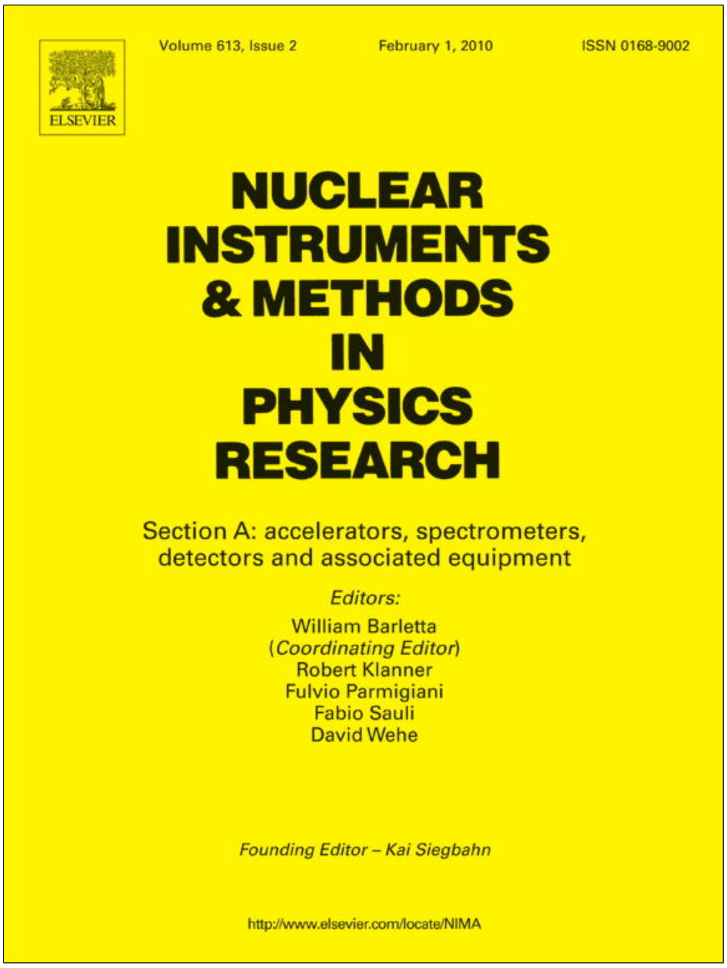
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A comparison of 48 MeV Li^{3+} ion, 100 MeV F^{8+} ion and Co-60 gamma irradiation effect on N-channel MOSFETs

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ABSTRACT

N-channel MOSFETs were irradiated by 48 MeV Li^{3+} ions, 100 MeV F^{8+} ions and Co-60 gamma radiation with doses ranging from 100 krad to 100 Mrad. The threshold voltage (V_{TH}), voltage shift due to interface trapped charge (ΔV_{Nit}), voltage shift due to oxide trapped charge (ΔV_{Not}), density of interface trapped charge (ΔN_{it}), density of oxide trapped charge (ΔN_{ot}), transconductance (g_m), mobility (μ) of electrons in the channel and drain saturation current ($I_{D\ Sat}$) were studied as a function of dose. Considerable increase in ΔN_{it} and ΔN_{ot}, and decrease in V_{TH}, g_m and $I_{D\ Sat}$ were observed in all the irradiated devices. We correlated the degradation of μ with the ΔN_{it} and the effect of ΔN_{ot} is found to be negligible for degrading the μ. The maximum degradation was observed for the devices irradiated with Co-60 gamma radiation when compared with those irradiated with ions, since gamma radiation can generate more trapped charge in field oxide when compared to the high energy ions.

1. Introduction

The metal oxide semiconductor field effect transistors (MOSFETs) are fundamental components in advanced integrated circuits (ICs) and are used in space, military and other radiation rich environments like large hadron collider (LHC) applications because of their faster switching speeds and simple drive requirements. However, MOS and bipolar devices are sensitive to radiation and are prone to parametric or even functional failure on exposure to ionizing radiations [1–5]. The basic damage effects of ionizing radiation in MOS devices results from the generation of electron–hole pairs in the gate oxide. When positive bias is applied to the gate, electrons drift rapidly under the influence of the applied electric field and most flow out into the external circuit. In this case holes have been shown to have lower mobility and drift slowly to the Si/SiO_2 interface, a fraction get trapped and thus forming the radiation induced oxide trapped charge [6–8]. These positive charges induce a negative shift in the threshold voltage and increase the leakage current, which leads to increased power consumption. During the hole transport and trapping processes, hydrogen is released within the oxide, and may be transported to the interface and react with silicon dangling bonds, forming interface traps. The density of these interface states is greatly enhanced by the positive bias voltage applied during the irradiation and they too can modify the overall charge dependent properties of MOS devices including the decrease in g_m and μ [9–12]. In many applications, particularly in mixed signal and digital technologies the parameter g_m will affect the speed and output drive. The degradation of room temperature g_m from total dose has been studied extensively and is attributed to mobility degradation from increased interface traps [13–15]. A few other investigators have observed degradation of g_m from total dose at lower temperature and showed that both ΔN_{it} and ΔN_{ot} can modulate the resistivity and hence alter the value of g_m [16–19]. In order to use MOS devices in space, the devices need to withstand few krad to few megarad of gamma equivalent total dose but for high energy physics experiments like in large hadron colliders (LHCs), the devices need to withstand 1 MeV equivalent $1\times10^{16}\,cm^{-2}$ fluence of neutron or 100 Mrad of total dose in their five year lifetime. The irradiation times needed to reach in case of high hadron fluences (proton, neutron, pion) at the current proton or gamma irradiation facilities have correspondingly increased. A possible way to decrease the irradiation times to more practical values could be to irradiate devices with energetic heavy ions, taking advantage of the large non-ionizing energy-loss, which significantly increases with the atomic number of the impinging ions. Therefore, the comparison of the effects of high energy ions on MOSFETs with Co-60 gamma radiation is essential in addition

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to basic understanding of the effects of high energy ions on MOS devices. Previously we reported the effects of 8 MeV electron irradiation on MOSFETs irradiated at different gate bias [5], and also the effects of 95 MeV oxygen ion irradiation [20]. The V_{TH} of the irradiated MOSFET was found to decrease significantly after irradiation. The ΔN_{it} and ΔN_{ot} were found to increase after irradiation. In the present work, we present, for the first time, a systematic comparison of 48 MeV Li^{3+} ions, 100 MeV F^{8+} ions and Co-60 gamma irradiation on the V_{TH}, g_m and μ of N-channel depletion MOSFETs in the dose range 100 krad–100 Mrad irradiated at gate bias, V_{GS} = +2 V. From the subthreshold measurements the ΔN_{it} and ΔN_{ot} were estimated. Further, the μ in the channel was estimated from the g_{mpeak} and mobility degradation is correlated with ΔN_{it}. The mobility degradation co-efficient due to interface traps (α_{it}) and oxide-trapped charge (α_{ot}) is also estimated and the results obtained are presented and discussed in this paper.

