THE COMPARISON OF GAMMA-RADIATION AND ELECTRICAL STRESS INFLUENCES ON OXIDE AND INTERFACE DEFECTS IN POWER VDMOSFET

by

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The behaviour of oxide and interface defects in n-channel power vertical double-diffused metal-oxide-semiconductor field-effect transistors, firstly degraded by the gamma-irradiation and electric field and subsequently recovered and annealed, is presented. By analyzing the transfer characteristic shifts, the changes of threshold voltage and underlying changes of gate oxide and interface trap densities during the stress (recovery, annealing) of investigated devices, it is shown that these two types of stress influence differently on the gate oxide and the SiO_2-Si interface.

Key words: VDMOSFET, gamma radiation, electrical stress, threshold voltage, gate oxide charge, interface traps

INTRODUCTION

The oxide and oxide-semiconductor interface in metal-oxide-semiconductor (MOS) system of various silicon-based electronic devices have been in the focus of investigation more than forty years [1]. This is because the existing oxide and interface electron states allow the external electric field applied (or gamma-irradiation in special device applications) to change the features of SiO_2 and SiO_2-Si interface influencing negatively on the operation efficiency of the devices. Numerous methods were used in the study of SiO_2 and SiO_2-Si interface nature and their characterization [1-4]. Anyway, it is possible to roughly divide them into the methods implemented on the MOS capacitor structure and the methods that are implemented on the complex MOS electron devices. Mostly, these techniques are electrical techniques, generally giving the results related to the energy distribution of defects in the oxide and at the interface and allowing to predict the defect nature and to establish a model of their behaviour. But, the technique based on the electron-spin resonance (ESR), that is also used [5], gives a picture of the structure of these defects allowing their modelling [6]. Thus, the silicon dangling bond defects detected on the SiO_2-Si(111) interface are characterized as P_b centers. The P_b center is designated as the Si_3 Si amphoteric defect that creates two levels with the distance of about 0.55 eV (0.3 and 0.85 eV above the valence band) in the silicon bandgap gap. These levels serve as correlation energy with broken bonds at SiO_2-Si interface. The ESR investigations of the SiO_2-Si(100) interface reveal two paramagnetic centers P_{b0} and P_{b1}. It is found that the P_{b0} center is identical to the P_b center at (111) Si surface, while the nature of the P_{b1} center is yet unclear. In the opinion of some authors [7], the P_{b1} center is a center of the Si_2O Si type. The second assumption is that the P_{b1} center is also the Si_3 Si defect without the oxygen as a structural part, but unlike (111) the Si surface, with another broken bond orientation related to (100) the Si surface. Also, the silicon dangling bond defects detected in SiO_2 [8] are characterized as E' centers of different varieties, and designated as the Si defects.

It must be noted that all so far published results regarding the SiO_2 and SiO_2-Si interface are of importance since they contribute to the process of determining the nature of the oxide and the interface defects. But, the fact is that some of them can bring confusion especially in the case of research related to complex electronic devices. Namely, in these cases, the information about the state of the oxide and interface has been obtained indirectly, on the base of the behavior of device electrical characteristics and parameters during

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the stress and the subsequent annealing. Because of that, in order to avoid the inconsistency in the interpretations and conclusions about the nature of the defects, any analysis of results must be careful and comprehensive; a special attention should be paid to the type of stress (the electric field stressing or the gamma-irradiation) and the annealing (the spontaneous recovery or the annealing at elevated temperature), as well as to the conditions under which they are carried (the environment temperature; the value and the character of the applied field in the case of the electrical stressing; the dose rate, the applied or not applied polarization in the case of gamma irradiation). In any case, one of the important factors is the stress/annealing duration, as well.

Because of their superior performances and reasonable production price, power metal-oxide-semiconductor field-effect transistors (MOSFET) are attractive devices for many space and terrestrial applications, in which they are exposed to the negative influence of gamma-radiation and high electric field [9]. For this reason they were the subject of numerous studies [10-16]. Recently, the studies of numerical simulation of high electrical field and radiation effects on various semiconductor devices [17-22], including the power MOSFET [19-22], were performed. The results of these investigations could significantly contribute to the process of predicting the device behavior upon appropriate conditions.

The results of earlier studies of MOS device instabilities [10, 11] have shown that the effects of the gamma radiation and the high electric field stress are very similar. The same conclusions were also obtained in the later investigations related to the power vertical double-diffused metal-oxide-semiconductor (VDMOS) transistors [12]. Based on these observations, the idea of electrical stress utilized as a method for accelerated testing, as well as for the radiation hardening of devices to be applied in the radiation environment, has been placed in the literature [13]. However, it should be noted that our earlier results [14] have proved that the radiation hardening by applying electrical stress is inapplicable. Also, the subsequent investigations on power VDMOS transistors [15] have indicated only the partial similarities between these effects (a similar behaviour of interface defects, and a different behaviour of oxide defects). This conclusion has been supported by the observed behaviour of channel carrier mobility [16].

