Chapter 5
Swift Heavy Ion (SHI) irradiation effects on pure and Ce doped
Sr$_{0.6}$Ba$_{0.4}$Nb$_2$O$_6$ thin films

Abstract
Swift heavy ion irradiation can produce various defects in a target material. However, these defects not necessarily make the material terrible. There is possibility of modifying the properties to make it attractive and enhancing the materials.

150 MeV Ag$^{12+}$ ions were irradiated on pure and cerium doped SBN films at various ion fluencies viz. $1 \times 10^{11}$, $1 \times 10^{12}$ and $5 \times 10^{12}$ ions/cm$^2$. The effect upon irradiation on the surface properties were studied using XRD measurements. Radiation induced amorphization of the surface at the higher fluence studies was ascertained both through XRD, PL and micro Raman measurements. The surface defects produced after irradiations have been quantified by the way of measurements like average grain size, surface roughness for each of ion fluence through AFM studies. The trapping of charges after irradiation could be perceived from current density measurements. The results were inter correlated with the tools taken for study.
CHAPTER 5

Swift Heavy Ion (SHI) irradiation effects on pure and Ce doped Sr$_{0.6}$Ba$_{0.4}$Nb$_2$O$_6$ thin films

5.1 Introduction

The swift heavy ion (SHI) irradiation of solid materials with high energy ions is extremely important from the fundamental physics as well as from the materials engineering point of view. The defect formations by radiation are of different types and energies have been studied in detail and the underlying phenomena involved are identified by many researchers. It is recognized that controlled irradiation through proper choice of the ions and its energy lends a tool to study the defect processes, to bring in desired change in the physical parameters of the material and to evaluate the critical irradiation conditions [1,2].

Interaction of ferroelectric ceramics with energetic ions is capable of inducing deep buried disorder and new types of defects are expected to be produced. The dynamics of the defects are expected to be influenced by many nonlinear mechanisms like creation of oxygen vacancies, interstitial cation vacancies etc. It is well known fact that swift heavy ion on passing through the materials losses its energy mainly by two ways: electronic energy loss $S_e$ (inelastic process) and nuclear energy loss $S_n$ (elastic process) [3].

The latter process is responsible for displacing atoms of the medium from their lattice positions. At medium ion energies (keV range), the damage is caused by the nuclear loss, whereas at high energies (MeV±GeV range) it is caused by the electronic loss mechanism. Since controlled irradiation can lead to a controlled introduction of defect states in the material system, it is being beneficially used to control the material properties. The irradiation also enhances the role of defects in altering material properties. The electrons and holes created by irradiation are violently separated and are then trapped at lattice point defects, stoichiometric defects, impurities and at grain boundaries.
5.1.1. Swift Heavy Ion Irradiation

The swift heavy ion (SHI) irradiation is known to create controlled defect states in the material and offers the possibility of tailoring the properties of materials. There are basically two modes of energy deposition of an ion beam in a material medium; inelastic energy loss due to electronic excitations (i.e. electronic energy loss $S_e$ or $(dE/dx)_e$) and elastic collision i.e. direct nuclear collision (nuclear energy loss $S_n$ or $(dE/dx)_n$). When energy of the incident ion is small enough (~ keV) so that the ion’s velocity is smaller than the Fermi velocity of the electrons of the target material, the incident ion collides and loses its energy directly with the nucleus. In this situation $S_n$ dominates over $S_e$.

In general for SHI (energy ~ MeV), the incident ion has velocity of the order of Fermi velocity of the electrons of the target material and suffers collision with the electronic system of the target material. In such a situation, $S_e$ is much higher than the $S_n$ value. Therefore, almost all the energy loss or the energy deposited in the material can be considered due to electronic energy loss, provided the thickness of the material is less than the range of the ion. There are various models to explain the energy loss process of SHI irradiation on a target material [4,5].

![Fig. 5.1](image.png)

Fig. 5.1. The dependence of $S_e$ and $S_n$ on the energy of the 150 MeV Ag$^{12+}$ ion impinging on SBN and Ce:SBN target
Fig. 5.1 shows the dependence of $S_e$ and $S_n$ on the energy of the 150 MeV Ag$^{12+}$ ion impinging on SBN and Ce:SBN target. This type of curve is usually called as Bragg curve. The two specific effects, in terms of materials modification that arises due to the $S_e$ mode of energy deposition by the ion beam, are annealing and phase change. Depending upon the magnitude of the $(dE/dx)_e$ and the characteristics of the material (insulating, semiconducting, metallic etc.), the energy deposited by the ion beam to the electronic sub-system of the material can either anneal out pre-existing defects or it can lead to the creation of defect or amorphized latent tracks along the ion path.