2. Experiment

The two serially connected N-channels with independent dual gate depletion MOSFETs (BEL 3N187) with isolated silicon substrate (<100> 4–11 Ω cm of thickness ~650 μm) and the gate oxide thickness (SiO_2) ≈ 750 ± 50Å were used in the present study [5]. The gate metal (Al) thickness is ≈ 1.2 μm while the device channel size is ≈ 1.2 × 5 μm^2. Special back-to-back diodes are diffused directly into the MOS pellet and are electrically connected between each insulated gate and the MOSFET source in order to avoid excess or transient voltage. The N-channel MOSFETs were exposed to 48 MeV Li^{3+} ions and 100 MeV F^{8+} ions at the 15 UD 16 MV Pelletron Tandem Van de Graff Accelerator at Inter University Accelerator Center (IUAC), New Delhi, India [21]. The MOSFETs were irradiated with ion fluence from 1.41×10^9 to 1.48×10^{13} ions/cm^2 at 300 K in an experimental chamber of diameter 1.5 m maintained at 10^{-7} mbar vacuum. The gamma equivalent dose for the above mentioned fluence is ranging from 100 krad to 100 Mrad. The fluence on the sample kept in cylindrical secondary electron suppressed geometry was estimated by integrating the total charge accumulated on the sample using a current integrator and then counting by a scalar meter. The ion beam was scanned over the samples in an area of 10 × 10 mm^2 by magnetic scanner in order to get uniform dose. The gate terminals of MOSFETs were biased at +2 V (V_{GS} = +2 V) during irradiation. The typical beam currents during irradiation were 1 and 0.125 pnA for 48 MeV Li^{3+} ions and 100 MeV F^{8+} ions respectively. The Co-60 gamma irradiation was done using gamma chamber with a dose rate of 167 rad/s at Pondicherry University in the dose range100 krad–100 Mrad. The total dose was kept identical for both high energy ions and gamma radiation.

The electrical characterization of the un-irradiated and irradiated MOSFETs were performed using computer interfaced 4155 HP Agilant Semiconductor Parameter Analyzer. The current resolution with the test setup was of the order of 1–100 fA. The threshold voltage (V_{TH}) and transconductance (g_m) was determined from the I_D versus V_{GS} characteristics. Among the several methods to measure the V_{TH}, one method is to choose a current level and define the V_{GS} required to produce that I_D as the V_{TH}. For example, V_{TH} equals the V_{GS} required to produce 1 μA of I_D, the total dose response determined using this method was qualitatively the same as the other methods like extrapolating the square-root of I_{DS} versus V_{GS} curve to I_{DS}=0 [22]. The mobility (μ) of carriers in the channel was determined by g_m measurements (at constant V_{DS}=0.1 V). While measuring the electrical parameters of the MOSFET, same voltage was applied to both the gates.

Table 1
The energy loss and range of 48 MeV Li3$^+$ ion, 100 MeV F8$^+$ ion and Co-60 Gamma radiation in metal oxide semiconductor (MOS) structure.

Source	LET in MeVcm^2/g			Range in μm		
	Al	Si	SiO_2	Al	Si	SiO_2
48 MeV Li^{3+} ions	412.2	421.6	454.7	254.1	289.5	266.0
100 MeV F^{8+} ions	9307	4427	4723	63.65	72.65	68.05
Co-60 Gamma	1.544	1.600	1.651	1072	1206	1171

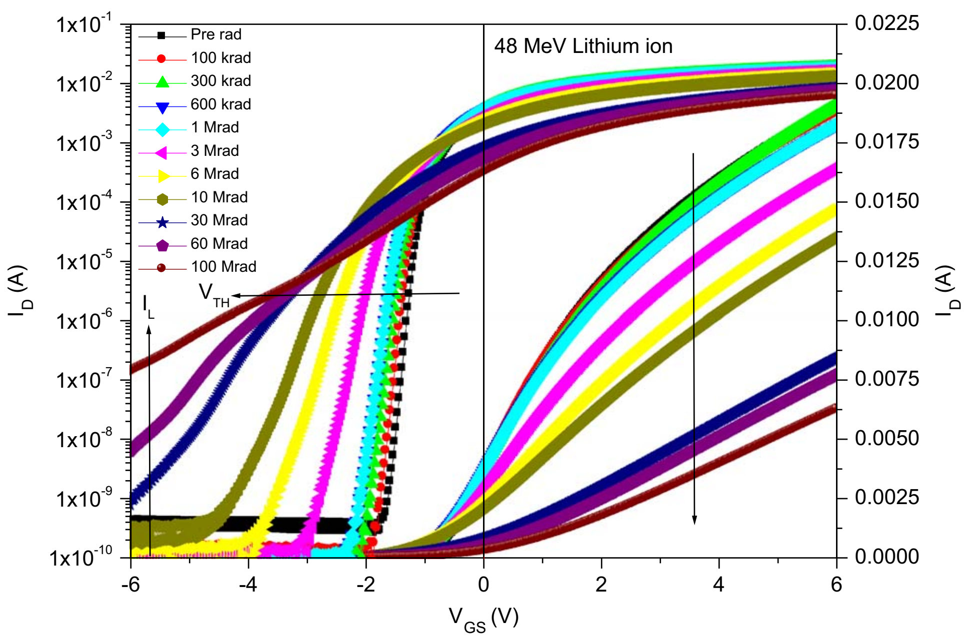

Fig. 1. Transfer characteristics of 48 MeV Li^{3+} ion irradiated MOSFET.

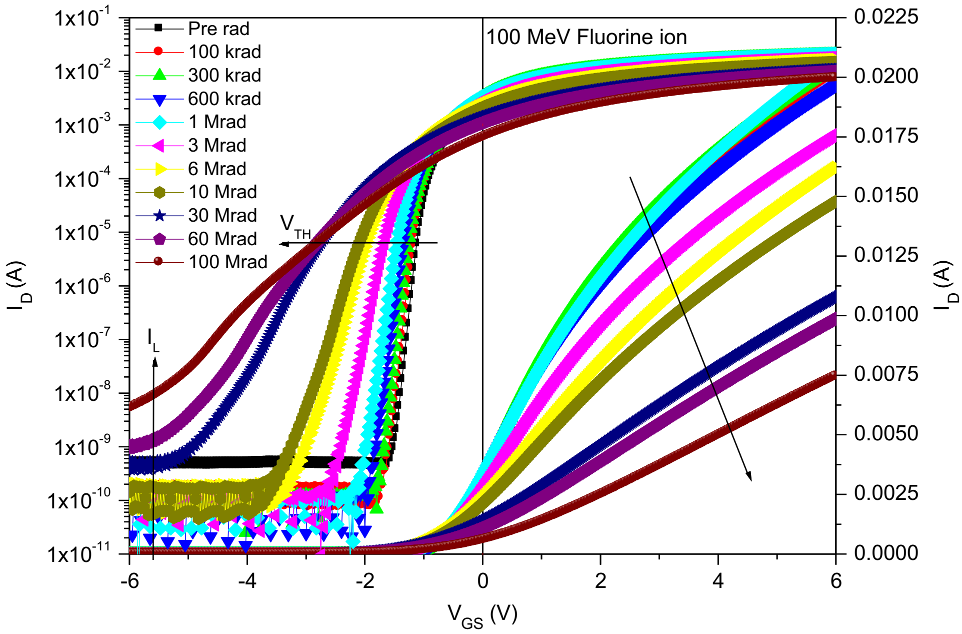

Fig. 2. Transfer characteristics of 100 MeV F^{8+} ion irradiated MOSFET.