In this paper we have performed a detailed analysis of high electric field and gamma-radiation stress, as well as the annealing effects in power vertical double-diffused metal-oxide-semiconductor field-effect transistors (VDMOSFET), with the aim to present the diversity of macro effects (the changes of their electrical parameters) due to the different treatment conditions, and also to try to explain them in the light of the electrochemical processes in SiO_2 and at SiO_2-Si interface.

THE EXPERIMENT

The experimental samples in this study were commercial n-channel power VDMOSFET built in a standard Si-gate technology (a 120 nm gate oxide grown in dry oxygen) with the hexagonal cell geometry, manufactured by the Ei-Semiconductors (Niš, Serbia). The transistors were divided into two groups: the first group has been stressed by the high electric field, and the second one by the gamma radiation. All stressed transistors have been spontaneously recovered at room temperature, and after that annealed at 125 °C. In order to detect the device's response to the stress, recovery and annealing, an intermediate electrical characterization was done by measuring the transfer characteristics in the saturation region (above-threshold and sub-threshold). It should be noted that the transistor transfer characteristics were recorded using the computer-controlled KEITHLEY 237 source measure unit. To analyse the underlying mechanisms, the threshold voltage V_T and carrier mobility μ were determined from the measured above-threshold transfer characteristics as the intersections between the V_G-axis and the extrapolated linear region of $(I_D)^{1/2}$ V_G curves and the slopes of these lines, respectively.

The electrical stressing was performed by applying the positive DC bias (+88 V, +90 V, and +92 V) to the gate electrode (the drain and the source were grounded). For each value of the applied gate bias, two sets of samples have been formed: one set of samples was electrically stressed up to the moment when transfer characteristics have manifested abrupt change of shift direction and slope, while the stressing of other samples has continued for total duration time of 120 min. The irradiation was performed using the ^{60}Co source (dose rate 0.13 Gy/s), at the Metrology Laboratory of the Vinča Institute of Nuclear Sciences, Belgrade, Serbia. During the radiation exposure, the 10 V positive DC gate bias was applied to all devices, with the drain and the source terminals grounded. Two sets of devices were irradiated, up to the total doses of 750 Gy and 200 Gy (with a total duration time of approximately 95 min and 25 min, respectively). All experiments were performed on groups of selected samples with close initial values of electrical parameters, which have provided the reproducibility of the obtained results. Also, it should be noted that the mean values of measured relevant electrical parameters (the threshold voltage and the carrier mobility) have been used for analysis conducted.

RESULTS AND DISCUSSION

The results obtained in this study indicate the existence of some similarities between the gamma radiation and the electrical stress effects in power VDMOS transistors, that are observed through the behavior of transfer characteristics during the stress and subsequent recovery and annealing. Generally, during the stress, the characteristics are shifted towards smaller V_G values up to the moment when they abruptly changed the direction to the initial positions with the continuously slope reduced. But, the fundamental difference between the investigated stress effects is in the time of the mentioned transfer characteristics shift and their returning to the initial positions.

In the case of 120 min electrical stress, a change of transfer characteristics behavior was observed very soon after the start of stress, firstly in the transistors subjected to the polarization of +92 V (10 min after stressing start), and then in those stressed by +90 V and +88 V, with a time distance of ten minutes. Upon the gamma irradiation, an abrupt change in direction of transfer characteristics shift appears only more then 100 minutes after the start of stress, the time which is comparable with the total duration time of electrical stress. Because of that, the radiation stress has stopped after 100 min in these experiments. In this way, the two parameters for electrical and radiation stress comparison were provided – the total stress time as well as the time to characteristics behaviour change.

In the case of 120 min electrical stresses, the transfer characteristics after they changed their direction have shifted to the higher V_G values, exceeding the initial positions. The distances between the last and the initial transfer characteristics have increased with the increase of the stress voltage. Also, the slope of transfer characteristics has decreased, mostly in the case of +92 V, and then in the case of +90 V and +88 V.

During the spontaneous recovery/annealing phase, the transfer characteristics of electrically stressed devices have again shifted to initial positions passing through them, and slowly increasing the slope. The characteristics of devices stressed by +88 V have appeared the initial positions at first (after 75 hours of spontaneous recovery), and than the characteristics of devices stressed by +90 V (at the start of annealing phase) and +92 V (after 1 hour of annealing).

