respectively (Fig 2). These levels are extremely low for current application use. Porosity in the samples may account for the low levels of magnetization. When the magnetic field passes through the empty space, it is not causing the dipoles to align

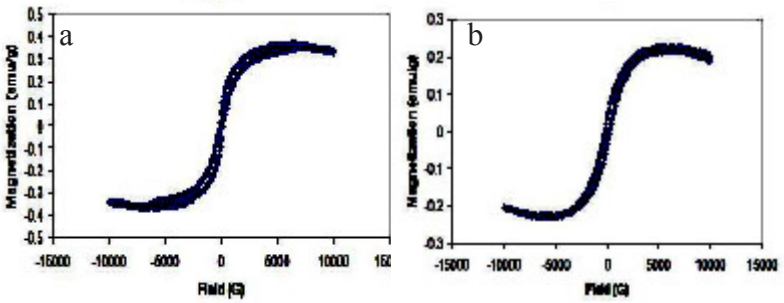

Figure 2 VSM curve for a)TiFe sytem b)BaFe system

and therefore is not magnetizing the material. It is presumed that the BaFe system's lower magnetization is due to its higher porosity. Ferroelectric results were obtained for the two samples. Fig 3a displays a hysteresis loop for the TiFe system, however, the loop is wider and not curved as a typical hysteresis. The sample does not reach a point of saturation because the loop curves down at the top. This shows that the dipoles are not aligned and that there are free flowing electrons causing some conduction. Fig 3b displays a plot of typical dielectric for the BaFe system.

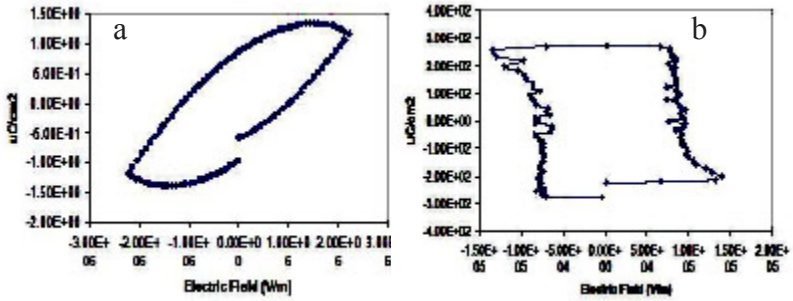

Figure 3 Ferroelectric results for a)TiFe b)BaFe system

Conclusion

When 10 m/o of Iron dopes a Titanium site of $BaTiO_3$ the crystal structure changes from tetragonal to hexagonal. It displays some magnetic properties but reduces ferroelectricity. When 10 m/o Iron dopes a Barium site of $BaTiO_3$ the material remained as a single phase. The magnetic properties are present but the sample displays a dielectric effect.

References

1. Nicola A. Hill, Alessio Filippetti; "Why are there any magnetic ferroelectrics?," 2002
2. C.L. Chew, A. Srinivas, T. Sritharan, F.Y.C Boey; "Mechanochemical activation of strontium bismuth tantalate synthesis," 2005.

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