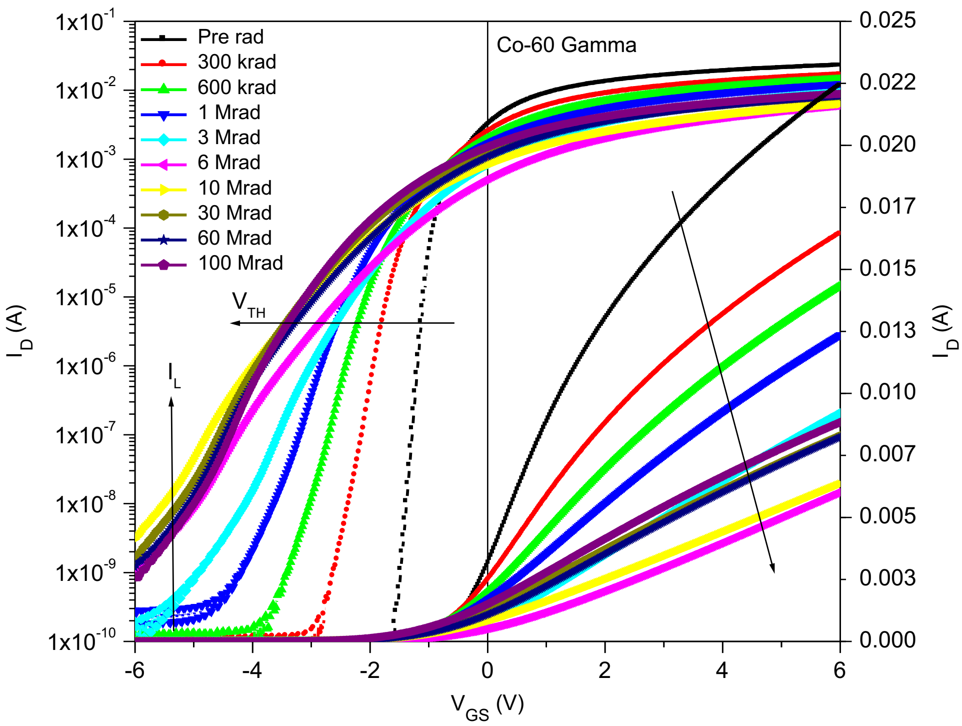

Fig. 3. Transfer characteristics of Co-60 gamma irradiated MOSFET.

3. Results and discussion

When high-energy ion passes through a solid, it looses its energy via two processes, namely, electronic excitations called an electronic energy loss, $\langle dE/dx \rangle e$ and direct nuclear collisions with the target atoms called as nuclear energy loss, $\langle dE/dx \rangle n$. The nuclear energy loss is much smaller than the electronic energy loss (three orders of magnitude) in a material due to smaller elastic scattering cross-section. Therefore all the energy deposited to the material is mainly due to electronic energy loss process during its early passage into the material. The nuclear energy loss becomes dominant near the end of the ion range and this produces point defects and collision cascades. We have used SRIM-2008 [23] simulation program to estimate the value of $\langle dE/dx \rangle e$, $\langle dE/dx \rangle n$ and the range of 48 MeV Li^{3+} ions and 100 MeV F^{8+} ions in the metal oxide semiconductor (MOS) device structure and are given in Table 1. From the SRIM calculations it is clear that the ions pass through the aluminum gate, SiO_2 layer and finally get implanted deep inside the silicon p-substrate at a depth of 290 and 72.7 μm respectively for 48 MeV Li^{3+} ions and 100 MeV

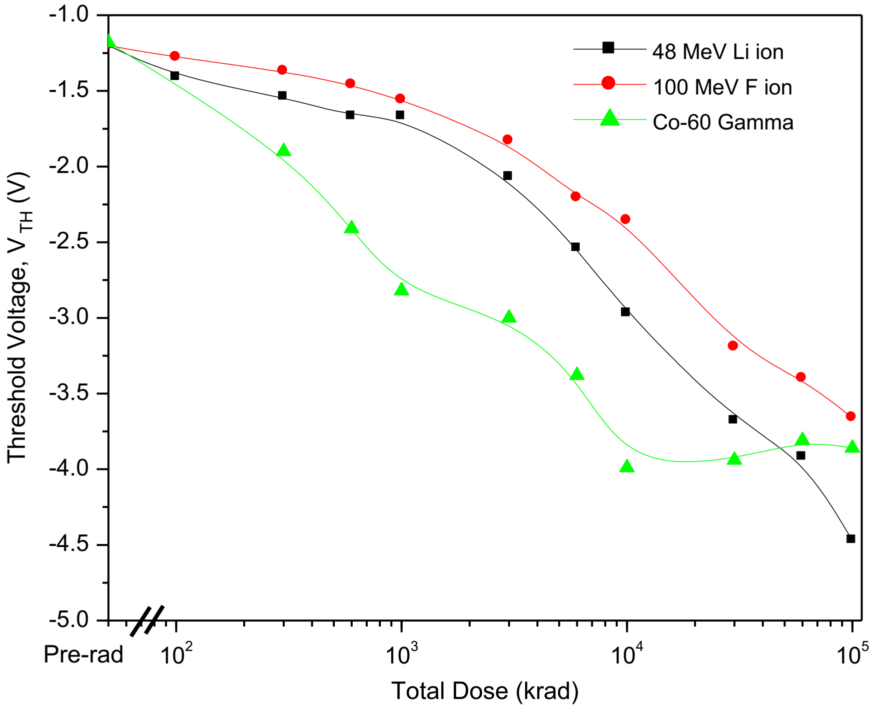

Fig. 4. Threshold voltage degradation as a function of dose.

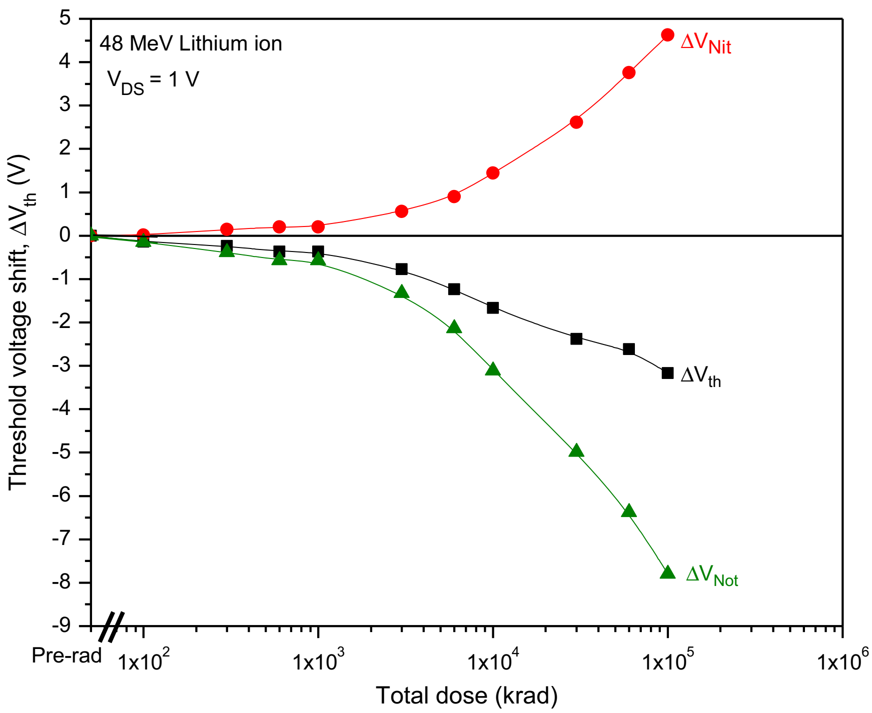

Fig. 5. Threshold voltage shift versus total dose for 48 MeV Li^{3+} ion irradiation.

