Electrical and Optical Properties of Yttrium Titanate Thin Films Synthesized by Sol-gel Technique

Apurba Mahapatra[1], P. Kumar[1*]
[1]Department of Physics & Astronomy, National Institute of Technology Rourkela, 769008, India
*Corresponding author- pawankumar@nitrkl.ac.in

ABSTRACT

Yttrium titanate ($Y_2Ti_2O_7$) thin films, having pyrochlore-type structure, were synthesized in single phase by sol-gel synthesis technique. Single phase formation was confirmed by X-ray diffraction (XRD) study. Surface morphology of thin films was studied by using FESEM and average grain size was found to be in nanometer range. Retention of stoichiometry in thin films was confirmed by EDX analysis. Optical property of $Y_2Ti_2O_7$ thin films was studied with the help of UV-Vis spectrometer and the energy band gap was found to be ~3.5eV. Dielectric properties of thin films are also studied and discussed in details.

INTRODUCTION

❑Yttrium titanate ($Y_2Ti_2O_7$/YT) with face-centered cubic structure is a classical pyrochlore oxide where A and B are +3 and +4 ions respectively.

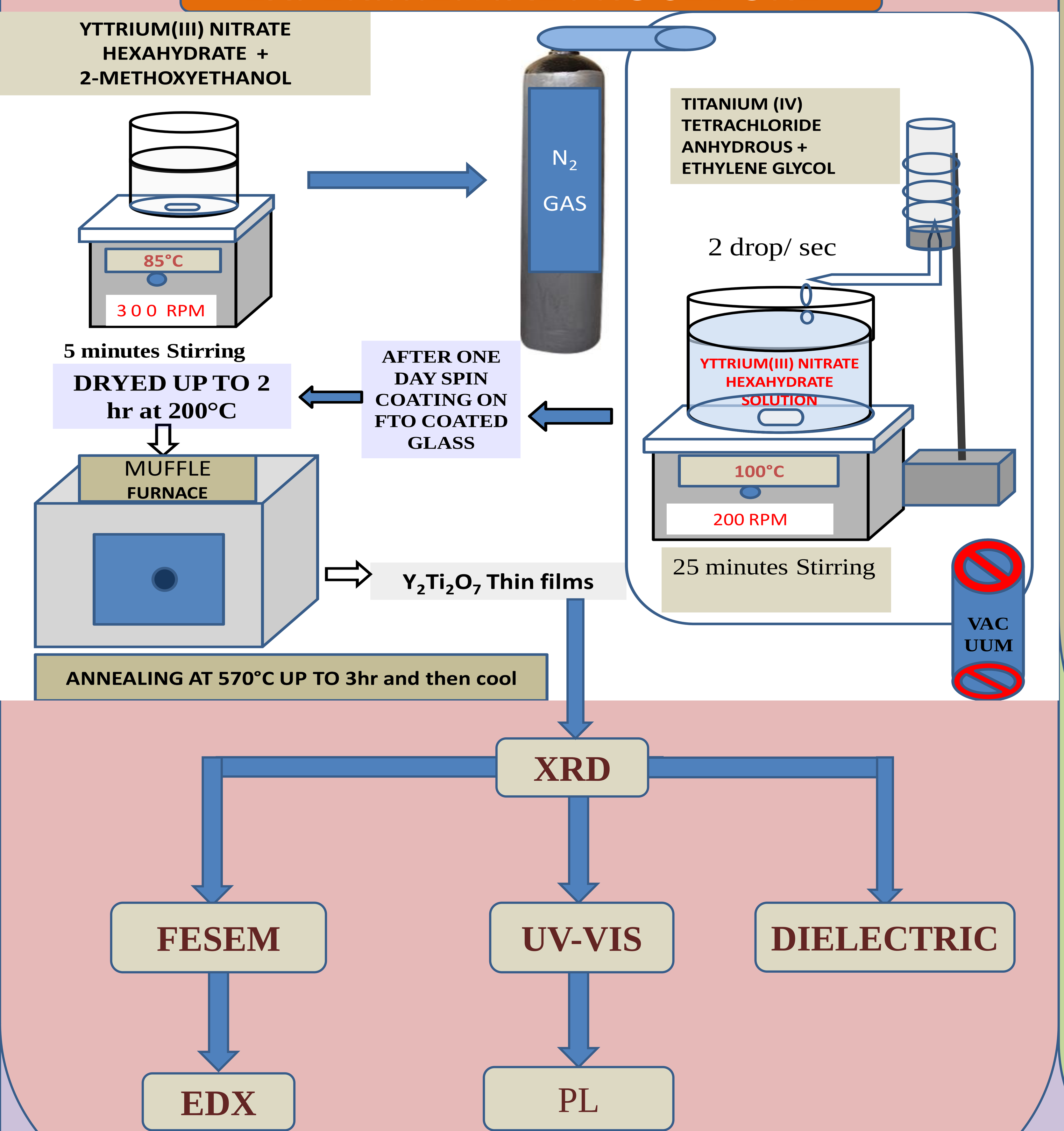
❑YT system is receiving special attention of the research community due to --