Against the electrical stress, the transfer characteristics have just negatively shifted during the 95 min gamma-irradiation, but to a significantly higher V_G values, while their positive shift to initial positions and exceeding them is detected during the spontaneous recovery and annealing.

The described behavior of transfer characteristics is reflected in the behavior of the threshold voltage V_T. The changes in threshold voltage of power VDMOS transistors during electrical and gamma radiation stresses are presented in figs. 1-3. The threshold voltage behaviour of devices stressed with approximately the same stress duration time is shown in fig. 1. As can be seen, the threshold voltage firstly decreases in both cases of stressing. However, during the 120 min electrical stress, after reaching its minimum, the

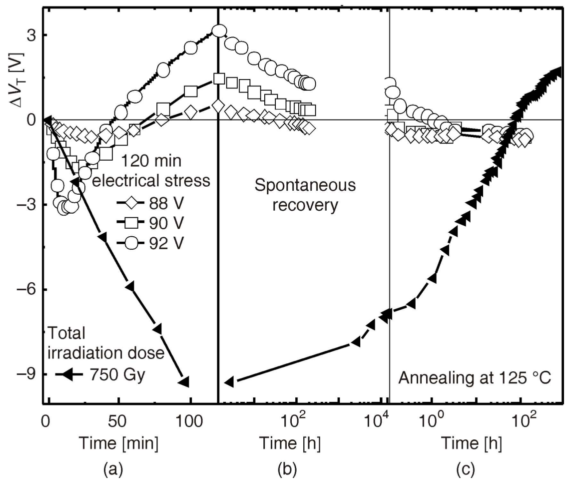

Figure 1. The threshold voltage behaviour during the electrical (120 min) and the radiation (95 min) stresses (a), spontaneous recovery (b), and annealing (c) of stressed power VDMOSFET

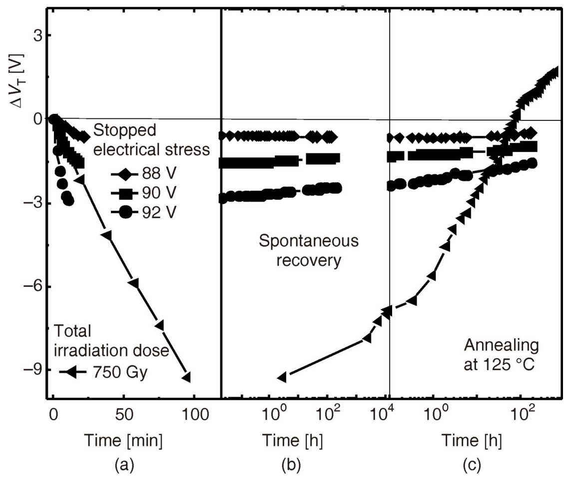

Figure 2. The threshold voltage behaviour during the stopped electrical (suspended before the turn around) and radiation (95 min) stresses (a), spontaneous recovery (b), and annealing (c) of stressed power VDMOSFET

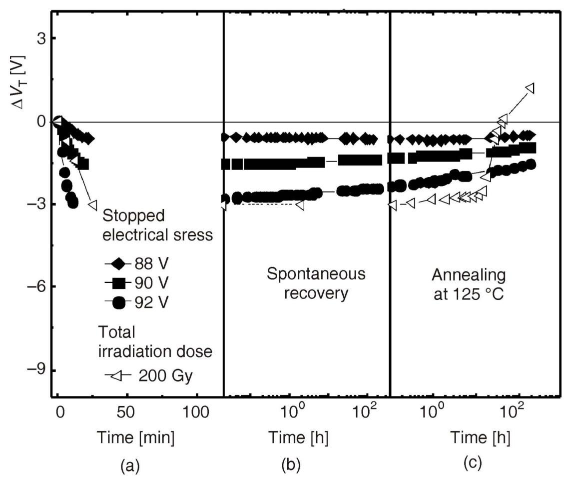

Figure 3. The threshold voltage behaviour during the stopped electrical (suspended before the turn around) and the radiation (25 min) stresses (a), spontaneous recovery (b), and annealing (c) of stressed power VDMOSFET

