INFLUENCE OF ELECTRON IRRADIATION ON MOS STRUCTURE WITH CZ AND NCZ SILICON SUBSTRATE

M. Žiška[1], L. Harmatha[1], M. Nemec[1], I. Benkovský[2]

1. Department of Microelectronics, Faculty of Electrical Engineering and Information Technology, Ilkovičova 3, 81219 Bratislava, Slovak Republic

2. Department of Farmaceutical Analysis and Nuclear Pharmacy, Comenius University, Odbojárov 10, 832 32 Bratislava, Slovak Republic

E-mail: milan.ziska@stuba.sk

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1. Introduction

Research is oriented on some properties of the MOS structure with grown silicon substrate by a standard Czochralski method (CZ) as well as with a substrate prepared by Czochralski-grown nitrogen-doped (NCZ) silicon irradiated with electrons using different fluences. The electro-physical parameters as a flatband voltage, effective charge density of MOS structure were calculated and analysed from extracted data of the C-V plots. Nitrogen doping attracts much attention because of some benefits against to CZ silicon. In addition to increasing the mechanical strength and strong dislocation locking, nitrogen, even in low concentration, enhances the nucleation and allows controlling oxide precipitation [1,2]. The aim of this work is to investigate and analyse the influence of electron irradiation on the parameters of the NCZ structure with respect to its above mentioned structural properties and compare such as obtained results with those measured on the CZ structure.

2. Experimental

The P-type (boron-doped) silicon substrates were grown by the method of Czochralski. A number of Si wafers coated on both sides by 1µm LP CVD-grown Si_3N_4 were used as a source of nitrogen by adding into the melt. The nitrogen-doped wafers and the reference CZ samples with the same resistivity ranges from 2 to 5 Ωcm and thickness of 500µm were used in the experiment. SiO_2 gate layer was prepared by thermal oxidation in

O_2+H_2O ambient at 1050°C resulting in the oxide thickness of 100 nm. Nitrogen concentration for NCZ was 1.6×10^{15}cm^{-3}. Aluminium gates were vapour deposited and patterned photolithographically. After manufacturing the MOS structures, the samples were annealed in the forming gas at 460°C for 20 minutes. The C-V measurements were carried out with the C-V measurement set up [1]. The electron irradiation by the linear accelerator 5MeV/1kW was performed at the Slovak Medical University, Trenčín. The structures were exposed to electron irradiation with the fluences of 1.4×10^{15}cm^{-2}, 5×10^{15}cm^{-2}, 1.7×10^{16}cm^{-2} and 5.3×10^{16}cm^{-2}.

3. Results and discussion

The experimental data obtained from C-V and C-t measurements are summarized in Table 1. The radiation-induced changes of the C-V plots for the CZ and NCZ structures are shown in Fig.1 and Fig.2 for both, the 1.0×10^{15}cm^{-2} and 5.0×10^{15}cm^{-2} fluences, respectively.

Tab. 1*: Summary of experimental data.*

Fluence of electrons	Substrate N-type	U_{FB} [V]	N_{ef} [m^{-2}]	S_g [ms^{-1}]	τ_g [µs]
nonirradiated	CZ48	-0,8	1.24 x10^{15}	9.3×10-^{4}	262.5
	NCZ37	-0,8	1.33 ×10^{15}	6.5×10^{-4}	48.2
1×10^{15} cm^{-2}	CZ48	-4.55	1.20 ×10^{15}		
	NCZ37	-4.40	1.20 ×10^{15}		
5×10^{15} cm^{-2}	CZ48	-5.20	1.33×10^{15}		
	NCZ37	-5.05	1.40×10^{15}		

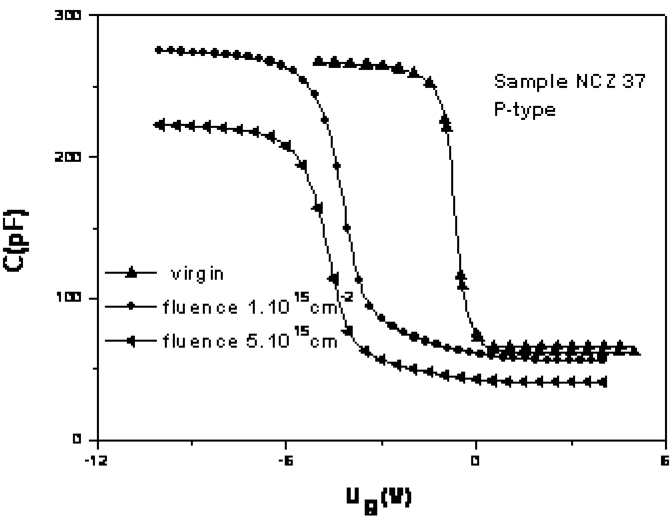

Fig.1: *The C-V characteristics of sample NCZ 37 before and after electron irradiation.*

The electron irradiation results in the shift to the negative voltage against virgin curve (Fig.1). This is typical distortion in a depletion region which indicates the presence of the voltage dependent charges in the Si-SiO_2 interface. The distortion C-V curves is observed in accumulation and inversion, as well.