It may be emphasized that as the highly charged energetic ion passes through the material, the neighbour target atoms get positively charged (via electronic interactions) and repel each other. The time spent by the energetic ion, passing through the material, at a particular site is very short ($10^{-17}$ sec) in comparison to the recombination time ($10^{-12}$ sec). Thus a long cylindrical channel of charged ions would be produced by SHI along its path. This channel of charged ions will explode radically due to conversion of electrostatic energy to radial movement of atoms under the coulomb repulsion force until the conduction electrons screen the ions. This results in the shock wave generation in the materials. This explanation is termed as Coulomb explosion model [4]. The second competitive process used is the thermal spike model [5]. The thermal spike is a two step thermodynamic process described by two differential equations that give a time and space dependence of $T_e$ and $T_l$ ($T_e$ and $T_l$ are temperatures of electronic and lattice systems respectively). According to this, the energy locked into the electron excitation is transmitted to the lattice via electron-phonon interaction to increase the local temperature of the lattice above its melting temperature. The increase of temperature is followed by a rapid quenching ($10^{13}$-$10^{14}$ K/sec), resulting in an amorphized columnar structure when the melt solidifies. To explain the track formation due to irradiation, the thermal spike model has been applied to metals and insulators.

Both the processes mentioned above (Coulombic explosion and thermal spike) are inseparable. The cylindrical shock wave generates strain in the lattice around the ion track and presence of thermal spike creates the amorphized columnar tracks.
In the present work 150 MeV silver ion (Ag$^{12+}$ ion) was employed to irradiate thin films of Sr$_{0.6}$Ba$_{0.4}$Nb$_2$O$_6$ and Ce doped Sr$_{0.6}$Ba$_{0.4}$Nb$_2$O$_6$ samples to observe any modification in its structural, electrical, optical and morphological properties. The irradiation was done at Inter University Accelerator Center, New Delhi-110067, India in materials science beam line using 15UD pelletron accelerator [6].

The 15 UD pelletron, as shown in Fig.5.2 and Fig.5.3, is a versatile, heavy ion tandem type of electrostatic accelerator. In this machine, negative ions are produced and preaccelerated to ~300 keV in ion source.

![Fig. 5.2. An overview of materials science beam line in Inter University Accelerator Centre – IUAC (Formerly Nuclear Science Center (NSC) New Delhi, India](image)

The ion beam is selected by injecting magnet, which selects the mass of the ion using mass spectroscopy. The pre-accelerated ions are injected into strong electrical field inside an accelerator tank filled with SF$_6$ insulating gas. At the centre of the tank is a terminal shell, which is maintained at a high voltage (~15 MV). The negative ions on traversing through the accelerating tubes from the column top of the tank to the positive terminal get accelerated. On reaching the terminal they pass through a stripper, which removes some electrons from the negative ions, thus transforming the negative ions into positive ions. These positive ions are then repelled away from the
positively charged terminal and are accelerated to the ground potential to the bottom of the tank. In this manner, same terminal potential is used twice to accelerate the ions. On exiting from the tank, the ions are bent into horizontal plane by analyzing magnet. The switching magnet diverts the high energy ion beams into various beam lines into the different experimental areas of the beam hall. The entire machine is computer controlled and operated from the control room.