threshold voltage begins to increase (the turn-around effect) up to the initial values and even exceeds them (the rebound effect). The turn around firstly appears in the case of +92 V polarization, and then in the case of +90 V and +88 V (following the changes of the transfer characteristic shift direction). The rebound is most pronounced for the +92 V and with the decreasing gate polarization it becomes less pronounced. Also, the negative threshold voltage shift in the moment of turn-around achieving is the largest (about 3 V) for the polarization of +92 V, and minimal (about 0.5 V) for the polarization of +88 V. As for gamma irradiation, the turn around has not been registered during the 95 min stress. However, the overall threshold voltage shift in period to the turn-around is much higher (about 10 V) than in the case of electrical stress. During the spontaneous recovery and the annealing phase, the threshold voltage shift of irradiated transistors was opposite to the threshold voltage shift of 120 min electrically stressed transistors. Namely, the threshold voltage of electrically stressed devices continuously decreases during both the recovery and the annealing (with the highest rate for +92 V), and after the 100 hours annealing, it reaches almost the same value (slightly less than initial). On the other hand, the threshold voltage of the irradiated transistors increases during the recovery and the annealing, with the higher increase rate during the annealing. After the 100 hours annealing, the rebound-effect is evident.

Having in mind that the threshold voltage turn-around has not been caused by the performed irradiation, it was of interest to compare these radiation effects with the effects of electrical stress that also has not been caused by the turn-around (fig. 2). As can be seen, after the decrease during the stopped electrical stress, for all applied polarizations, the threshold voltage shifts in positive direction (oppositely to 120 min electrically stressed samples) during both the recovery and the annealing, but so much slowly than in the case of the irradiated samples (caused by a much smaller negative shift during the stress), remaining all the time on the values less than initial ones.

Generally, the similarity of the threshold voltage behaviour during the electrical and gamma radiation stresses have been noticed, but only qualitatively, in the period before the turn-around.

However, not only qualitative, but quantitative differences between gamma radiation and electrical stress effects in VDMOS transistors can be seen in figs. 1 and 2, respectively. As the threshold voltage behaviour is caused by the defects formed in the gate oxide and at the SiO_2-Si interface during the stress/annealing [23-25], the observed differences point out to the conclusion that the electrical stress and the irradiation probably initiate different mechanisms of defects formation in the gate oxide and at the interface. This can be confirmed by fig. 2, in which the comparing parameter is the level of the device strain. But, regardless of the fact that all devices have been stressed up to the turn-around, the threshold voltage beaviour of electrically stressed devices during the annealing (the threshold voltage shif is much smaller and the rebound is not found) differs from the threshold voltage beaviour of irradiated devices.

The observed differences during the recovery and the annealing are the consequences of different irradiation and electrical stress influence on threshold voltage, the shift of which is so much larger in the case of irradiation. From this reason, the following question has imposed here: what would be the threshold voltage behaviour during the recovery/annealing if during the irradiation and the electrical stress it reaches the same values? In order to get the answer, an additional irradiation experiment was done. The devices were irradiated to the total dose of 200 Gy (25 min irradiation time), which resulted in the threshold voltage shift of approximately 3 V (as in the case of the +92 V electrical stress). After stressing, the devices have been spontaneously recovered, and then annealed at elevated temperature in the same way as in the previous experiments. With regard to a small threshold voltage shift caused by the irradiation, similar effects of annealing both electrically stressed and irradiated devices are expected (small changes of threshold voltage to values slightly lower than the initial, without expressing the rebound effect). But, as can be seen in fig. 3, the annealing effects of irradiated devices are not as expected.

Namely, the threshold voltage rebound is also observed during annealing of 25 min irradiated devices (fig. 4). In addition, the fact is that after 10 hours of annealing, for both cases of irradiation, the annealing rates are almost the same. This definitely supports previous conclusion on the diversity of electrical stress and gamma irradiation effects in power VDMOS transistors.

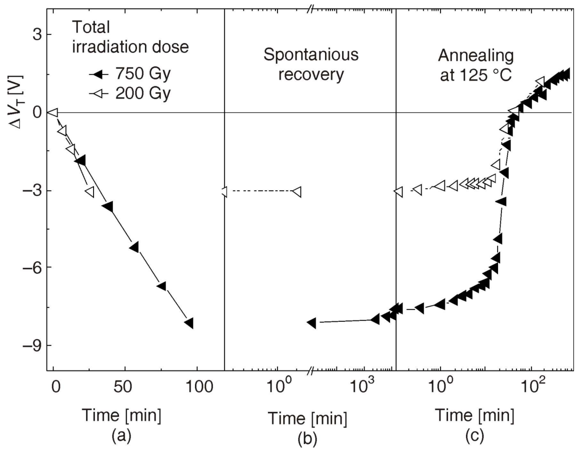

Figure 4. The threshold voltage behaviour during the radiation (95 min and 25 min) stresses (a), spontaneous recovery (b), and annealing (c) of stressed power VDMOSFET

For described threshold voltage behaviour the changes of gate oxide charge ΔN_{ot} and interface states ΔN_{it} densities during the stress and subsequent spontaneous recovery and annealing phase are responsible (figs. 5-10).