F^{8+} ions from the surface. When MOS devices are exposed to high energy ions, these ions pass through the SiO_2 layer, they deposit at higher energy through electronic excitations, which lead for ionization or breaking bonds and displacement of atoms along its path during irradiation process [5]. From the SRIM simulation data it is revealed that each ion can create around 870 and 3790 vacancies/ion before it stops in the silicon substrate for 48 MeV Li^{3+} ions and 100 MeV F^{8+} ions respectively. In the MOSFETs, the role of Si/SiO_2 interface is very important in determining the device performance. Some of the radiation induced electron–hole pairs quickly undergo recombination and are not available for any further radiation effect and some of the positively charged holes make slow dispersive transport towards the Si/SiO_2 interface where they are trapped in deep hole traps. The microscopic origin of the dispersive transport is likely to be multiple trapping and detrapping of the holes or hopping of the holes through shallow traps. This results in addition of oxide charges (N_{ot}) and reduction of V_{TH}. These N_{ot} are located at or near the Si/SiO_2 interface and

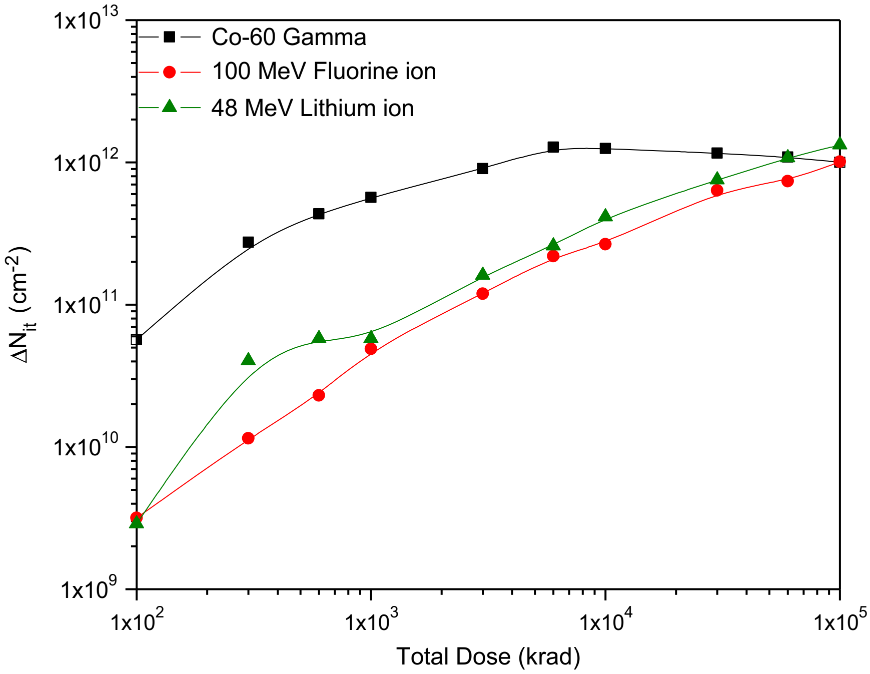

Fig. 6. Interface trap density versus total dose for irradiated MOSFETs.

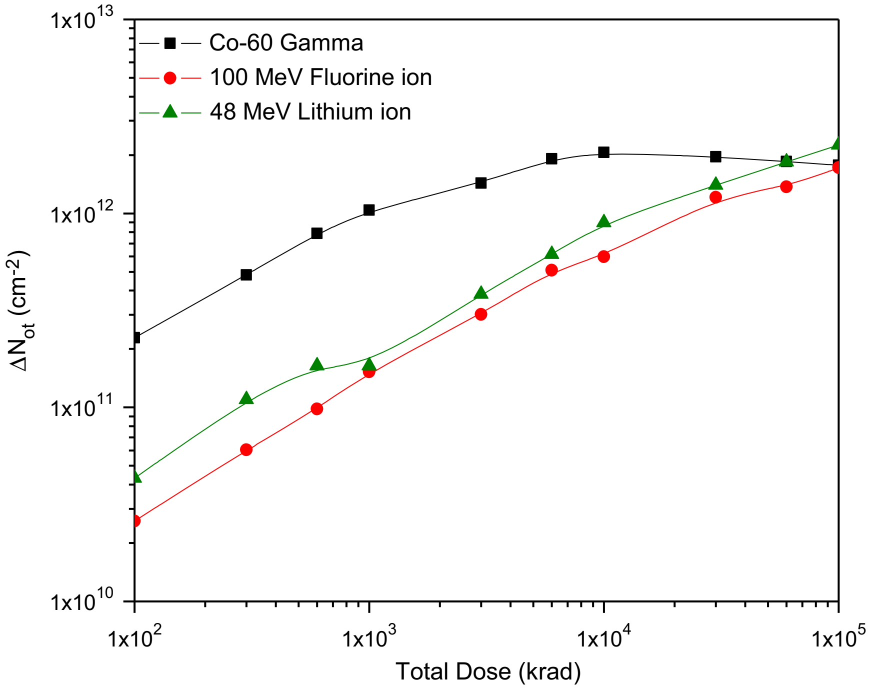

Fig. 7. Oxide trap density versus total dose for irradiated MOSFETs.

are immobile under applied electric fields. The electron trapping in SiO_2 is negligible because the capture cross-section of electron traps is very small (by a factor of 10^4). It is well known that gamma rays produce radiation damage via the creation of Compton electrons, which results in the charge deposition at the oxide–semiconductor interface and the nearby oxide layer. By analyzing silicon displacement cross-sections for electrons and the secondary electron spectrum in a Co-60 source for electron energies from 0.2 to about 1.0 MeV, equivalent displacement damage of 0.6 MeV electrons can be estimated [24]. These secondary electrons can also produce simple point defects in bulk of the semiconductor in addition to ionization and in turn degrade the device performance. Therefore LET and range of Co-60 gamma radiation is assumed to be equivalent of 0.6 MeV electrons and is shown in Table 1 [25].

