Topic Code:

Influence of trivalent non-magnetic ion on structure, optical, magnetic and dielectric properties of $YCrO_3$ perovskite

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Abstract: In this report, effect of Bi^{3+} doped on structural, optical, magnetic and dielectric properties is studied. Upon Bi substitutions, unit cell volume shows an evolution and the average grain size is elongated. The optical band gap of the prepared samples decreases with increasing Bi content. The maximum magnetization (M_s) value decreases and coercively (H_c) increases that can be attributed to the increasing structural distortion with Bi content. There is an anomaly observed at around magnetic transition in the temperature dependent dielectric study. The dielectric permittivity is enhanced upon Bi substitutions.

1. INTRODUCTION

In past few decades, there has been significant interest in perovskite type rare earth chromite family due to its intriguing magnetic and transport properties. In recent years, rare earth orthochromites (general formula $RCrO_3$, R= rare earth metal) have received huge attention in enormous fields of applications such as interconnected material of solid oxide fuel cells, negative temperature coefficient thermistors and humidity sensors. $YCrO_3$ is an important material in the class of rare earth chromites. It exhibits orthorhombic perovskite structure with *P*nma space group. The centrosymmetric nature of this compound has attracted considerable attention due its potential applications as a magnetoelectric material. It exhibits a well-accepted canted antiferromagnetic ordering with a weak ferromagnetic moment below T_N = 140 K and a relaxor-type dielectric behaviour with presence of an anomaly around 473 K [1, 2]. In this report, a detailed investigation of structural, magnetic and dielectric properties of polycrystalline samples $Y_{1-x}Bi_xCrO_3$ (x = 0.00, 0.05, 0.10, 0.15) is carried out.

2. EXPERIMENTAL DETAILS

A series of $Y_{1-x}Bi_xCrO_3$ (x = 0.00, 0.05, 0.10, 0.15) polycrystalline samples are synthesized through sol-gel auto combustion route [3]. For the phase confirmation XRD technique is adapted. FESEM technique used to study the surface morphology. UV spectroscopy is used to study the band gap of all the samples. For magnetic study, VSM is used and to know the dielectric behavior, impedance analyzer is adopted.

3. RESULTS AND DISCUSSION

XRD spectra along with Rietveld refinement shows the pure phase formation of all the compounds and crystallize in distorted orthorhombic perovskite structure (*P*nma space group). FESEM morphology depicts that grain size is increased with Bi substitution due to the cationic size mismatch as shown in Fig.1. Energy band gap is reduced upon Bi substitution confirm from UV study. The maximum magnetization (M_s) value decreases and coercively (H_c) increases can be attributed to the structural distortion with Bi content shown in Fig.2. Dielectric permittivity is enhanced with increasing Bi content and a dielectric anomaly is found near magnetic transition.

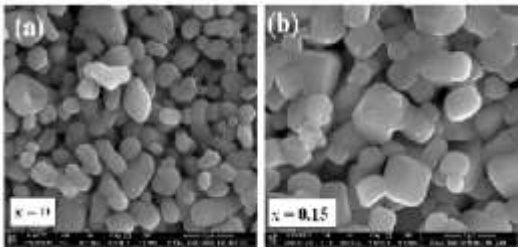

Fig.1. (a-b) FESEM morphology of $Y_{1-x}Bi_xCrO_3$ (x = 0.00 & 0.15).