The changes of ΔN_{ot} and ΔN_{it} were determined by using the sub-threshold mid-gap (SMG) technique [26], except in the case of highly deformed transfer characteristics when this method is proved inapplicable. Based on these changes of ΔN_{ot} and ΔN_{it}, it can be concluded that the radiation primarily affects the gate oxide of devices, while the electrical stress primarily affects the SiO_2-Si interface. Namely, during the 95 min irradiation the ΔN_{ot} exceeds double value achieved during the electrical stress (after about thirty minutes of electrical stress, the ΔN_{ot} tends to saturation, fig. 5). During the spontaneous recovery of irra-

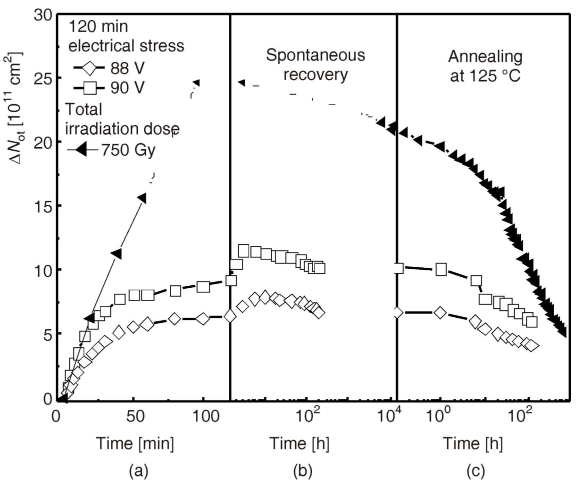

Figure 5. The changes of ΔN_{ot} during the electrical (120 min) and radiation (95 min) stresses (a), spontaneous recovery (b), and annealing (c) of stressed power VDMOSFET

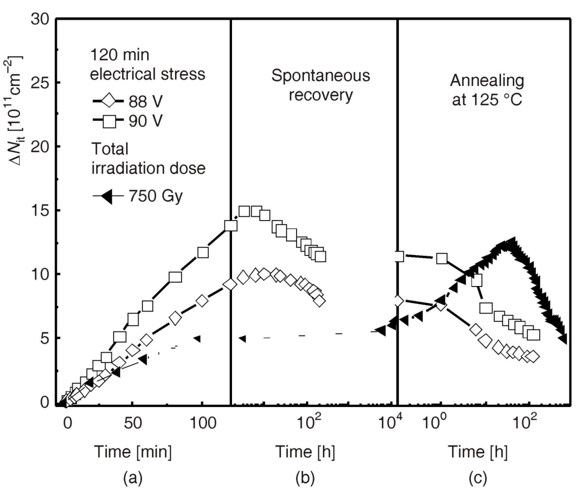

Figure 6. The changes of ΔN_{it} during the electrical (120 min) and radiation (95 min) stresses (a), spontaneous recovery (b), and annealing (c) of stressed power VDMOSFET

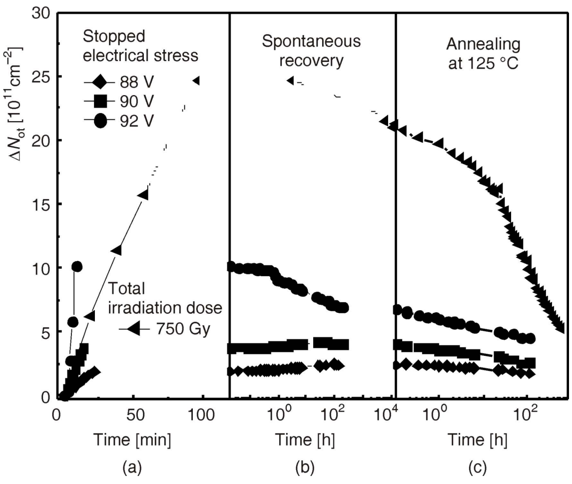

Figure 7. The changes of ΔN_{ot} during the stopped electrical (suspended before the turn around) and radiation (95 min) stresses (a), spontaneous recovery (b), and annealing (c) of stressed power VDMOSFET