Figs. 1–3 depict the transfer characteristics (I_D versus V_{GS}) of 48 MeV Li^{3+} ions, 100 MeV F^{8+} ions and Co-60 gamma irradiated MOSFETs at $V_{DS}=1$ V. To determine the V_{TH}, we studied the subthreshold behaviour of irradiated MOSFETs as a function of total dose. The V_{TH} for these devices is defined as the negative gate voltage for which the drain current becomes 1 μA ($V_{TH} \equiv V_{GS}$ @ $I_D=1$ μA) [22]. Further, V_{TH} is the primary degradation monitor

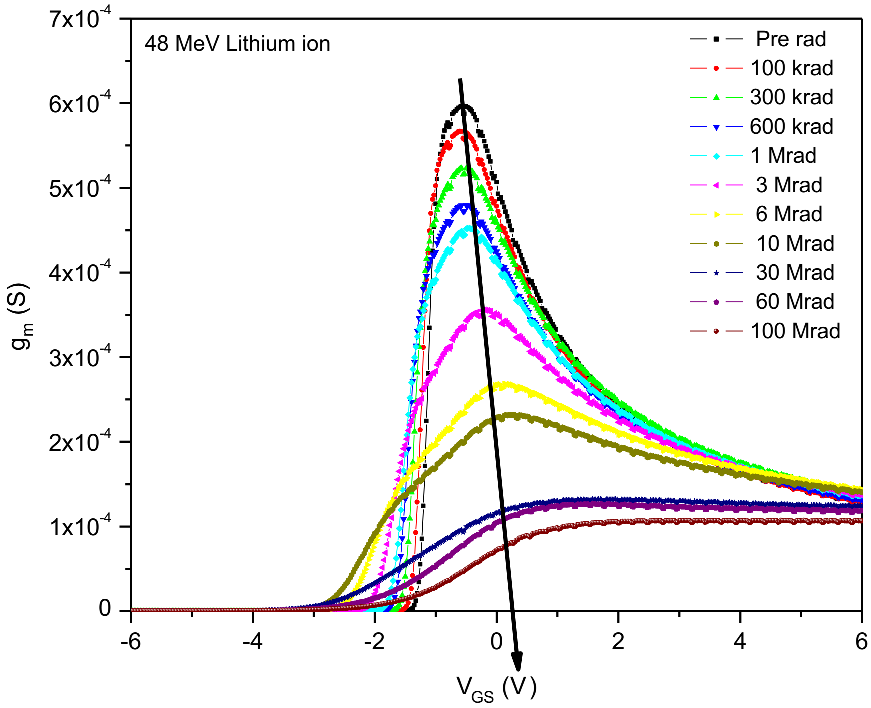

Fig. 8. Transconductance characteristics of 48 MeV Li^{3+} ion irradiated MOSFET.

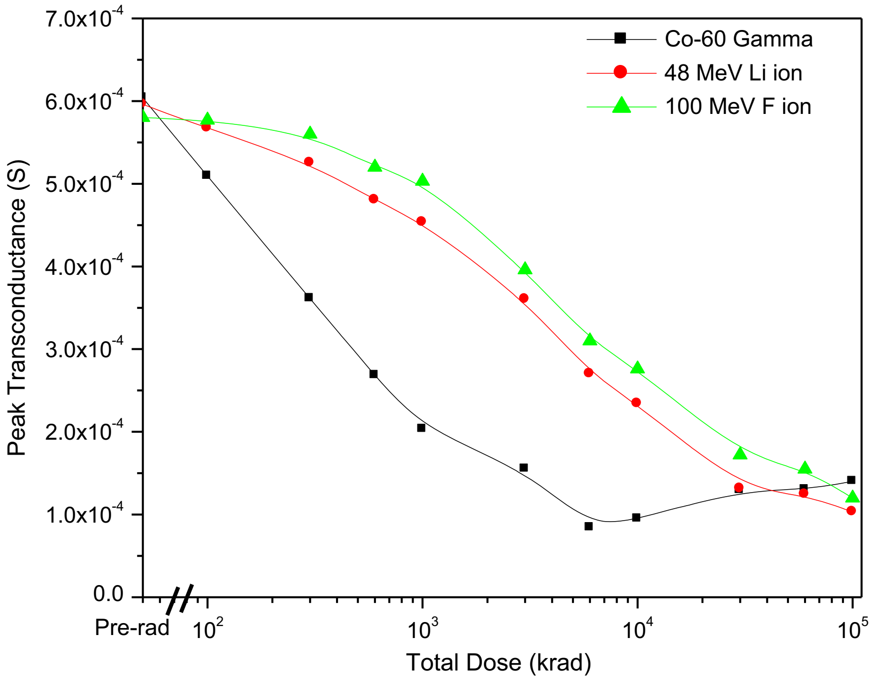

Fig. 9. Peak transconductance versus total dose for irradiated MOSFETs.

and is obtained from I_D-V_{GS} curve. In Figs. 1–3, it is clearly seen that the I_D swings towards negative voltages with the increase of dose. This means that the V_{TH} decreases with increase in dose. Fig. 4 shows the variation in V_{TH} with respect to the dose for ion and Co-60 gamma irradiated MOSFETs. For the MOSFETS irradiated with 48 MeV Li^{3+} ions and 100 MeV F^{8+} ions at total dose up to 100 Mrad, the V_{TH} decreased from –1.2 to –4.47 V and −1.12 to −3.66 V respectively. The MOSFETs irradiated with Co-60 gamma radiation, the V_{TH} decreases up to 10 Mrad and later increases slightly. This recovery in V_{TH} after 10 Mrad is expected due to increase in the temperature of the gamma irradiation chamber. The temperature of the irradiation chamber was about 55 °C after a total dose of 10 Mrad and some of the trapped charge might have annealed. Therefore we cannot observe any change in the I_D-V_{GS} curves after 10 Mrad of total dose. The above results clearly reveal that the Co-60 gamma irradiation up to 10 Mrad of total dose creates more trapped charge than 48 MeV Li^{3+} ions and 100 MeV F^{8+} ions in the insulating oxide of the MOSFET there by decreasing the V_{TH}. In other words, lower LET radiation Co-60 gamma creates more trapped charge in oxide layer than the