- Good chemical stability,
- Nonlinear optical property,
- Excellent mechanical property,
- Good catalytic activity,
- Excellent thermal stability,
- Low conduction temperature,
- Low photonic cutoff energy,
- high melting point,
- Excellent ion-electron conductivity

❑With the above mentioned properties, this systems is finding its use in following applications

- Base material of a phosphor
- Storage vessels of nuclear waste
- Pigment of ceramic
- N type semiconductor in sensor and transistor devices
- As photo-catalyst for hydrogen production by splitting of water
- In efficient er^{3+} luminance as host material
- As an ion conductor in a gas sensor and fuel cell
- As electrolytes material in solid-oxide fuel cell

EXPERIMENTAL PROCEDURE



RESULTS AND DISCUSSION

XRD

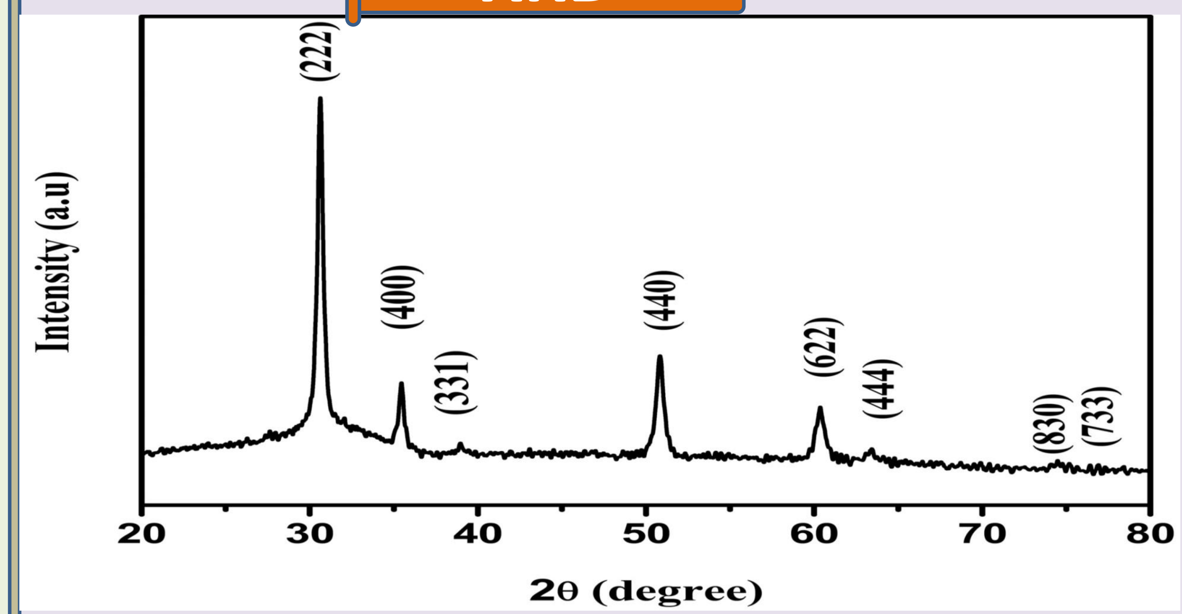


Fig. 1. XRD pattern of YT thin films.

✓XRD pattern of YT thin films confirmed face-centered cubic structure, matched with JCPDS no. 79-1697.

✓Using Debye-Scherrer formula, calculated average crystallite size is found to be ~45nm.

