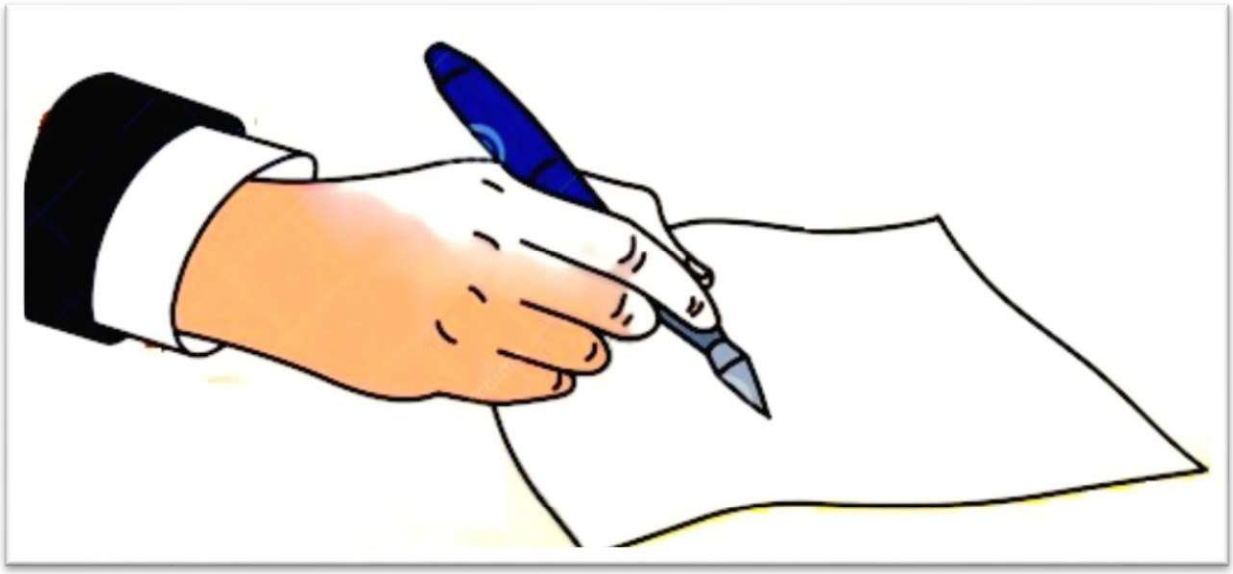
भारतीय
प्रौद्योगिकी
संस्थान
काशी हिन्दू विश्वविद्यालय

IIT

INDIAN
INSTITUTE OF
TECHNOLOGY
BANARAS HINDU UNIVERSITY

Chapter 6

Conclusion and Future scope



Chapter 6: Conclusion and Future scope

This chapter is dedicated to summarized the valuable and important findings of the present thesis research work, we also briefly discussed the futuristic research plan related to presented research work in this thesis.

6.1 Summary of the present work

In the present work we have develop and explore an environmental friendly and low cost $LiNbO_3$ based ceramics materials for the energy applications. Our motive was to enhancement in the properties like sintering of $LiNbO_3$ pellets, enhancement in dielectric, ferroelectric and optical properties by keeping no structural change as well as maintaining the very high curie temperature of the materials. Getting a dense $LiNbO_3$ ceramic pellet after sintering is a very difficult task due to high volatile nature of the Lithium with respect to temperature increment, in this research work we surpassed from this problem by optimizing the material sintering process. To full fill the objectives we have developed K_2O added $LiNbO_3$ ceramic, Sm^{3+} doped ceramic and Dy^{3+} and Ti^{4+} modified $LiNbO_3$ solid solutions with an optimized sintering method and temperature. The bulk development at low cost and enhanced properties was a major concern that made possible in this research work.

The important finding of this present whole research work are summarized as follows:

1. $LiNbO_3$ based ceramics can be developed through high energy ball mill for the bulk by providing an optimize milling time and optimize milling rotation rate.

2. Dense $LiNbO_3$ ceramic pellets can be sintered through by providing small and complete closed environment so the MgO can be used as sealing agent because its high thermal stability.

In this research work for the all three type of $LiNbO_3$ based ceramics are sintered at 1050 ºC. Densified pellets make LN based ceramics a potential material for the variety of applications.

3. For the single element addition or doping in LN Ceramic, the Stoichiometry of $LiNbO_3$ not too disturbed till certain amount of the addition/doping but as the concentration of additive or dopant increases secondary phases are arises and for these Rhombohedral crystal structure found with R3c space groups its show there are no significant changes is lattice parameters, while for the two different co-doped element in the $LiNbO_3$ Stoichiometry of $LiNbO_3$ disturbed and as result two phases co-exist together, one is Rhombohedral crystal structure with R3c and another is Cubic with F-43m space group with two different sets of lattice parameters. After a certain doping amount of Dy^{3+} and Ti^{4+} the crystal structure start changes. Not changing in the crystal structure ensure that the desired properties can't be abruptly change so that we can rely on this research for the suitable applications purposes.