![Diagram of Pelletron facility](image)

Fig.5.3. A schematic of 15 UD Pelletron facility at IUAC

5.2 Ion irradiation process and its doses to SBN films

In a ferroelectric material, the trapped charges pin the domains and consequently affect the ferroelectric properties. Some of the lead-based ferroelectric compositions are studied for their gamma, electron and neutron irradiation responses. The lanthanum
doped lead zirconium titanate (PLZT) and lead strontium niobate (PSN) class of relaxor ferroelectrics are shown to be affected by the gamma-, electron- and neutron irradiation. However, there are not many reports on high energy heavy ion irradiation effects on ferroelectrics in general and on lead iron niobate (PFN) and lead magnesium niobate-lead titanate (PMN–PT) relaxors. In particular there are only a few reports on the study of high-energy heavy ion irradiation effects on ferroelectric thin films. SBT thin film memories when exposed to xenon ions with a fluence of $1.5 \times 10^7$ ions/cm$^2$ did not lose any data [7]. The X-ray and $\gamma$-ray irradiations of lead zirconium titanate (PZT) thin films showed degradation of the ferroelectric properties. The influence of neutron irradiation and annealing on the dielectric properties of ferroelectric PLZT-8 and antiferroelectric PZ thin films were also reported earlier [8]. Measurements on neutron irradiated PLZT ceramics showed a significant decrease and a broadening of the dielectric constant around curie point (Tc) as well as reduction in Tc [9-11]. X-ray irradiated PZT films and multidomain crystals of TGS showed a shift in the hysteresis loops, which was related to an internal electric field caused by induced radiation and trapped charges.

A model for the defect evolution in perovskites and the effect of radiation induced charges on the dielectric properties was also made. It was observed that there is a decrease in Tc of ferroelectric poly vinylidene fluoride–bifluoroethylene copolymer thin films when irradiated by electrons of 2.55 MeV energy. It was concluded that the lowering of the Tc after irradiation is due to the destruction of the ferroelectric ordering and the breaking of the macro-polar domains into micropolar domains, which in turn reduce the polar region size.

In the present case, good quality uniformly grown films ascertained from SEM analysis have been used for irradiation experiments with 150 MeV with Ag$^{12+}$ ions. The experiment was performed for both the pure and Ce doped SBN thin films at various ion fluencies viz., $1 \times 10^{11}$, $1 \times 10^{12}$ and $5 \times 10^{12}$ ions/cm$^2$. Using the magnetic scanner, the entire area of the film was scanned by the incident ion beam so as to ensure the dose uniformity on the sample. The samples were electrically grounded to minimize the sample charging. The beam current used was 0.5 pA (particle nano ampere). The
Thin films of pure SBN and Ce:SBN

Stopping power and ranges of 150 MeV of Ag$^{12+}$ ions on SBN films were computed using SRIM-2008 code [12].

Table 5.1. The electron stopping power (Se), Nuclear Stopping power (Sn) and range of 150 MeV of Ag$^{12+}$ ions in the pure and Ce doped SBN.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Se = (dE/dx)$_e$ eV/$\mu$m</th>
<th>Sn= (dE/dx)$_n$ eV/$\mu$m</th>
<th>Se/Sn</th>
<th>Projected Range (R) $\mu$m</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBN</td>
<td>3.471X10$^1$</td>
<td>1.356X10$^{-1}$</td>
<td>256</td>
<td>17.83</td>
</tr>
<tr>
<td>Ce:SBN</td>
<td>3.403X10$^1$</td>
<td>1.340X10$^{-1}$</td>
<td>254</td>
<td>17.90</td>
</tr>
</tbody>
</table>

From the above table 5.1, it is seen that the projected range of the incident ions 150 MeV of Ag$^{12+}$ ion was about 17.83 $\mu$m. Since the thickness of the grown films (from SEM pattern) of SBN & Ce:SBN were found to be only in the range of 3.5 – 3.7 $\mu$m, even there is no remote chance for Ag$^{12+}$ ions getting implanted in the film. Further, as the film thickness is small compared with the range of Se (electronic energy loss) has almost constant value throughout the film. Hence, irradiation effects are expected to be produced uniformly through the thickness of the film. For the sake of having a comprehensive view of changes brought by irradiation, the results of the characterization done before and after irradiation for the thin film samples of pure SBN and cerium doped SBN to the ion fluence 1 x 10$^{11}$, 1 x 10$^{12}$ and 5 x 10$^{12}$ ions/cm$^2$ are presented as discussed below.