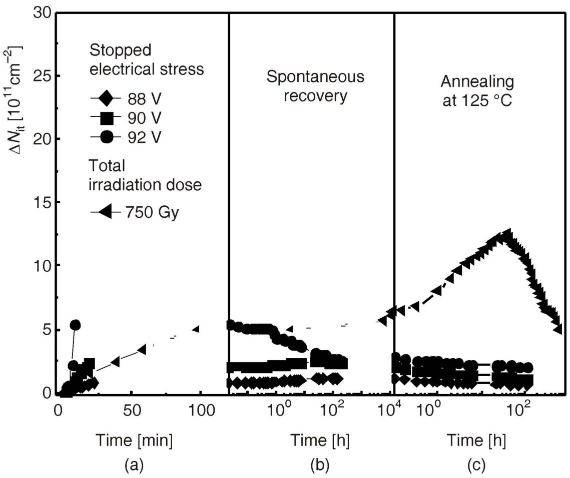

Figure 8. The changes of ΔN_{it} during the stopped electrical (suspended before the turn around) and radiation (95 min) stresses (a), spontaneous recovery (b), and annealing (c) of stressed power VDMOSFET

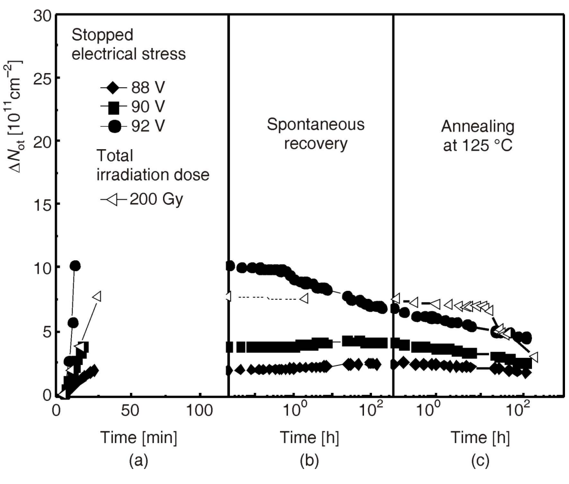

Figure 9. The changes of ΔN_{ot} during the stopped electrical (suspended before the turn around) and radiation (25 min) stresses (a), spontaneous recovery (b), and annealing (c) of stressed power VDMOSFET

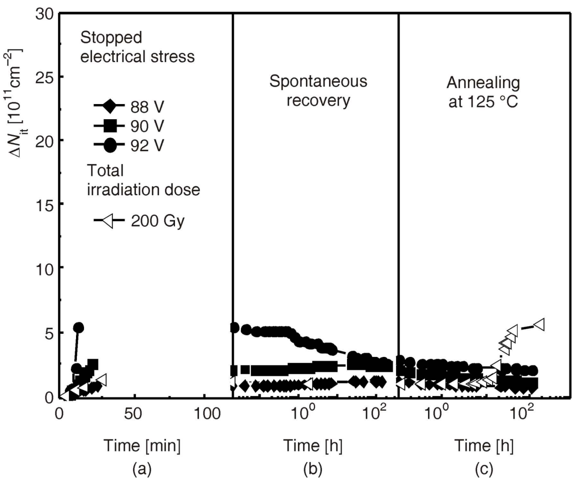

Figure 10. Changes of ΔN_{it} during the stopped electrical (suspended before turn around) and radiation (25 min) stresses (a), spontaneous recovery (b), and annealing (c) of stressed power VDMOSFET

diated transistors, the ΔN_{ot} slowly decreases, and the decrease also continues during the annealing, but much faster. In the case of electrically stressed transistors, during the first hour of spontaneous recovery, after a small increase, the ΔN_{ot} slightly decreases and continues during the annealing.

On the other hand, during the 120 min electrical stress, the ΔN_{it} continually increases significantly overcoming the values achieved during the irradiation (fig. 6) (the changes of N_{it} are larger in the case of higher gate polarization).

During the spontaneous recovery and annealing of electrically stressed transistors, the N_{it} behaves similarly to N_{ot}; after the stress, the N_{it} firstly increases, and then decreases (it decreases several times faster than the N_{ot}), which is continued during the annealing phase. During the spontaneous recovery of irradiated transistors, the N_{it} slightly increases appearing saturation. During the annealing phase, the N_{it} rapidly increases, reaching a maximum value after 50 hours of annealing, after which also rapidly decreases (a latent build-up of the N_{it}), the effect of which is also registered in [27]. But, although the irradiated devices were of the same type as in this study, it should be noted that the behaviour of N_{ot} and N_{it} during the annealing has been observed as different. It was probably caused by the different gate oxide thickness of used devices, as well as by different experimental conditions (the gate voltage polarization, the radiation dose, the annealing temperature).

The diversity between the irradiation and electrical stress effects is evident from figs. 7 and 8, respectively. On the basis of the N_{ot} (fig. 7) and N_{it} (fig. 8) values during the stress, it can be seen that the stopped electrical stress, like the irradiation, has stronger influence on the gate oxide than on the SiO_2-Si interface. However, regardless of this fact, during the spontaneous recovery and annealing, the N_{ot} and N_{it} in stopped electrical stressed devices behave differently in comparison with them in irradiated devices.

