SIMULATIONS FOR IRRADIATION OF SILICON-BASED STRUCTURES

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1. Introduction

Recently, the studies of the radiation damage of semiconductor-based devices have demanded the attention of the researchers. Although, the impact of the radiation on the performance of electronic devices has already been studied, there is still wide range of new materials or devices unexamined. Prior to irradiation of the silicon wafers for electronic devices by an electron beam [1], the dose-distribution simulations must be performed. The simulations of the dose-distribution in the irradiated object are an evitable tool not only for the optimization of irradiation but also for the wafer arrangement.

2. Experimental Details

The 640 μm thick Si wafers were irradiated at the University Centre of Electron Accelerators in Trenčín. This facility has at disposal a linear electron accelerator UELR 5-1S with the precise conveyor. This equipment enables the irradiation of Si wafers by 5 MeV electrons at wide range of doses. In order to set the appropriate parameters of the accelerator and the conveyor, the software ModePEB [2] was used, which noticeably optimized the irradiation process. The software ModePEB (Modelling of Electron Beam processing in multilayer flat objects) was designed especially for calculation of absorbed dose within multilayer packages irradiated with scanned electron beam. The accelerator and conveyor set-up used for selected doses is shown in Tab. 1.

The main task during the irradiation was to create the majority of defects at the bottom of the Si wafer. There are two types of basic radiation-damage mechanisms: ionization damage and displacement lattice damage. The damage caused by irradiation is proportional to the energy absorbed by the irradiated object, the irradiation dose. The ModePEB software enabled to simulate the dose distribution along the Si wafer thickness. As it can be seen in Fig. 1, the dose first slightly increases with the material thickness and then decreases down to zero at about 1.2 cm (the range of 5 MeV electrons in Si). As the thickness of the wafer is only 640 μm, according to the simulation results, the top-side irradiation was chosen to reach the majority of defects at the bottom of wafer. The very low thickness of irradiated object caused also the great importance of boundary conditions. It means in this case the great influence of the density of the supporting material, on which the wafer was placed during the irradiation, on the absorbed dose. Fig. 2 shows the dose distribution in silicon when placed on a 2 cm thick wooden board compared to dose distributions when placed on a 1 cm thick Fe board. It can be seen that the dose absorbed in Si on Fe board is significantly higher and with higher slope than in Si placed on wood. The density of wood used in the simulation was 0.7 g/cm^3 and the density of Fe was 7.8 g/cm^3.

Tab. 1. *The accelerator and the conveyor set-up used at the experiments together with measured doses.*

S.	**Planned dose (kGy)**	**Accelerator parameters**			**Really measured dose (kGy)**		
		Beam frequency (Hz)	Scan frequency (Hz)	Conveyor velocity mm/s	Mean top-side dose (kGy)	Mean back-side dose (kGy)	Back-side dose % of top dose
G1	5	120	2	4.6	5.11	5.85	114
G2	10	120	2	3.2	10.16	11.28	111
G3	20	120	2	1.7	19.95	21.97	110
G4	30	120	2	1.1	30.15	31.3	103
G5	50	240	2	1.2	52.4	57.9	110
G6	70	240	3	0.9	69.2	77.7	112

