Chapter 6
Summary and Suggestions for future work

Abstract
An endeavor to understand the character and physics of any system has never an ending. However, an effort shows a way to follow and prepare for next attempt to appreciate the Nature...........

In this chapter we will briefly discuss about the conclusions obtained during the course of research work. The suggestion for future work is discussed in detail in terms of future application point of view.
6.1. Summary

The present investigation is aimed at the synthesis of Strontium barium niobate (SBN) and Ce doped strontium barium niobate (Ce:SBN) ceramic powders. The growth of the material into thin films was attempted using RF sputtering technique.

Optimized conditions were found out for the single phase synthesized of SBN powders from solid state reaction and various substrates like quartz, pt-Si as p-type silicon were used to attempt for growing better quality thin films. Repeated trials were made under different radio-frequency powder to deposit crack free films on the platform having close lattice mismatch and thermal expansion coefficient.

After a series of failures, appropriate conditions and right choice of substrate were found out. It has been experienced through our experimental results that form solid state reaction and to the purity of samples used by us, a minimum of 1400 C appear to have been required to avoid secondary phase formation in SBN ceramics. For thin films irrespective of substrate RF power of 100 W would be more suitable for depositing the thin films of SBN and Ce:SBN. Despite all substrate could be utilized for deposition, as per XRD pattern recorded, it has been learnt that use of silicon platform gives diffraction peaks of SBN and Ce doped SBN with less full-width half maximum (FWHM) values, ensuring good crystallinity of the title compound.

Further, XRD analysis on pure SBN ceramics confirmed the tungsten bronze structure of the unit cell with space group P4bm and point group 4 mm. It has also been concluded that cerium incorporation on the SBN lattice has not altered the crystal structure.

Elemental composition analysis (EDAX) in SBN and cerium doped SBN cermic sample compound the stoichiometry of compound taken for synthesis. Surface morphology of SBN and Ce:SBN showed that there exists abnormal group growth (AGG) for all calcinations temperatures. For SEM measurements, it was ascertained that the average grain size of SBN and Ce:SBN powders were about 2 – 6 µm and 2 – 10 µm.
respectively. The possible stretching modes in SBN and Ce:SBN were elucidated through FTIR spectra.

Dielectric studies performed on SBN and Ce:SBN sintered pellets revealed that the dielectric constant \( (\varepsilon_r) \) of SBN was found to be 1232 at 1.1 MHz and it has increased by a factor 1000 on cerium doping. The pattern increased by a factor 1000 on cerium doping. The pattern obtained from dielectric data showed that it belongs to relaxor type of ferroelectrics. Dielectric loss measurement of SBN and Ce:SBN ceramics suggest that both samples have low tan \( \delta \) values at the higher frequencies studied (0.021 and 0.020 at 1 MHz).

Photoluminescence measurements on SBN and Cerium doped SBN has revealed the fact that red shift in the absorption spectrum may be due to the incorporation of cerium (Ce\(^{3+}\)) ions as it was observed for SBN host.

Ferroelectric loop measurements on SBN and Ce:SBN gives the saturation polarization, coercive fields and remnant polarization values viz., 3.73 \( \mu \)C/cm\(^2\), 20.61 kV/cm and 1.84 \( \mu \)C/cm\(^2\) and 2.75 \( \mu \)C/cm\(^2\), 6.2 kV/cm and 1.4 \( \mu \)C/cm\(^2\) respectively.

Piezo studies on poled samples of SBN and Cerium doped SBN ceramic pellets exhibited the \( d_{33} \) coefficient value of 11pC/N and 14 pC/N for a poling field of 2 kV/cm at about 80 °C. Thin film XRD measurements on pure and cerium doped SBN confirmed the lattice parameters obtained for single crystals of SBN reported earlier. In addition to the above, it has evident that there was no texture growth on the surface of the substrate as the texture coefficient was estimated to be less than 1 (one).

UV-Vis-NIR measurements on thin films of SBN and Ce:SBN showed that cerium has not altered the reflectance property of the parent phase and micro Raman measurements indicated the possibility of A2 sites in SBN tungsten bronze phase by Ce\(^{3+}\) ions. PL measurements on Ce\(^{3+}\) ion doped SBN films revealed that Ce\(^{3+}\) has the binding energy above the valence band minimum (VBM) and appearance of red shift occurs at 623 and 750 nm.