5.3 X-ray diffraction analysis on irradiated samples of pure and Ce doped SBN

X-ray diffraction pattern of unirradiated SBN and Ce doped SBN thin films shows the presence of crystallization phase, as shown in Fig.5.4 (a) and (b). The XRD patterns of the unirradiated samples match well with the standard JCPDS patterns (No. 88-0785 for SBN) confirming the 100% tungsten bronze phase formation in both pure and cerium doped SBN films. Upon irradiation at the fluence we could see that the diffusion rate of both type of films, which is indicative of presence of amorphous material. The appearance of crystalline peaks over the amorphous background shows that the irradiation has produced same amount of amorphous substance having the crystal structure same as the unirradiated material. It has been proposed that the amorphization
observed in XRD is produced by the fast ions either through the coulomb explosion or the thermal spike mechanisms. Indeed, amorphization due to irradiation especially at the grain boundary region under identical irradiation condition was already noticed elsewhere [13].

![X-ray diffraction for silver ion irradiated films of SBN and Ce:SBN](image)

Fig.5.4(a) & (b). X-ray diffraction for silver ion irradiated films of SBN and Ce:SBN

In the case of the fluence of $5 \times 10^{12}$ ions/cm$^2$, for cerium doped SBN samples the intensity of diffraction peaks have become feeble and thereby charging as a amorphizable solid. Whereas the pure SBN samples, crystallinity found to have been improved in the sample due to the reasons that the crystallization forms a partially discarded state require at least short-range diffusion, which might have been thermally activated and could not be possible at lower exposure time.
Hence at maximum ion fluence studied, it was noticed that in pure SBN samples, there has been a radiation induced recovery of crystallization and its Ce doped SBN ones, it is amorphizable at higher ion fluences due to substantial creation of oxygen vacancies which automatically leads to non-stoichiometric proportions. Similar kind of observations have already have made in many insulators [14].

5.4 UV-Vis-NIR analysis on pure and Ce doped SBN films

UV-Vis-NIR reflectance spectra of unirradated SBN and irradiated samples of Ce:SBN were recorded in the wavelength range 300 – 2000 nm as shown in Fig.5.5. SHI has marginally affected reflectance percentage for both pure and Ce doped SBN samples.

Fig.5.5(a) & (b). UV-Vis-NIR spectra of silver ion irradiated films of SBN and Ce:SBN
As fluence increases, reflectance of the grown samples found to increase, thereby indicating the optical absorption of the films getting modulated in accordance with the ion fluence. However, no wavelength shift has been witnessed for any of the samples studied. Similar kind of observation was also reported for ferroelectric films of LiNbO$_3$ samples reported elsewhere [15].

5.5 Micro Raman measurements on pure and Ce doped SBN films

Micro-Raman spectra was carried out for pristine and irradiated films of silver ion irradiated thin films in the frequency range 100 – 800 cm$^{-1}$ and it is shown in Fig.5.6. The Raman shift observed at 520 cm$^{-1}$ corresponds to the substrate peak due to silicon. In general two prominent peaks around 303 and 430 cm$^{-1}$ have been reported for single crystals [16,17]

![Raman spectra for Silver ion irradiated thin films of SBN and Ce:SBN](image)

Fig.5.6. Raman spectra for Silver ion irradiated thin films of SBN and Ce:SBN

These peaks mostly involve transverse A1 symmetry modes. The reasons for the fairly broadened lines for the spectra observed in the case of irradiated specimen of pure and cerium doped SBN may be due to the lattice disorder which produces a breakdown of the wave-vector selection rules, making difficulty for the definitive assignments of the different new peaks seen in lower frequency in the irradiated films. Further broadening of peaks with respect to ion fluence would also infer that crystallinity of the films got affected due to radiation induced surface modifications of the grown samples.
5.6 Effect of SHI irradiation on photoluminescence of pure and Ce:SBN

PL spectra obtained for 150 MeV of Ag\(^{12+}\) ions in ion irradiated Ce:SBN in the wavelength range 400 – 800 cm\(^{-1}\) is shown in Fig.5.7.