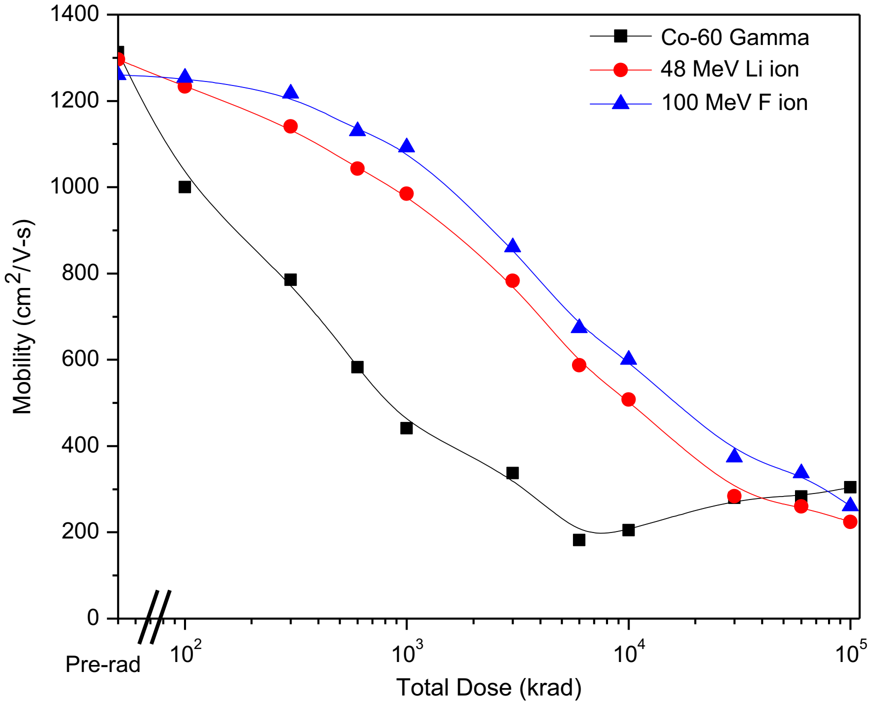

Fig. 10. Variation in field effect mobility after 48 MeV Li^{3+} ion, 100 MeV F^{8+} ion and Co-60 gamma irradiation.

Table 2
The effect of different radiation on mobility degradation coefficients of N-channel MOSFETs.

	Co-60 gamma	48 MeV lithium ion	100 MeV fluorine ion
α_{it} (cm^2)	$(4.591 \pm 0.628) \times 10^{-12}$	$(3.699 \pm 0.189) \times 10^{-12}$	$(3.748 \pm 0.041) \times 10^{-12}$
α_{ot} (cm^2)	$(3.57 \pm 1.63) \times 10^{-15}$	$(-9.693 \pm 8.268) \times 10^{-15}$	$(-1.206 \pm 0.098) \times 10^{-18}$

higher LET radiations like 48 MeV Li^{3+} ions and 100 MeV F^{8+} ions. Experiments performed by Schwank et al. [26] have yielded similar trends. Showing increased degradation in buried and isolation field oxides for Co-60 gamma radiation compared to proton irradiation. The observed trends were attributed to the secondary electrons generated via Co-60 gamma photons. These electrons of low stopping power are believed to generate electron–hole pairs with large spatial separation, leading to large numbers of charge carriers that escape before recombination [27]. This increased charge yield due to Co-60 gamma radiation has also been observed in the literature extensively for MOS devices [28–30] and is very plausible explanation for the effects observed in these MOSFETs.

The leakage current (I_L) is the current flowing in the source to drain junction when MOS transistor is in OFF condition. Besides the change in the V_{TH} due to the build up of N_{it} and N_{ot}, the other major effect of ionizing radiation on MOS transistor is the increase in the I_L and is related to the N_{it} and N_{ot} build up. Increase in I_L leads to increased currents flow in the circuit and therefore increased static power dissipation. This can have a serious impact on electronics, not only on the affected components but also on the other components connected to the same power supply. The increase in I_L also can be seen in the subthreshold characteristics of the irradiated MOSFETs (Figs. 1–3).

The net threshold voltage shift (ΔV_{TH}) and contribution to that shift due to the interface traps (ΔV_{Nit}) and the trapped oxide charge (ΔV_{Not}) was calculated from the subthreshold measurements using the technique proposed by McWhorter and Winokur [31] and a representative plot for 48 MeV Li^{3+} ions irradiated MOSFET is shown in Fig. 5. The ΔN_{ot} is calculated using the standard expression $\Delta N_{ot}=\Delta V_{ot}\, C_{ox}/q$ and the ΔN_{it} is calculated by the expression $\Delta N_{it}=\Delta V_{it} C_{ox}/q$, where $q=1.6 \times 10^{-19}$ C, ΔN_{ot} is the effective oxide-trapped charge density in cm^{-2} as projected to the interface and C_{ox} is the oxide capacitance per unit area. The variation of the ΔN_{it} as a function of dose is shown in Fig. 6 for all the three types of radiation. It can be seen from these figures that ΔN_{it} is increased from 2.88×10^9 to 1.33×10^{12} cm^{-2} for 48 MeV Li^{3+} ions and 3.17×10^9 to 1.01×10^{12} cm^{-2} for 100 MeV F^{8+} ion irradiated MOSFETs up to a total dose of 100 Mrad. Further, ΔN_{it} is found to increase from 5.67×10^{10} to 1.25×10^{12} cm^{-2} for 10 Mrad of gamma radiations and later not much changes. The variation of the ΔN_{ot} as a function of dose are shown in Fig. 7 for ion and gamma irradiated devices. For 48 MeV Li^{3+} ion irradiated devices, the ΔN_{ot} is found to increase from 4.32×10^{10} to 2.25×10^{12} cm^{-2} and for 100 MeV F^{8+} ion irradiated devices, the ΔN_{ot} increased from 2.59×10^{10} to 1.72×10^{12} cm^{-2} for a total dose of 100 Mrad. In case of Co-60 gamma irradiation, ΔN_{ot} is increased from 2.29×10^{11} to 2.06×10^{12} cm^{-2} for a total dose of 10 Mrad and beyond it almost saturates. From Figs. 6 and 7 it is clear that ΔN_{ot} is higher than ΔN_{it} and because of this the V_{TH} shifts towards negative voltage side.

The mobility (μ) of electrons in the channel was estimated from transconductance (g_m) measurements. The representative plot for the behaviour of g_m for 48 MeV Li^{3+} ion irradiated MOSFETs are shown in Fig. 8. It can be seen from this figure that there is a significant decrease in g_m after ion irradiation. From

Fig. 8, the maximum or peak transconductance (g_{mpeak}) was noted for different doses and the variation of $g_{m\ peak}$ for 48 MeV Li^{3+}, 100 MeV F^{8+} ion and Co-60 gamma irradiated MOSFETs are shown in Fig. 9. For 48 MeV Li^{3+} ion irradiated MOSFETs the $g_{m\ peak}$ decreases from 5.96×10^{-4} to 1.03×10^{-4} S and for 100 MeV F^{8+} ion, it decreases from 5.80×10^{-4} to 1.2×10^{-4} S for a total dose of 100 Mrad. In the case of Co-60 gamma irradiated devices g_{mpeak} is found to decrease from 6.04×10^{-4} to 9.45×10^{-5} S for 10 Mrad. The μ of carriers in the channel was estimated from the g_{mpeak} (called field effect mobility, μ_{FE}) and Fig. 10 illustrates the results obtained for variation in normalized μ_{FE} for ion and gamma irradiated MOSFETs. From this figure, it can be seen that the μ_{FE} of the irradiated devices decreases with increase in dose and about 80% degradation was found after a total dose of 100 Mrad.