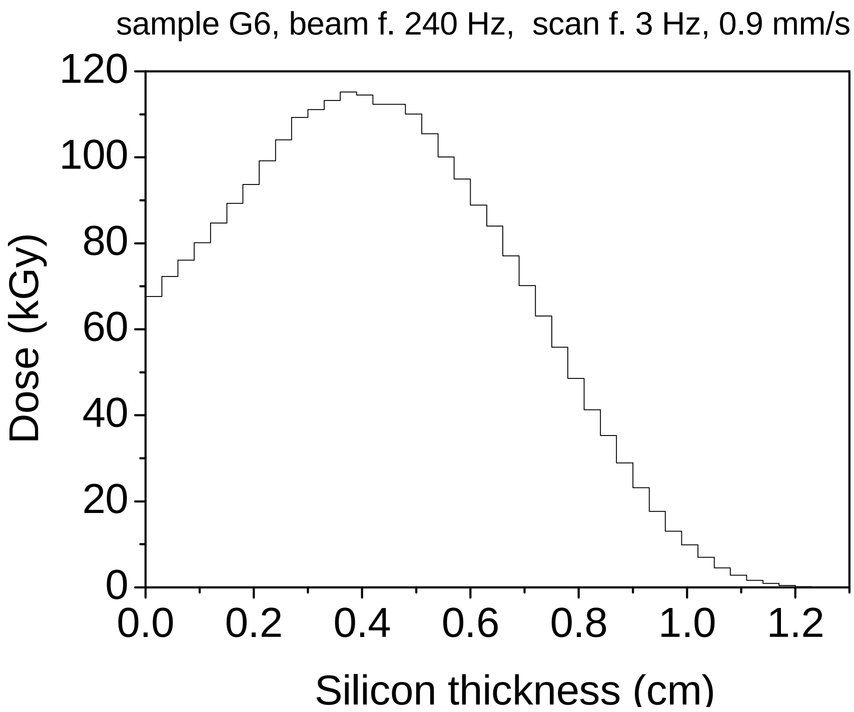

Fig.1: *Simulation of the dose depth- distribution in the silicon material irradiated by electron beam under conditions labelled G6 in Tab. 1.*

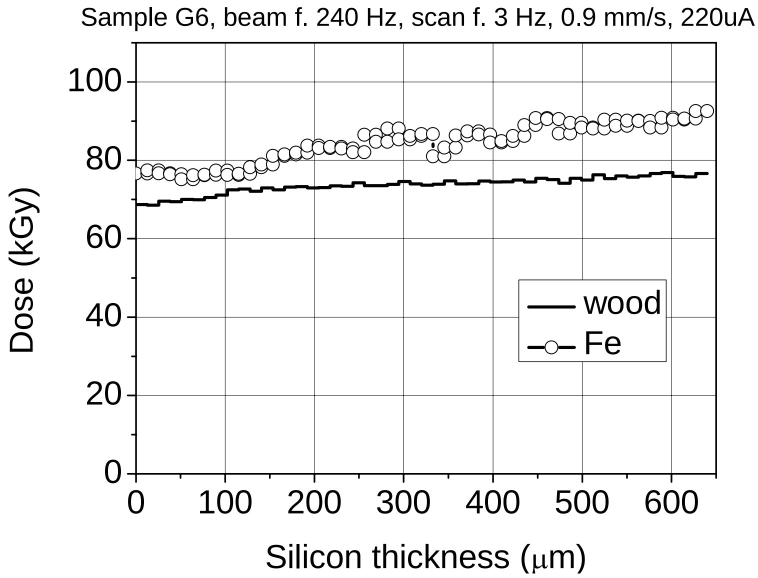

Fig.2: *Simulation of the dose depth-distribution in the silicon material irradiated by 5 MeV electron beam placed on wooden board (line) vs. Fe board (scatter).*