Even in the case of 25 min irradiation, when relatively low densities of ΔN_{ot} and ΔN_{it} are formed, their behaviour is different in comparison with the case of stopped electrical stress, especially the behaviour of ΔN_{it} during the annealing phase (figs. 9 and 10). In other words, relatively low density of ΔN_{it} formed during the irradiation, results in a latent build-up during annealing.

The above mentioned findings on differences between the electrical and the irradiation stresses can be supported by the comparison of electrical stress with stopped electrical stress, as well as the 95 min irradiation with the 25 min irradiation, where annealing is followed by the latent buildup of N_{it} (figs. 7-10). It is evident that the changes of N_{ot} (as well as of N_{it}) have the same trend for the same type of stressing.

THE RESPONSIBLE MECHANISMS

Numerous generalized models that explain the mechanisms responsible for the N_{ot} and N_{it} changes during the gamma and electrical stress, as well as during the annealing of stressed devices, are published in the literature [1]. All these models are based on the fact that the precursors (formed during the device fabrication) of charge traps exist in the gate oxide and at SiO_2-Si interfaces. In the case of irradiation, a high energy (MeV magnitude) gamma-radiation from ^{60}Co source breaks not only the weak covalent bonds between the Si atoms and impurity H atoms (Si_o – H), and between the Si atoms and impurity OH hydroxyl group (Si_o – OH), but also the regular bonds between the oxide atoms Si_o – O – Si_o [28]

$$Si_o \quad O \quad Si_o \xrightarrow{hv} Si_o \quad Si_o \quad O \quad e \quad h$$

One part of the formed $e^- - h^+$ pairs can recombine re-establishing broken atomic bonds [1]. Many electrons that escaped the recombination can also break covalent atomic bonds in the oxide forming new $e^- - h^+$ pairs (it is shown that this process is more dominant than breaking the bonds by radiation). The holes move through oxide to the SiO_2-Si interface (this moving is supported by the local electric field, too). The fact is that much more precursors of E' centers are located near the SiO_2-Si interface, which in reaction to the received holes transforms into E' centres, finally contributing to the increase of N_{ot}. In the case of electrical stress, the values of N_{ot} are rather less than in the case of irradiation (fig. 5). Beside the holes, a drift of hydrogen ions from the oxide to SiO_2-Si interface due to the permanent effects of the electric field can also contribute to the increase of N_{ot}. But, due to the rapid transport through the oxide to SiO_2-Si interface, the holes and hydrogen ions are generally not trapped in the oxide. Through the series of electrochemical reactions [24], most of the holes and hydrogen ions are trapped near the SiO_2-Si interface, contributing to the increase of N_{ot}. For smaller final values of N_{ot}, the Fowler/Nordhaim tunnelling of electrons is also responsible. Namely, the electrons tunnelling from the substrate into the oxide can compensate/neutralize certain number of formed N_{ot}. It should be noted that our findings on the values of N_{ot}, formed during the electrical stress, are in agreement with the results of similar studies [29], in which the effects of the high electrical field (>7 MV/cm) were compared with the ionizing radiation effects. Based on the ESR results it is confirmed that, in the case of electrical stress, the E' centers are not entirely responsible for the N_{ot} formation, but very possibly some other defects, as well. This assertion can be implemented in our experimental results. Namely, it is known that during the stress up to the turn around, the negative shift of the threshold voltage is caused by the increase of N_{ot}. So it would be understandable that the same threshold voltage shift of 3 V (during the 92 V electrical stress and during the 25 min gamma irradiation) is a consequence of the same N_{ot} values. However, the different values of N_{ot} are obtained (figs. 3 and 9).

The increase of P_b centers density during these types of stresses is also caused by the holes and the hydrogen species, primarily by the H_2 [23, 24]. Namely, the H_2 molecules from the adjacent structures diffusing through the oxide react with the positive charged oxide traps, and the result of that is the neutralization of positive oxide traps followed by the H^+ ions releasing [30] (*i. e.*, the reduction in slope of electrical stress time dependence of ΔN_{ot}, fig. 5)

$$\mathrm{Si_o} \quad \mathrm{H_2} \qquad \mathrm{Si_o} \quad \mathrm{H^+}$$

The released H^+ ions drift to the SiO_2-Si interface along with the holes. At the interface, the H^+ ions trap the electrons from the substrate and transform into high reactive hydrogen atoms H^0. In reaction with the precursors of P_b centers, the H^0 atoms can form the H_2 (or H_2O) molecules, creating the P_b centers [31, 32]

$$\mathrm{Si_s} \quad \mathrm{H(OH)} \quad \mathrm{H^0} \qquad \mathrm{Si_s} \quad \mathrm{H_2\,(H_2O)}$$