4. The Thermo Gravimetric analysis conformed that thermal behavior of $LiNbO_3$ found lossy in terms of weight percentage loss while the K2O addition in the system makes more lossy for a certain amount of K_2O additive addition, while for the Sm^{3+} doping and Dy^{3+} and Ti^{4+} doping in the system is found highly stable at high temperature up to 1000 ºC. In the some of the composition very less weight loss makes this research valuable for those applications where high temperature environment present.

5. Morphological analysis revealed that there is various size of grains are found with a certain type of shape for the K_2O addition as well as for the Sm^{3+} doping with varying average grain size as concentration of the dopant/additive varies but for the Dy^{3+} and Ti^{4+} doped LN ceramics the shape of the grains changes as the Ti^{4+} concentration increases in the system and it's become plates like structure due to superstructure formation.

6. The hygroscopic nature of the K_2O added $LiNbO_3$ confirmed through the XPS spectra as the K_2O amount increases the prepared absorbed moisture from the environment.

7. In this research work for the all synthesized materials the FTIR Analysis have been done which confirmed that presence of Li-O bond and Nb-O bonding, where Nb-O related to octahedral of Oxygen and niobium atoms.

8. Direct and Indirect band gap are calculated by using Tauc plot equation for the all compositions, and the minimum direct and indirect band gap for K_2O added L are 2.36 ± 0.003 eV and ~1.61 ± 0.003 eV, for Sm^{3+} modified LN 2.97 ± 0.003 eV and 3.09 ± 0.003 eV and for Dy^{3+}, Ti^{4+} co-doped LN are ~2.4 ± 0.03 eV and 2.95 ± 0.03 eV respectively. During the both type band gaps determination it was found that there is no exact and confirmed tangent line is obtained for are the samples so that we rely with direct band gap. Reduced band gaps with tuned absorbance properties makes this research works valuable for the many optical and energy based applications.

9. Emission spectra confirmed that for the K_2O added LN exhibit distinct green, yellow, and red emission peaks, Sm^{3+} modified LN exhibit distinct green, orange, and red color bands while Dy^{3+}, Ti^{4+} co-doped LN exhibits of Yellow, Cyan, and Blue color emission bands. For the Sm^{3+} modified LN the different color bands are very sharp with a higher intensity, emergence of different color bands make LN modified ceramic materials a suitable and potential candidate for LEDs, Yellow laser and display devices applications.

10. Enhanced dielectric constant in K_2O added LN, Sm^{3+} modified LN and Dy^{3+}, Ti^{4+} co-doped LN obtained without any transition temperature up to 500 ºC for the varied frequency from 100 Hz to MHz, enhanced dielectric constant without any transition at such high

temperature indicate that this research work is also relevant for the high temperature applications.

11. Enhanced ferroelectric properties with improved hysteresis loop obtained, For K_2O added LN, Sm^{3+} modified LN and Dy^{3+}, Ti^{4+} co-doped LN the maximum polarization values are ~1.16 $\mu C/cm^2$, 0.66 $\mu C/cm^2$ and 0.8 $\mu C/cm^2$ respectively, the obtained such high Polarizations values are never reported before.

12. The maximum energy density was calculated and obtained, for the Sm^{3+} modified LN is 5.66 mJ/cm^3 and for the Dy^{3+}, Ti^{4+} co-doped LN 13.78 mJ/cm^3, which are never before reported.

13. The maximum energy efficiency ((η) %) calculated and obtained, for the Sm^{3+} modified LN is 46.64 % and for the Dy^{3+}, Ti^{4+} co-doped LN 34.00 %, and these energy efficiency values are also never reported before.

6.2 Future Scope of this research work

These are some points which can be valuable for this research work for the future prospects, and points are as follows.

- High temperature and Low temperature analysis can be added in the X-ray diffraction part to check the structural properties which can make it more valuable for the odd conditioned based applications in the variety of area.
- Dielectric characteristic above the 500 ºC to transition temperature can be helpful for the high temperature applications so these type characterizations and analysis needed.
- High temperature up to several 100 ºC Ferroelectric properties investigation needed for the high temperature switching and power electronics applications.

- Time dependent and Temperature Dependent Photoluminescence characterizations and study can make this research work very worthy for the Laser, display, LEDs and sensing based optical devices, so that these kind of applications need.
- Thermally highly stability might be beneficial for the Pyroelectric investigations so that it works is also has to be investigate.
- LN ceramics exhibits with Less piezoelectric properties with their original crystal structure so that the improvement in Piezoelectric behavior without changing in crystal structure can be very beneficial for the high temperature sensor actuator and transducers device
- LN exhibit with their biological active properties so that this area is also open for the extensive research.
- LN exhibits with electrolytic catalysis properties so that in the waste water treatment research area this can be useful, which has to be done.