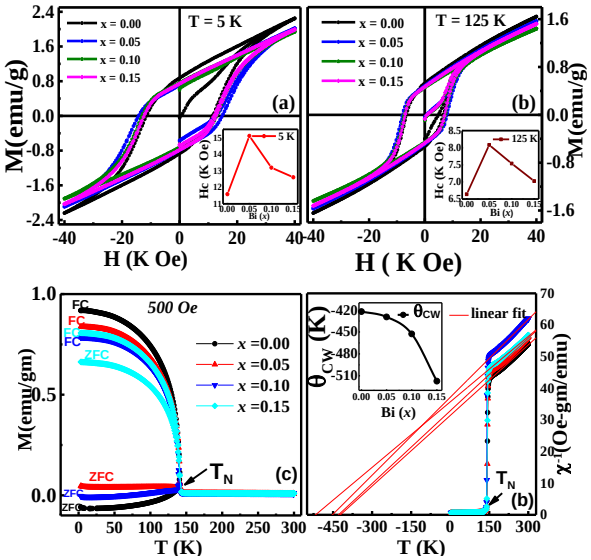

Fig.2. (a-b) M-H, (c-d) M-T plots and Curie Weiss fitting of $Y_{1-x}Bi_xCrO_3$ (x = 0.00, 0.05, 0.10, 0.15).

REFERENCES

[1]. C. R. Serrao et al Phys. Rev. B **72** (2005) 220101.
[2]. A. K. Mall et al J. Euro. Ceram. Soc. **38** (2018) 5359.
[3]. T. Lakshaman Rao et al j. Appl. Phys. **126** (2019) 064104.

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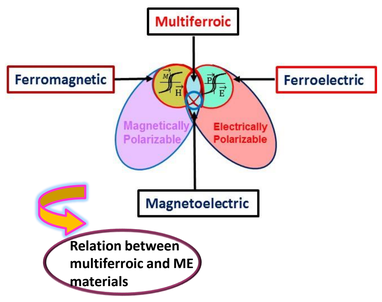
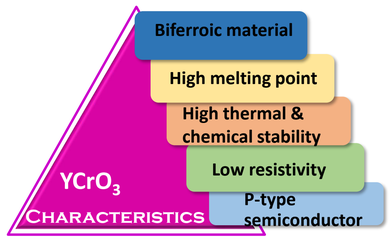
Abstract: In this report, effect of Bi^{3+} doped on structural, optical, magnetic and dielectric properties is studied. Upon Bi substitutions, unit cell volume shows an evolution and the average grain size is elongated. The optical band gap of the prepared samples decreases with increasing Bi content. The maximum magnetization (Ms) value decreases and coercivity (Hc) increases as compared to parent sample that can be attributed to the increasing structural distortion with Bi content. It is observed that energy band gap decreases with increasing Bi substitution. There is an anomaly observed at around magnetic transition in the temperature dependent dielectric study. The dielectric permittivity is enhanced upon Bi substitutions and all the compounds show relaxor like ferroelectric behavior.

Introduction





- biferroic having an orthorhombic structure with the *Pnma* space group.
- a canted antiferromagnet with weak ferromagnetism due to Dzyaloshinskii-Moriya interaction below the Neel temperature (T_N) of 140 K.
- Ground state magnetic spin configuration is $\Gamma_4(G_x, A_y, F_z)$.
- Shows relaxor ferroelectric transition (T_c) around 450 K.
- Ferroelctricity mainly comes from Y displacements with respect to the oxygen cage.

Applications

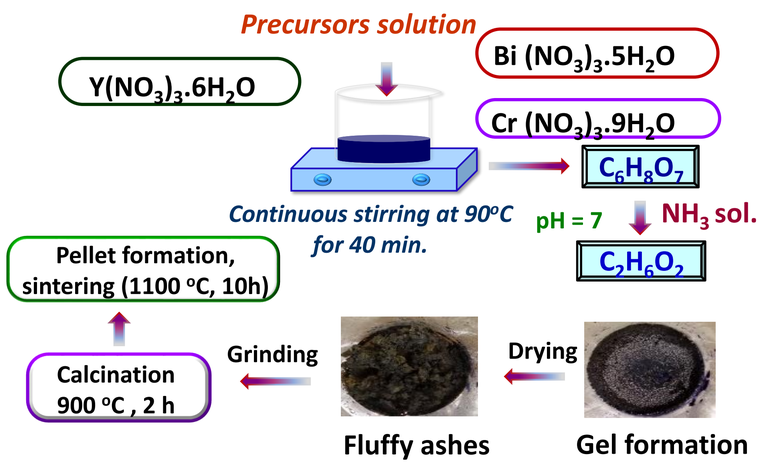
- solid oxide fuel Cell
- humidity sensor
- thermistor
- magnetoelectric material