![Fig.5.7. PL spectra of silver ion irradiated Ce:SBN](image)

PL emission transition from Ce\(^{3+}\) ion play a vital role in lowering CTVE (charge transfer vibration exciton) energy. From the graph, it has been perceived that significant emissions observed around 625 nm and 750 nm appeared in unirradiated Ce\(^{3+}\) doped SBN films continue to exist even after irradiation at the lower fluence \(1 \times 10^{11}\) and \(1 \times 10^{12}\) ions/cm\(^2\). However, for the fluence \(5 \times 10^{12}\) ions/cm\(^2\), the PL intensity changes and broadening of peaks were also experienced. This may be probably due to amorphization at the surface level of the films and radiative transition are broadly affected due to the loss of crystallinity throughout the surface of the film. The increase and decrease in the PL intensity at lower and higher fluences may be attributed to the presence of oxygen defects and variations in density of the grown films.
5.7 AFM measurements on irradiated films of pure and Ce doped SBN films

Fig.5.8 (a-d) and Fig.5.9 (a-d) represents the pure and silver ion irradiated 2D and 3D AFM images measured by non-contact mode. Fig.5.10(a-f) represents the 2D and 3D AFM images pure Ce:SBN and silver ion at various fluences of $1 \times 10^{11}$ and $5 \times 10^{12}$ ions/cm$^2$ films by non-contact mode. Based on the sectional analysis, the following results were obtained and are provided in below table 5.2.

Table 5.2. Average grain size and sample roughness for pure and Ce:SBN and their corresponding silver ion irradiated samples.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Fluence (ions/cm$^2$)</th>
<th>Average grain size (nm)</th>
<th>Sample roughness (RMS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBN</td>
<td>Pristine</td>
<td>54.66</td>
<td>13.90</td>
</tr>
<tr>
<td></td>
<td>$1 \times 10^{11}$</td>
<td>110.27</td>
<td>10.56</td>
</tr>
<tr>
<td></td>
<td>$5 \times 10^{12}$</td>
<td>137.31</td>
<td>11.16</td>
</tr>
<tr>
<td>Ce:SBN</td>
<td>Pristine</td>
<td>368.64</td>
<td>6.11</td>
</tr>
<tr>
<td></td>
<td>$1 \times 10^{11}$</td>
<td>42.27</td>
<td>5.55</td>
</tr>
<tr>
<td></td>
<td>$5 \times 10^{12}$</td>
<td>201.49</td>
<td>13.28</td>
</tr>
</tbody>
</table>

The average grain sizes of the particle distributed over 2 μm$^2$ area of the film were calculated for each ion fluence. The particle size distribution from 2D and 3D images reveal the fact that at lower ion fluence, the average grain size for pure and cerium doped SBN were 110.27 and 42.27 respectively, whereas for virgin samples they were about 54.68 and 368.64 nm respectively to $1 \times 10^{11}$ ions/cm$^2$. 
Fig. 5.8 (a-d) represents the pure and silver ion irradiated 2D AFM images measured by non-contact mode.

After irradiation, rod like structure appears to have been formed in the pure SBN films due to formation of cylindrical ion channels. This in turn gives anomalous increase in grain size. Similarly the RMS roughness of the unirradiated films and irradiated films of pure and cerium doped SBN films have shown a decrease from 13.90 to 10.56 nm for pure and 6.12 to 5.55 nm for cerium doped SBN films. The decrease in roughness values in both cases may be attributed to large amount of energy transfer (electronic energy) dumped on the SBN, leading to ionization molecules as it softens the sample surface.
Fig. 5.9(a-d) represents the pure and silver ion irradiated 3D AFM images measured by non-contact mode.

In respect of cerium doped SBN thin films, the average grain size initially decreases from 368.64 to 42.27 nm for $1 \times 10^{11}$ ions/cm$^2$ and thereafter, it shoots up to 201.45 for $5 \times 10^{12}$ ions/cm$^2$. Similar trend was also reciprocated in its RMS roughness value which increases from 5.51 to 13.28 nm for ion fluence of $5 \times 10^{12}$ ions/cm$^2$, pristine sample of cerium doped has the roughness value of about 6.12 nm. The increase in the grain size for the higher fluence can be attributed to the fact that during irradiation, the kinetic energy of the electrons ejected from atom is transferred to lattice by electron-phonons interaction which increases the local temperature over the melting point of the material. Considering the small grain volumes, we suppose that heat gets confined within the grain volume. This gives rise to a non-equilibrium state which as a consequence raises the volume of the grain resulting in grain agglomeration on the surface.
Fig. 5.10 (a-f) represents the 2D and 3D AFM images of pure Ce:SBN and irradiated films of Ce:SBN at $1 \times 10^{11}$ and $5 \times 10^{12}$ ions/cm$^2$. 