It can also be observed from Fig. 10 that for ion and gamma irradiated devices the mobility (μ) of carriers in the channel decreases with increase in the dose. The reduction in the μ of carriers in channel is mainly due to radiation-induced trapped charge and these act as Coulomb scattering centers [19]. Earlier, the μ degradation was attributed mainly due to the interface-trapped charge (N_{it}), the effect of oxide-trapped charges (N_{ot}) which lie further away from the inversion layer was considered to be negligible. Following the μ model of Sun and Plummer [19], the μ was related to the build up of interface-trapped charge, ΔN_{it} through the equation;

$$\mu=\mu_o/(1+\alpha\,\Delta N_{it}) \quad (1)$$

where μ_o is the pre-irradiation value of μ and α is a constant. This model was fairly successful in explaining the observed data of decrease in μ. In recent years, it is recognized that the ΔN_{ot} can also play a role in degrading the μ at liquid nitrogen temperatures. Stojadinovic et al. [32], Zupac et al. [33] and Dimitrijev et al. [34,35] have suggested the use of a modified version of Eq. (1) as:

$$\mu=\mu_o/(1+\alpha_{it}\,\Delta N_{it}+\alpha_{ot}\,\Delta N_{ot}) \quad (2)$$

where ΔN_{ot} is the radiation induced oxide trapped charge. The experimental results of Zupac et al. [33] on irradiated and annealed MOSFETs convincingly demonstrated that taking ΔN_{it} only into account does not adequately fit the data and ΔN_{ot} also has to be considered at low temperature measurements. There has been some discrepancy in the reported values of α_{it} and α_{ot}. The different methods of fabrication of devices may be the cause of this discrepancy. From the detailed analysis of experimental data of MacLean and Boesch [18], a good fit was obtained with $\alpha_{it}=3.1\times10^{-12}\,cm^2$ and $\alpha_{ot}=7.0\times10^{-15}\,cm^2$. On the other hand Zupac et al. [33,36] studies gave $\alpha_{it}=3.9\times10^{-12}\,cm^2$ and $\alpha_{ot}=7.0\times10^{-13}\,cm^2$ as good fit values for Eq. (2). In both the cases the α_{ot} value is quite small compared to α_{it} value, although in the case of MacLean and Boesch [18] studies the value is significantly smaller. The smaller value of α_{ot} reflects the fact that the ΔN_{ot}, further away from the interface, is less effective in scattering inversion layer carriers than ΔN_{it}. The best fit values of α_{it} and α_{ot} for the experimental data on mobility for 48 MeV Li^{3+},

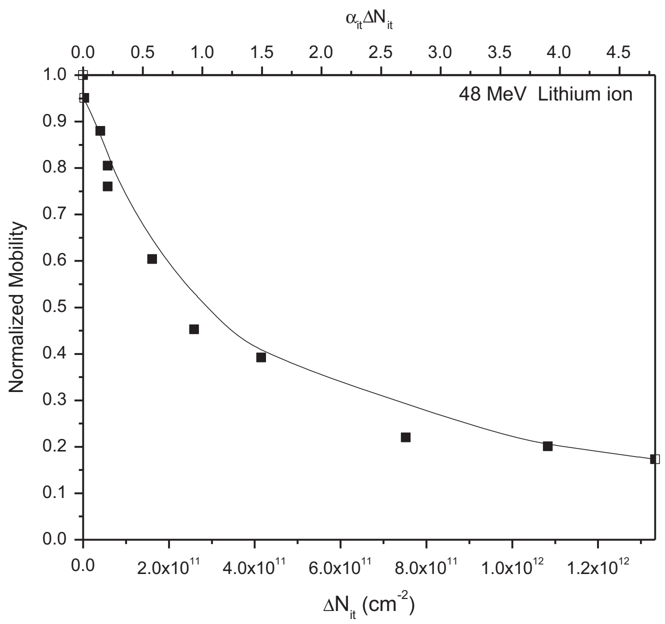

Fig. 11. Normalized mobility degradation during 48 MeV Li^{3+} ion irradiation as a function of interface trapped charge. The top axis shows the values of the dimensionless product of $\alpha_{it}\,\Delta N_{it}$.

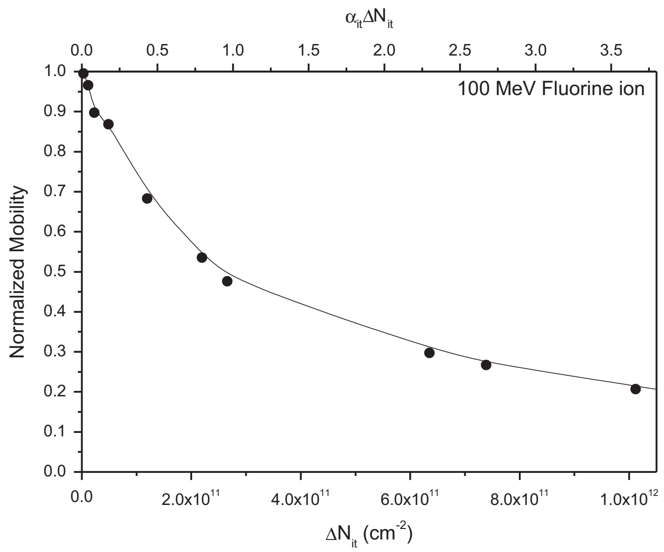

Fig. 12. Normalized mobility degradation during 100 MeV F^{8+} ion irradiation as a function of interface trapped charge. The top axis shows the values of the dimensionless product of $\alpha_{it}\,\Delta N_{it}$.

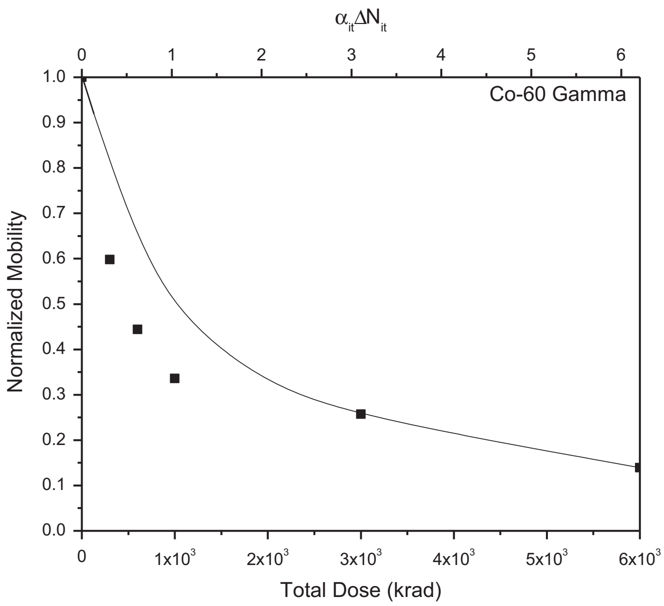

Fig. 13. Normalized mobility degradation during Co-60 gamma irradiation as a function of interface trapped charge. The top axis shows the values of the dimensionless product of $\alpha_{it}\,\Delta N_{it}$.