Objectives

In this report, a detailed investigation of structural, optical, magnetic and dielectric properties of polycrystalline samples $Y_{1-x}Bi_xCrO_3$ (x = 0.00, 0.05, 0.1, 0.15) is carried out. As Bi^{3+} contains a $6s^2$ lone pair of electrons, which can be intended to enhance the polarization and it will be affected the other physical properties.

Experimental Details

Synthesis



XRD – Rigaku Ultima-IV X-ray Diffractometer

FESEM- FEI NOVA nanoSEM450

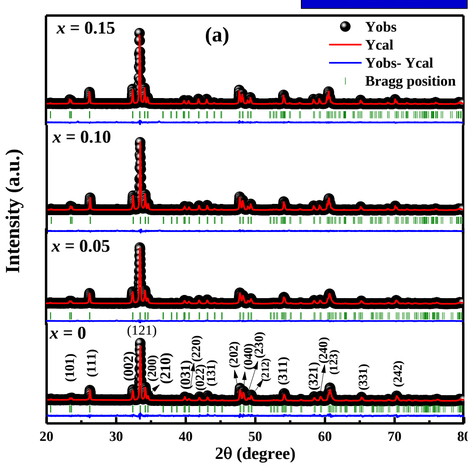
UV spectroscopy- JASCO V-750

VSM- 9T-PPMS-VSM (M/s. QD, USA)

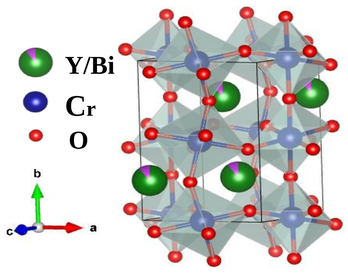
Impedance Analyzer- IM3570 (HIOKI)

Result and discussions

XRD



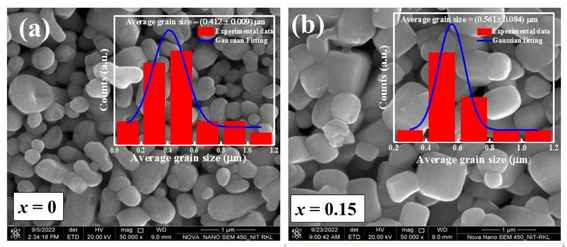
- Structure – Orthorhombic
- Space group - *Pnma*
- *JCPDS card no.-* 34-0365



Parameters	x = 0	x = 0.05	x = 0.10	x = 0.15
a (Å)	5.5157 (6)	5.5114 (7)	5.5198 (1)	5.5182 (6)
b (Å)	7.5215(1)	7.5227 (1)	7.5393 (4)	7.5409 (8)
c (Å)	5.2341 (5)	5.267 (7)	5.2340 (7)	5.2461 (1)
V (Å^3)	217.14 (4)	217.010 (5)	218.32 (7)	218.38 (4)
χ^2	1.79	3.15	2.89	3.79

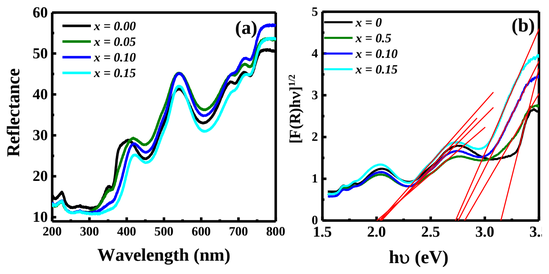
Surface Morphology

FESEM



- The average grain size of $YCrO_3$ and $Y_{0.85}Bi_{0.15}CrO_3$ is calculated from ImageJ software are found to be (0.412 ± 0.009) µm and (0.561 ± 0.084) µm respectively.
- grain growth takes place and the grains are elongated with Bi-substitution.