UV-VIS SPECTRA ANALYSIS

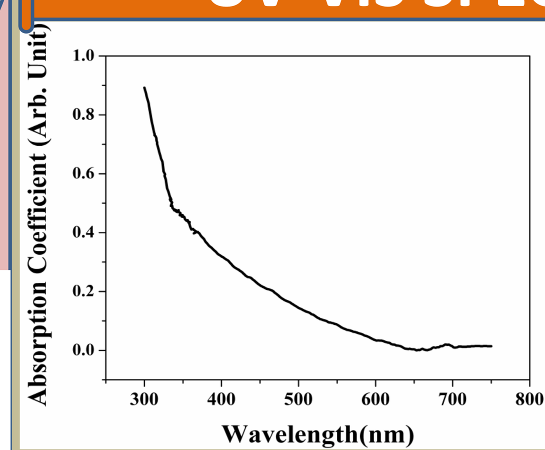


Fig. 4. UV-Visible absorption spectrum of the YT thin films.

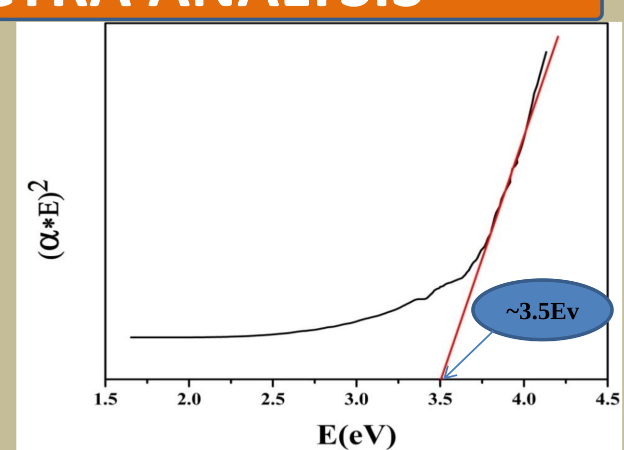


Fig. 5. Tauc plot of absorption spectrum (for direct band gap calculation) of YT thin films.

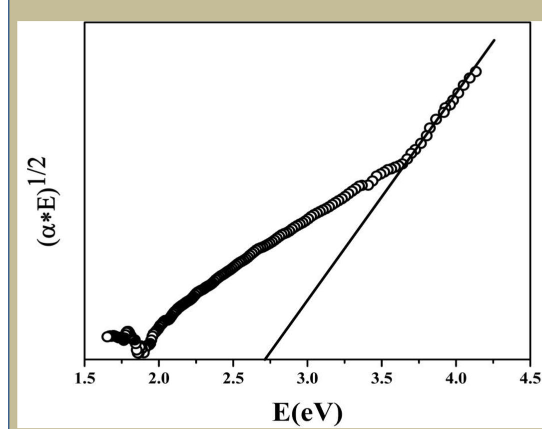


Fig. 6. Tauc plot of absorption spectrum (for indirect band gap calculation) of YT thin films.

✓The absorbance is good at the UV region and decreasing when it goes to visible region.

✓The direct and indirect band gap of YT thin films was estimated from Fig. 5. and Fig. 6. which is equal to ~3.5 eV and 2.71 eV respectively.

FESEM & EDX

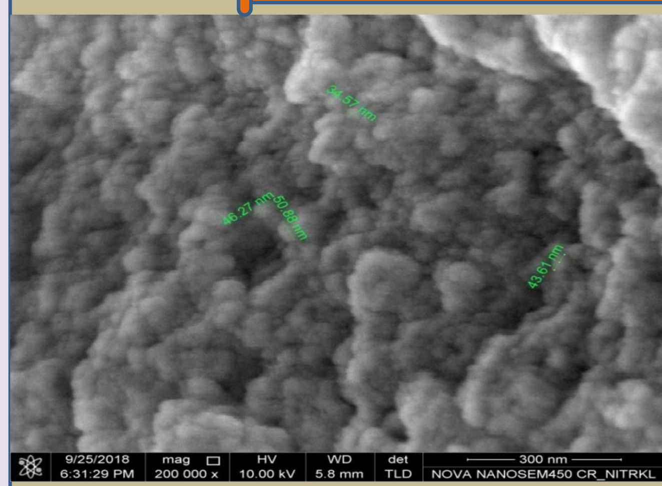


Fig. 2. Surface morphology of YT thin films.