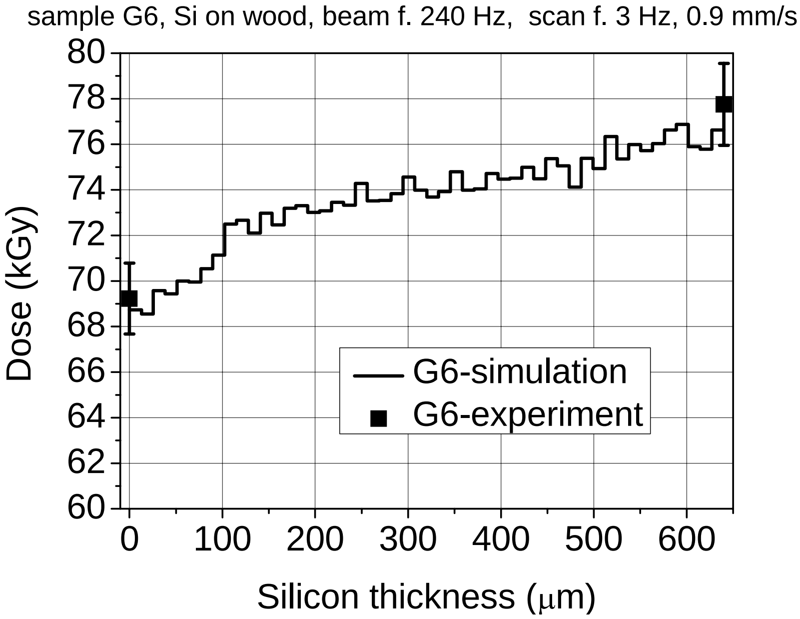

Fig.3: *The dose depth-distribution in the silicon substrate placed on wood irradiated by electron beam. Experimental results (scatter) compared to simulation (line).*

3. Results

The dose distributions simulated with the Monte Carlo ModePEB code were compared with the experimental results. The experimental values were measured by B3 radiochromic films placed on the top and at the bottom of the silicon wafer. Absorbance of the films was evaluated by the GENESYS20 spectrophotometer. In Fig. 3, the ModePEB simulation is compared with experimental data obtained as a mean value of the dose measured by four B3 film-dosimeters placed either on or under the irradiated wafer. The parameters of the accelerator set-up are listed in Tab. 1 under the label G6. The expected dose was 70 kGy. The mean value of measured dose was 69 kGy on the top wafer side and 77 kGy at the bottom wafer side. The simulation results are in a very good agreement with the experimental ones. The dose increasing along the silicon thickness predicted by simulation was proved by the dose measured at the periphery of the wafer. Similar simulations and measurements were done for other planned doses listed in Tab. 1, at different accelerator set-ups, with similar agreement between the simulation and the experiment (see Fig. 4). The required radiation treatment (lower dose at the top wafer side) was obtained in realized experiment when the doses measured at the bottom of the wafer were usually 103 – 114 % of the doses measured on the wafer surface (Tab. 1).

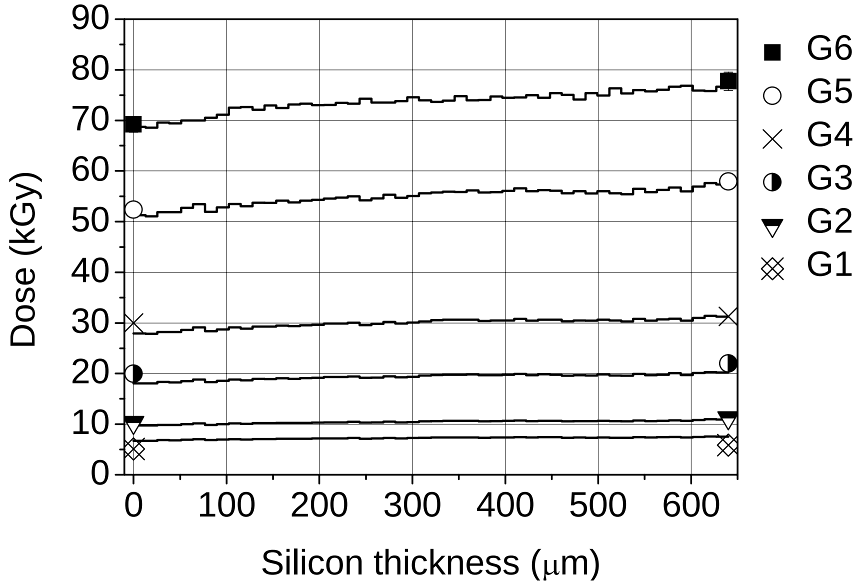

Fig.4: *The dose depth-distributions in the silicon substrate placed on wood. Irradiation conditions G1 – G6 listed in Tab. 1. Experimental results (scatter), simulations (line).*

4. Conclusions

The software ModePEB for modelling of electron beam processing in multilayer flat objects was shown to be a very useful tool for optimization of the irradiation of silicon based structures. Except its significant help in setting-up the accelerator parameters corresponding to a desired dose, its proven reliability and consistency with the measured data makes the ModePEB an inevitable instrument for design and optimization of electron irradiation experiments.

Acknowledgement

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