SEM measurements provide the information about the thickness of the grown films on silicon as 3.5 and 3.7 \( \mu \)m for SBN and Ce:SBN films. AFM images recorded on SBN and Ce doped SBN gives valuable information about the roughness of the surface, average grain size and crystalline quality of the grown films.
DC leakage current analysis on SBN and Ce:SBN brought out the information that leakage behavior is mainly due to electron as addition of Ce$^{3+}$ has appreciably affected in lower voltage regime.

Swift heavy ion (SHI) irradiation experiments using 150 MeV Ag$^{12+}$ ions on pure and Ce:SBN thin films showed that dumping of electronic energy at higher velocities has marginally affected all its spectral, electrical properties as well as its surface morphology. Specifically AFM images of irradiated films clearly showed that radiation induced amorphization has occurred at higher fluencies studied ($5 \times 10^{12}$ ions/cm$^2$). DC leakage behavior after irradiation found to be considerably charged due to trapping of charge carrier and formation of columnar tracks during irradiation.

**Suggestion for future work**

i. Low keV ion implantation experiments using rare earth ions can be made for improving photorefractive properties of SBN thin films, instead of following conventional doping mechanism.

ii. Electro-optic measurement shall be performed for oriented films of SBN and rare earth doped SBN with the aid of various platform for the possible use of optical modulating elements.

iii. Fruitful attempt could be made for depositing the SBN films with the help of sintered pellets using MOCVD facility for the MEMS device fabrication.

iv. Nano-indentation experiments on these SBN films could provide the mechanical hardness of the grown films in order to ensure the possible use of SBN for commercial applications.

v. Attempt shall also be made with SBN films for particle irradiation using electron, gamma ray at various fluences / dosages. Post irradiation experiments could be done for obtaining valuable information in the possible favourable changes on optical, electrical and surface characteristics.
International Publications

[1] Structural, Microstructural and Electrical Properties of Strontium Barium Niobate (SBN60) Ceramics
   V. Mathivanan, S. Gokul Raj, G. Ramesh Kumar, R. Mohan

[2] Crystal structure and vibrational analyses of nonlinear optical L-histidinium trifluoroacetate single crystals
   V. Mathivanan, S. Gokul Raj, G. Ramesh Kumar, Thenneti Raghavalu, R. Mohan, K. Suriya Kumar, M. Kovendhan, Babu Varghese

   V. Mathivanan, Thenneti Raghavalu, M. Kovendhan, S. Gokul Raj, G. Ramesh Kumar, R. Mohan, and K. Suriya Kumar

[4] Synthesis and characterization of a new nonlinear optical single crystal: L-Lysinium trifluoroacetate'
   V. Mathivanan, Thenneti Raghavalu, M. Kovendhan, K. Suriya Kumar, S. Gokul Raj, G. Ramesh Kumar, R. Mohan,
List of Papers presented in International/National Conferences


2. Participated in the international symposium on materials chemistry ISMC-2006 Between 4th-8th December 2006 at Baba Atomic Research Centre, Mumbai -4


4. Presented a paper on “Effect of 150 MeV Ag^{12+} ion beam irradiation on SBN thin films” in National Conference on “Emerging trends in Materials Science” organized by Muthayamal College of Arts and Science, Rasipuram-637 408, Namakkal, Tamilnadu.
CURRICULAM VITAE

Mr. V. MATHIVANAN was born on 3rd December 1977 at Kesavanankuppam village, Sholingur, Vellore district, Tamil Nadu, INDIA. He had his school educations from Government Higher Secondary School, Walajah Pet. He received his Bachelor degree in Science from the University of Madras through C. Abdul Hakeen College, Melvishram. He obtained his Master degree in Science through Presidency College (Autonomous), Chennai - 600 005, the only institution in India which has produced two Nobel Laureates, viz., Sir. C. V. Raman (Raman effect named after him) and Dr. S. Chandrasekaran (Chandrasekar’s limit named after him) and Master of Philosophy from the University of Madras through A.M. Jain College, Meenambakkam, Chennai - 600 084.

He joined the Department of Physics, Presidency College in April 2006 for research and registered for Ph.D., in July 2006. He carried extensive work on the synthesis and characterization of pure and Cerium doped Strontium Barium Niobate ceramics and thin films. In addition he was also involved in the synthesis and characterization of many optically active amino acids such as L-histidine, L-threonine and L-arginine and their derivatives.

He has to his credit 10 papers published in International journals. He has also presented 4 papers in national and international conferences.