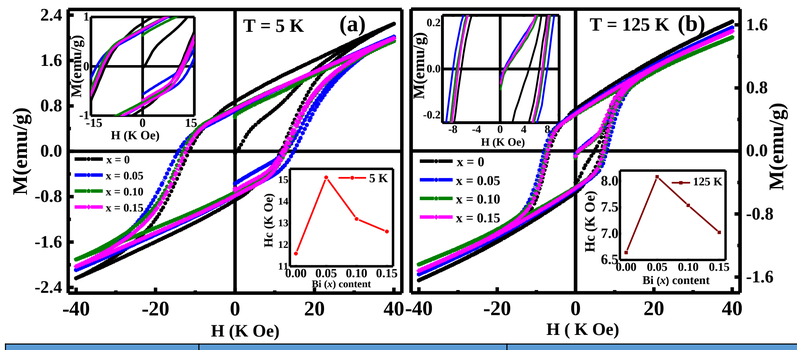
Optical Study



- Kubelka -Munk (KM) function F(R) as $F(R) = \frac{(1-R)^n}{2R}$
- The optical band gap Eg can be evaluated using the relation, $\alpha h\upsilon = A\left(h\upsilon - E_g\right)^n$, hυ is the photon energy in eV, α is absorption coefficient, A is material constant and E_g is energy band gap.
- with increasing Bi^{3+} content, the energy band gap decreases ranges from 3.15 to 2.72 eV and 2.04 to 2.00 eV.

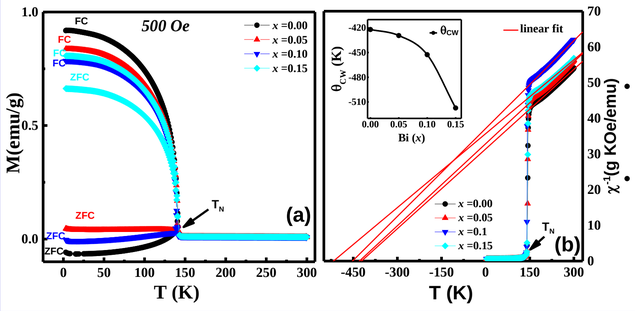
Magnetic study

M-H



Temperature (K)	5 K				125 K			
Bi concentration	x = 0	x = 0.05	x = 0.1	x = 0.15	x = 0	x = 0.05	x = 0.1	x = 0.15
M_{max} (emu/g)	2.23	2.00	1.94	1.99	1.64	1.56	1.42	1.52
H_c (KOe)	11.58	15.10	13.18	12.60	6.64	8.08	7.53	7.02
M_r (emu/g)	0.87	0.71	0.75	0.78	0.52	0.48	0.45	0.47

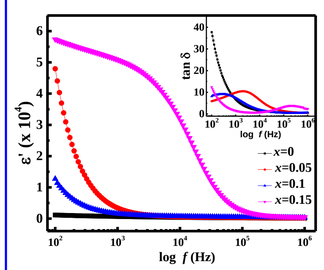
M-T



- T_N value varies slightly between 140 K to 142 K.
- Curie Wiess (CW) law, $\left(\chi^{-1} = \frac{C}{T-\theta_{CW}}\right)$.
- The negative θ_{CW} value shows in all the compositions is attributed to AFM interaction exist.