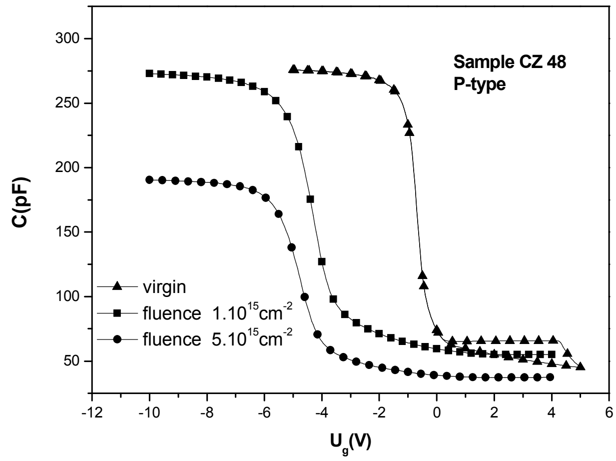

Fig.2: *The C-V characteristics of sample CZ 48 before and after electron irradiation with different fluences.*

The higher fluence has the same influence on a shift of the C-V curve for both, the CZ and NCZ structure but the higher fluence causes bigger influence on the C_{ox}/C_{min} ratio of the respective C-V chart.

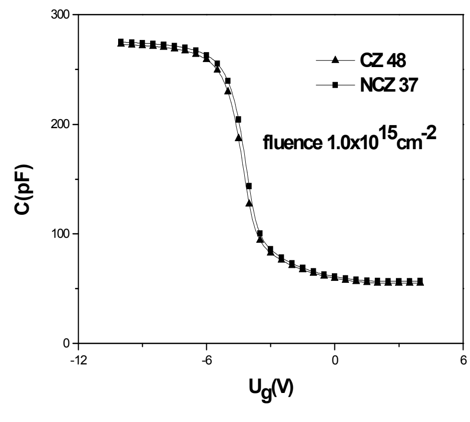

Fig. 3: *Effect of 1.0x10^{15} cm^{-2} fluence on C-V plot of CZ and NCZ samples.*

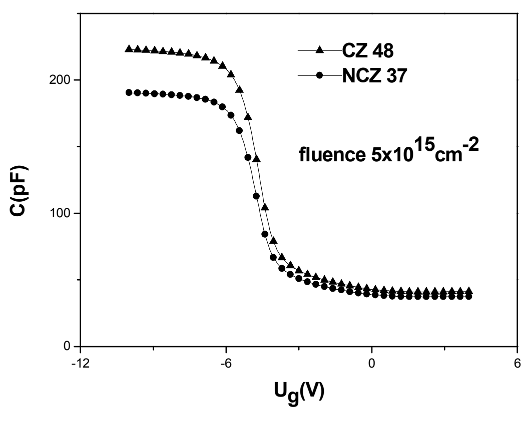

Fig. 4: *Effect of 5×10^{15}cm^{-2} fluence on C-V plot of CZ and NCZ samples*

The electron fluences higher than 5.0×10^{15}cm^{-2} resulted in degradation of C-V plot. Therefore, the evaluation of results such as samples was impossible.

4. Conclusion

The effect of electron irradiation, using $1.0\times10^{15}cm^{-2}$, $5.0\times10^{15}cm^{-2}$, $1.7\times10^{16}cm^{-2}$ and $5.3\times10^{16}cm^{-2}$ fluences on the MOS structure with CZ and NCZ type of substrates was investigated. The higher electron fluence the bigger negative voltage shift was detected as in before a very similar performed experiments [3]. No relevant differences were observed on C-V plot for both the CZ and NCZ samples irradiated with $1.0\times10^{15}cm^{-2}$ and $5.0\times10^{15}cm^{-2}$ electron fluences. The fluences $1.7\times10^{16}cm^{-2}$ and $5.3\times10^{16}cm^{-2}$ resulted in total degradation of C-V plot.

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References

[1] L. Harmatha, M. Ťapajna, V. Slugeň, P. Ballo, P. Písečný, J. Šik, G. A. Kögel: Author: *Microelectronics Journal*, **37**, 283 (2006).

[2] V. D. Akhmetov, H. Richter, O. Lysytskiy, R. Wahlich, T. Muller: *Sci. Semicond Proc.*, **5**, 391 (2006).

[3] J. Staňo, V. A. Skuratov, M. Žiška: *JINR Communication*, **1**, E7-2001-37 (2001).