The N_{it} formed in these electrochemical reactions is much higher in the case of the 120 min electrical stress than in the case of the 95 min gamma irradiation (fig. 6). It is because the holes from the oxide traps can directly tunnel at the interface defect levels [11], increasing the N_{it}. On the other hand, during the irradiation all available H^+ ions do not participate in the formation of P_b centers (because of the low applied field during the irradiation, a relatively small number of H^+ ions reaches the SiO_2-Si interface causing much less P_b centers being formed). In the case of irradiation, the N_{it} reaches its maximum value, comparable with the maximum value during the electrical stress, only during the annealing phase (a latent build-up of the interface traps). The main role is attributed to the other available molecules of the hydrogen [16] being trapped in the oxide which is followed by the neutralization of the positive oxide charge and the release of H^+ ions. As the H^+ ions diffusing to the SiO_2-Si interface are trapped on numerous oxygen vacancies, their diffusion through the oxide is slowed. Because of that, the above mentioned electrochemical reaction starts with a delay (it starts during the annealing phase when the H^+ ions are thermally excited). The latent build-up of N_{it} is followed by the latent decrease of ΔN_{ot}, (figs. 5, 6, 9, 10), which were found to depend on the type of ionizing radiation [33].

Finally, the decrease of ΔN_{it} during the spontaneous recovery and during the annealing (in the case of electrical stress), and after the latent build-up during the annealing (in the case of irradiation) is attributed to the hydrogen species H_2 and H^0, as well [34], as a result of the P_b centers passivation

$$\mathrm{Si_s} \quad \mathrm{H_2} \qquad \mathrm{Si_s} \quad \mathrm{H} \quad \mathrm{H^0}$$

$$\mathrm{Si_s} \quad \mathrm{H^0} \qquad \mathrm{Si_s} \quad \mathrm{H}$$

CONCLUSIONS

Although some authors claim that the effects of gamma radiation and electrical stress in MOS devices are similar, in this paper it is shown that in power VDMOS transistors these effects are different. The obtained results are based on the threshold voltage changes of transistors investigated not only during the stresses, but also during the subsequent spontaneous recovery and annealing. The stressing was carried out to enable the three terms of devices parameters comparison: approximately the same values of the total duration time of gamma radiation and electrical stress, the device stressing to the threshold voltage turn-around, and the device stressing to achieve close values of the threshold voltage shift. The analysis of the changes in ΔN_{ot} and ΔN_{it}, which resulted in a corresponding change of ΔV_T, indicates the following significant differences between investigated effects:

– the gamma radiation stress primarily affects the gate oxide (significantly higher final values of ΔN_{ot} compared to ΔN_{it} were achieved), regardless of the stress level,
– before the turn-around, the electrical stress also primarily affects the gate oxide, while after the turn-around, it primarily affects the SiO_2-Si interface (a significantly higher final values of N_{it} compared to N_{ot} were achieved), regardless of the stress level,

– regardless of the similar final values of V_T changes, different values of N_{ot} (N_{it}) influenced by the gamma radiation (200 Gy) and electric stress before the turn around were observed, and
– the latent interface trap build-up occurred during the annealing phase is a typical phenomena for irradiated devices (in which the threshold voltage rebound is also detected), but not for the electrical stressed ones.

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AUTHOR CONTRIBUTIONS

All authors were equally involved in experimental and theoretical work on this paper. Also, all authors discussed and analysed obtained results, and participated in the writing of the manuscript. Research was co-ordinated by N. Stojadinović.

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ПОРЕЂЕЊЕ УТИЦАЈА ГАМА ЗРАЧЕЊА И ЕЛЕКТРИЧНОГ НАПРЕЗАЊА НА ДЕФЕКТЕ У ОКСИДУ И НА МЕЂУПОВРШИНИ КОД VDMOS ТРАНЗИСТОРА СНАГЕ

У овом раду истраживани су и упоређивани ефекти гама зрачења и електричног напрезања код n-каналних VDMOS транзистора снаге. Анализирањем помераја преносних карактеристика и промена напона прага испитиваних транзистора, као и одговарајућих промена густина наелектрисања у оксиду гејта и на међуповршини SiO_2-Si, током напрезања и пратећег спонтаног опоравка (оджаривања), показано је да ова два типа напрезања различито утичу на оксид гејта и на међуповршину SiO_2-Si.

Кључне речи: VDMOS транзистор снаге, гама зрачење, електрично напрезање, напон прага, наелектрисање у оксиду гејта, површинско стање