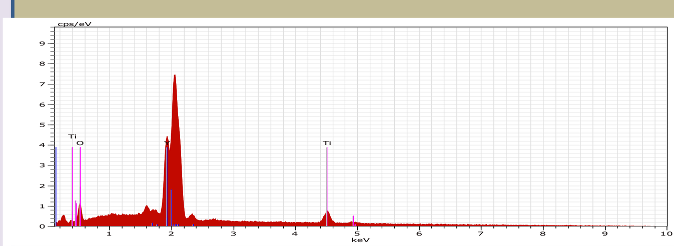


Fig. 3. EDX pattern of YT thin films.

Element	Wt. %	Atom %
O,K	28.89	62.37
Y,L	51.79	20.12
Ti,K	24.26	17.5

Table-1. Elemental composition of YT thin films from EDX study.

✓Spherical like particles with an average size of ~50nm.

✓EDX pattern confirmed the stoichiometric ratio of YT thin films.

✓Table-1. gives the stoichiometric ratio of Y:Ti:O as 2.3:2:7.128, which is quite similar with the theoretical ratio.

PL EMISSION SPECTRUM

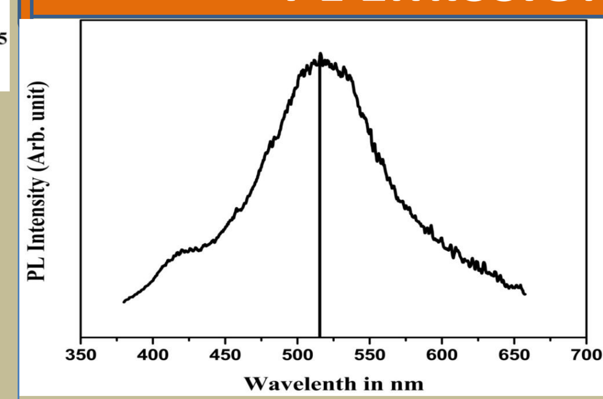


Fig. 7. Photoluminescence emission spectrum of the thin films.

✓A broad peak ranging from~ 375 nm to ~ 660nm, which get maximized at ~516 nm, corresponds to the band gap of ~2.41 eV

DIELECTRIC PROPERTIES

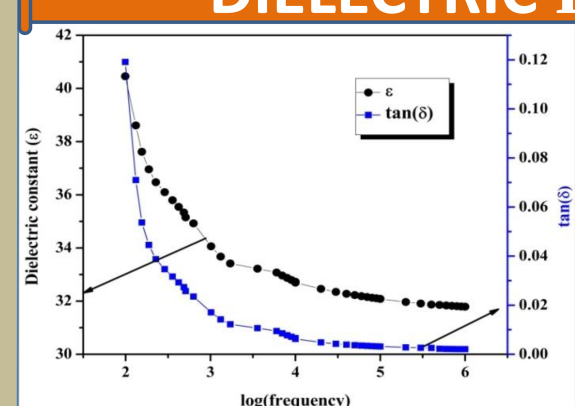


Fig. 8. Dielectric constant and dielectric loss of this material.

✓The variation of dielectric constant and the dielectric loss of YT thin films are proportional to frequency and they are found to be ~31.8 and ~0.005, respectively at 1MHz.

CONCLUSIONS

❖YT thin films were successfully prepared in single phase by sol gel method at a relatively lower temperature compared to other synthesis processes of YT material.

❖The dielectric loss and the dielectric constant of this material inversely proportional to the value of frequency.

❖This work suggest its use as a photo-catalyst for hydrogen production by splitting of water and as semiconductor in sensor and transistor devices due to its lower dielectric loss.

REFERENCES.

1. Jenouvrier, G. Boccardi, J. Fick, A. -M. Jurdyc, M. Langle, Up-conversion emission in rare earth-doped Y2Ti2O7 sol–gel thin films, Journal of Luminescence 113, 291-300(2005).
2. W. J. Lee, D. S. Bae, Synthesis and Characterization of Y2Ti2O7 Photocatalytic Powders by Thermal Assist Process, Defect and Diffusion Forum 380, 86-91(2017).
3. M. A. Subramanian, G. Aravamudan, G.V. S. Rao, Oxide Pyrochlores - A Review, Progress in Solid State Chemistry 15, 55-145(1983).
4. Z. Chen, W. Gong, T. Chen, G. Xiong, G. Huang, Preparation of Y2Ti2O7 Nanocrystal by Sol-gel Method and its Characterization, Advanced Materials Research 97, 2175-2179(2010).