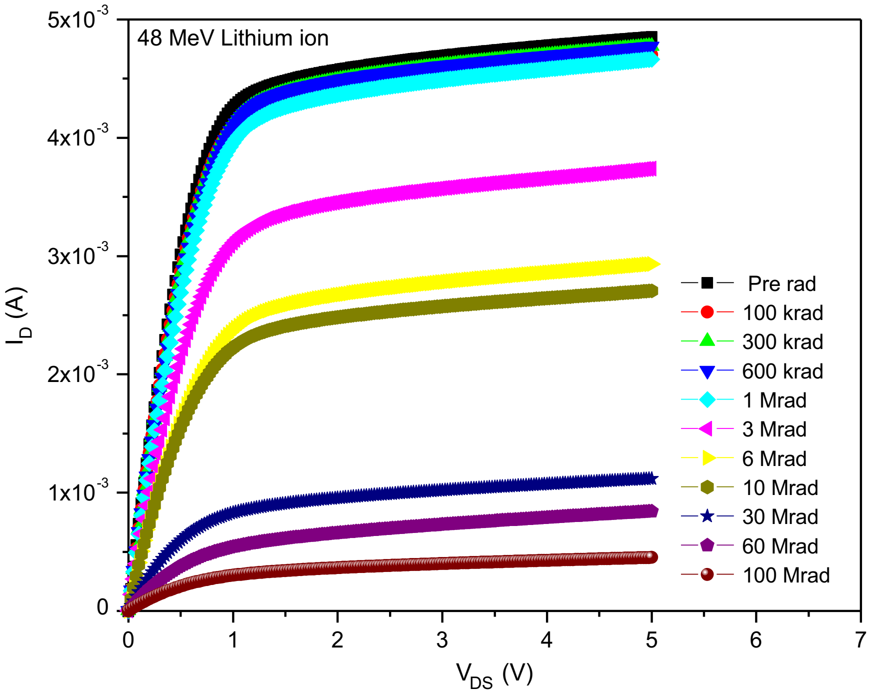

Fig. 14. $I_D - V_{DS}$ characteristics: before and after 48 MeV lithium ion irradiation (at V_{GS}=0.1 V).

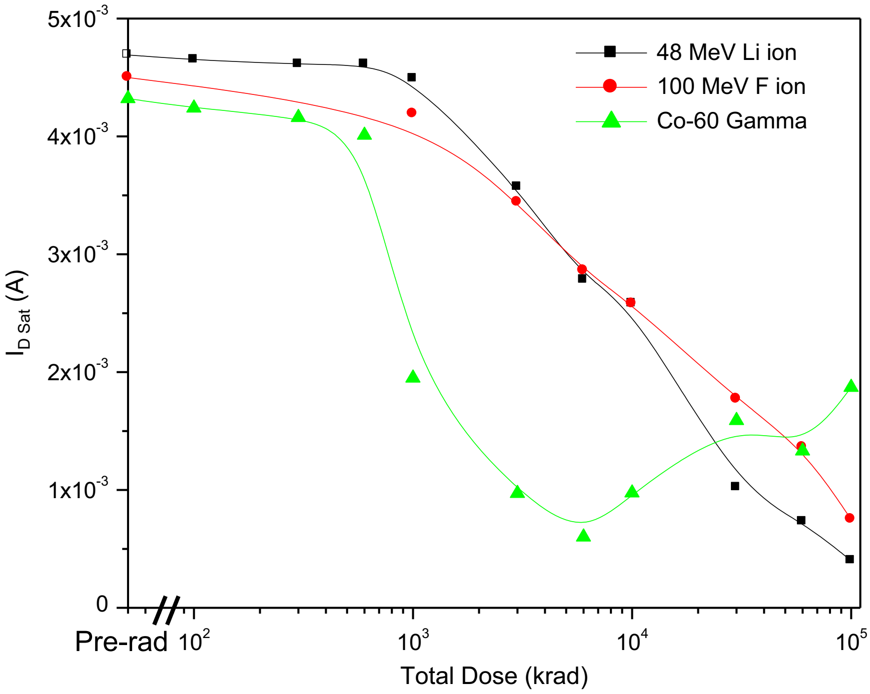

Fig. 15. Variation in the drain saturation current (I_{DSat}) for Co-60 gamma, Li and F ion irradiated MOSFETS (at V_{GS}=0.1 V).

100 MeV F^{8+} ion and Co-60 gamma irradiated MOSFETs are presented in Table 2. It can be seen from Table 2 that the value of α_{it} is $\approx 10^{-12}$ cm^2 and the value of α_{ot} is not consistent and it is even negative besides being very small compared to α_{it} values. Similar results have seen by Dimitrijev et al. [34,35]. Hence, as inferred by the earlier investigations, the effect of ΔN_{ot} on mobility is negligible. The values of α_{it} obtained in the present work are consistent and agree with the results reported by earlier investigation. So normalized mobility of carriers in the channel were correlated with ΔN_{it} and it is found that the decrease in mobility is indeed significant after irradiation. To facilitate better illustration, the results obtained for the normalized mobility degradation as a function of ΔN_{it} (circles) and the values of dimensionless product $\alpha_{it}\Delta N_{it}$ (solid line) are shown graphically in Figs. 11–13 respectively for 48 MeV Li^{3+} ions, 100 MeV F^{8+} ion and Co-60 gamma irradiated MOS devices. It can be seen that the mobility decreases around 80% after total dose of 100 Mrad.

The I_{DSat} of irradiated MOSFET was extracted from V_{GS} to I_D characteristics. Drain current (I_D) of the MOSFET becomes saturated after a certain gate voltage (V_{GS}) and can be referred as I_{DSat}. The representative plot of I_D-V_{DS} for 48 MeV Li^{3+} ions irradiated MOSFET is shown in Fig. 14 and the effects of ionizing radiation on I_{DSat} of the MOSFETs were studied for various doses. The high-energy radiation may produce defects and their complexes in inbuilt channel and produce carrier removal effect and this in turn increases the resistance of the channel. In addition to this Coulomb scattering between the free carriers in the channel and radiation induced trapped charge decreases the I_{DSat}. The variation in the I_{DSat} of the ions and gamma irradiated MOSFETs is shown graphically in Fig. 15 and it can be seen that the I_{DSat} decreases drastically for all the different radiations.

4. Summary

The transfer and output characteristics of N-channel MOSFETs were studied after exposure to 48 MeV Li^{3+} ions, 100 MeV F^{8+} ions and Co-60 gamma radiations in the dose range 100 krad–100 Mrad. The threshold voltage (V_{TH}) of the irradiated MOSFETs decreases significantly for all the different radiations. The interface trapped charge (ΔN_{it}) and oxide trapped charge (ΔN_{ot}) was calculated from the subthreshold measurements and ΔN_{ot} was found higher compared to the ΔN_{it} after irradiation. The peak transconductance (g_{mpeak}) was extracted from the I_D versus V_{GS} data taken at V_{DS}=100 mV and mobility of carriers (μ) in channel was estimated from the g_{mpeak}. Around 80% degradation was found in transconductance (g_m) after receiving a total dose of 100 Mrad. We correlated μ with the ΔN_{it} and effect of ΔN_{ot} is negligible for degrading the μ. It is observed that the values of α_{it} is $\approx 10^{-12}$ and α_{ot} is very small compared to α_{it} values. The maximum degradation was observed for the devices irradiated with Co-60 gamma radiation when compared to ions since gamma radiation can create more trapped charge in SiO_2.

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