Thin films of pure SBN and Ce:SBN
In cerium doped SBN, at lower fluence, the decrease in grain size will in turn may decrease its refractive index values. This surface modulation of optical property of the material may likely to occur. Similar observations have also been indicated elsewhere Sanjukta Ghosh, et al.[18].

5.8. DC leakage behavior of pure and Ce doped SBN films

The DC leakage current plots are shown in Fig. 5.10 (a & b) for unirradiated and irradiated pure SBN and cerium doped SBN thin films. Both the plots show two distinct regions: a linear region indicating ohmic behavior and a nonlinear region representing space charge limited conduction region. The ohmic range voltage and corresponding current density values for samples irradiated under various fluences are depicted in table 5.3.

![Graphs showing DC leakage current plots](image)

Fig. 5.11 (a & b). The DC leakage current plots for unirradiated and irradiated pure SBN and cerium doped SBN thin films

The unirradiated samples of SBN and Ce:SBN films show the ohmic character upto 16.2 and 16.8 volts respectively. Upon irradiation, linear region in respect of SBN films slightly extended up to 16.7 volts (values obtained from linear fit R (factor) = 0.85 – 0.99) whereas in cerium doped one, ohmic regions decreases from 16.8 to 15.7 volts. For higher fluences, it has reached to 16.6 volts and for the maximum fluence studied, the ohmic region even extends up to 18.6 volts.
Table 5.3. The ohmic range voltage and corresponding current density values for samples irradiated for various fluences

<table>
<thead>
<tr>
<th>Sample</th>
<th>Ion Fluence (ions/cm²)</th>
<th>Ohmic region (in volts)</th>
<th>Current (amp)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SBN</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pristine</td>
<td>16.2</td>
<td>16.7</td>
<td>1.12</td>
</tr>
<tr>
<td></td>
<td>1 x 10¹¹</td>
<td></td>
<td>1.008</td>
</tr>
<tr>
<td></td>
<td>1 x 10¹²</td>
<td>16.4</td>
<td>9.52</td>
</tr>
<tr>
<td></td>
<td>5 x 10¹²</td>
<td>16.4</td>
<td>4.416</td>
</tr>
<tr>
<td><strong>Ce:SBN</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pristine</td>
<td>16.8</td>
<td></td>
<td>1.278</td>
</tr>
<tr>
<td></td>
<td>1 x 10¹¹</td>
<td>15.7</td>
<td>6.92</td>
</tr>
<tr>
<td></td>
<td>1 x 10¹²</td>
<td>16.6</td>
<td>5.89</td>
</tr>
<tr>
<td></td>
<td>5 x 10¹²</td>
<td>18.6</td>
<td>3.78</td>
</tr>
</tbody>
</table>

Furthermore, not only is the magnitude of pre-irradiation current density differ in two type of films, it also behaves differently on irradiation. In cerium doped SBN films, the current values increases from 1.12 A to 6.9 A at lower fluences and decreases upto 3.78 for 5 x 10¹² ions/cm². It may be due to trapping of charge carriers by the irradiation induced defects [19,20]
5.8 Conclusions

i. XRD analysis on SBN and cerium doped SBN films confirms that at lower fluences, radiation induced surface amorphization occurs either due to Coulombic explosion or due to thermal spike. Further it was also noticed that recovery of crystallization found to have been experienced at higher fluence for pure SBN films.

ii. UV-Vis-NIR spectra of SBN and Ce:SBN has revealed optical reflectance of both kind of samples has got affected marginally upon irradiation which in turn modulates the surface optical properties of the samples taken for study.

iii. From micro-Raman measurements, it has been inferred that many peaks have broadened upon irradiation which reflects in the XRD results showing radiation induced amorphization (RIA).

iv. Based on PL measurements, it has been confirmed that after irradiation, cerium doped SBN films have shown lower PL intensity at higher fluences due to presence of oxygen defects and may probably arise from the non-uniform density of grown films.

v. AFM images provide valuable information about the influence of radiation on average grain size and surface roughness which in turn give a clue about the crystallinity of the film even after irradiation.

vi. DC leakage current characteristics on pure and cerium doped SBN films indicate the possible trapping of charge carriers after irradiation. The variation in ohmic region and current density values would ascertain the above result.
Thin films of pure SBN and Ce:SBN

References


Thin films of pure SBN and Ce:SBN