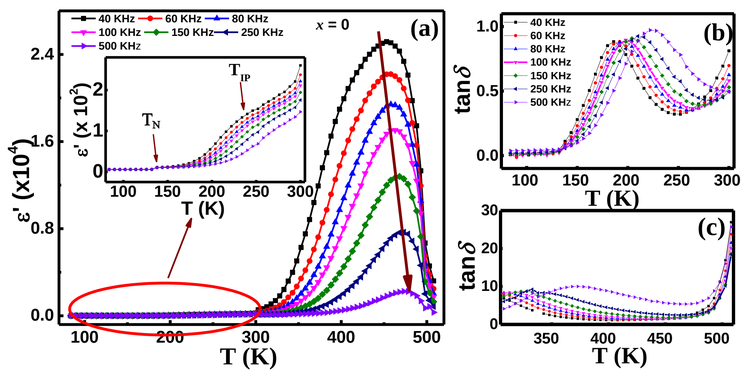
Dielectric Study

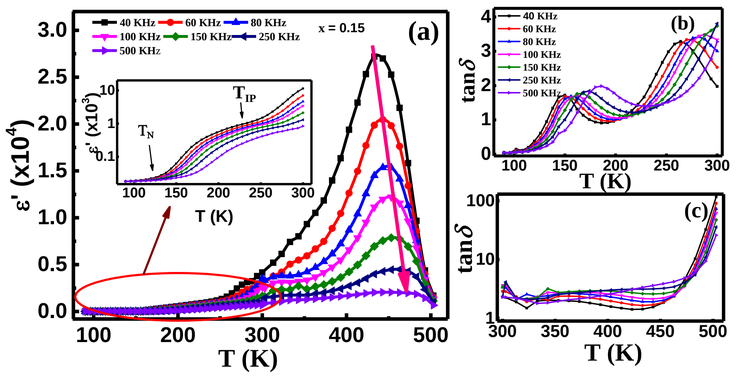
ε' ~ f & *tanδ* ~ f



- With increase in frequency dielectric constant decreases and attains a constant value at higher frequency.
- Obeys Maxwell-Wagner and Koops phenomenological theory.
- the dielectric constant increases and tangent loss decreases as compared to parent sample.

ε' ~ T & *tanδ* ~ T





- Parent and doped sample show realxor like ferroelectric behavior.
- Shows an anomaly around magnetic transition.

Conclusion

- In this report, a series of polycrystalline samples $Y_{1-x}Bi_xCrO_3$ ($0 \le x \le 0.15$) is synthesized through ethylene glycol assisted sol-gel auto combustion route to investigate structural, optical, magnetic and dielectric properties.
- XRD data reveals that, all the samples are retained its original orthorhombic structure with Pnma symmetry, but with Bi content, unit cell volume shows an evolution.
- With introduction of Bi at Y site, average particle size is elongated which is further shows by surface morphology.
- Energy band gap is reduced from 3.15 to 2.72 eV with Bi contents that may be due to structural distortion.
- The maximum magnetization decreases and coercivity increases as compared to parent sample that might due to the changes in bond length and bond angle.
- With increasing Bi content, ε' increases and *tanδ* decreases.
- There is an anomaly found near magnetic transition temperature.
- These results are helpful for good dielectric materials and applicable for magnetoelectric materials.

References

[1] C. R. Serrao et al Phys. Rev. B **72** (2005) 220101.

[2]. A. K. Mall et al J. Euro. Ceram. Soc. **38** (2018) 5359.

[3] T. Lakshaman Rao et al j. Appl. Phys. **126** (2019) 064104.

[4] N. A. Hill, J. Phys. Chem. B, **104** (2000) 6694.

[5] W. Eerenstein, N. D. Mathur, J. F. Scott, Nature, **442** (2006) 759.

[6] S. W Cheong, M. Mostovoy, Nature materials Nat. mater, **6** (2007) 21.

[7] N. A. Spaldin, Proc. R. Soc. A., **476** (2019) 0542.

[8] K Ramesha et al., J. Phys.: Condens. Matter, **19** (2007) 102202.

[9] A. Duran et al., J. Solid state Chem., **183** (2010) 1863.

[10] A. Duran , C. Meza F, Gregorio Guadalupe Carbajal Arizaga., Mater. Res. Bull., **47** (2012) 1442.

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