Irradiation of DEPFET-like transistors with CO-60 gamma source up to 10 MRad

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ABSTRACT

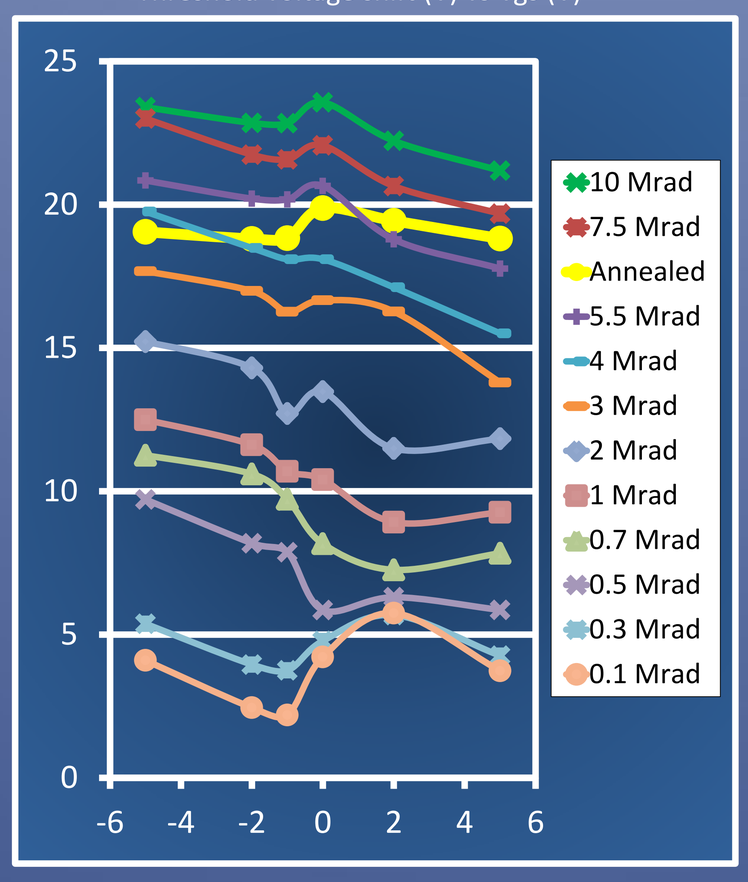
The Pixel Detector (PXD) of the Belle II experiment at superKEKB accelerator in Japan is based in the DEPFET technology. Two layers of 8+12 modules at a radius of 13 and 22 mm will give a spatial resolution below 10 µm. The radiation level expected in the first layer in ten years of operation is about 10 MRad of total ionizing dose. In order to study the tolerance of the DEPFET technology sixty devices were irradiated using a standard procedure like ^{60}Co gamma source. Different doping types, channel sizes and biasing conditions were studied.

SETUP

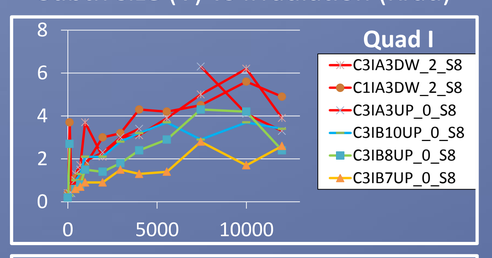
Two dies with 30 devices each of 3 doping types were instrumented. Initially (14, 22, 24) devices of types (QI, QII, QIV) with threshold voltages (3.5V, 0.5V, -2V) were irradiated. Due to different problems, mostly electrostatic discharges during manipulation not related to the irradiation, only 22 of them survived (see table). Threshold voltage shift, gain variation and sub-threshold size were studied with different biasing conditions. The influence of manufacturing and operational parameter such as doping, channel dimension and biasing voltage were studied. The irradiation took place in 11 steps during the summer 2010 in the Radiation Physics Laboratory of the Santiago de Compostela University using a radioactive source of 2080 Ci of activity allowing a dose of 11 krad/h.

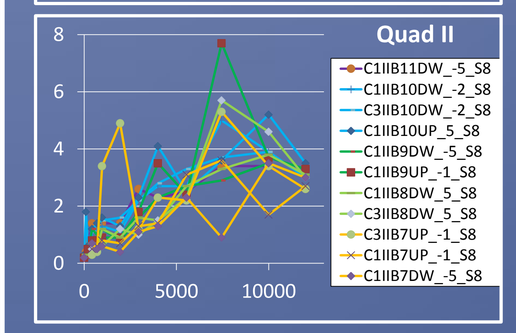
Type	Vth0	Transistor	W(um)	Vd	Vg	State
QI	3.5	c2-IB7-1	6	-5	0	On →Off
		c2-IB8-1	10	-5	0	On →Off
		c2-IB10-1	40	-5	0	On →Off
		c1-IA3-2	120	-5	2	On →Off
		c2-IA3-1	120	-5	2	On →Off
		c2-IA3-2	120	-5	2	On →Off
QII	0.5	c1-IIB7-1	6	-5	-1	On →Off
		c1-IIB7-2	6	-5	-5	On →Off
		c2-IIB7-1	6	0	-1	Off
		c1-IIB8-2	10	-5	5	Off
		c2-IIB8-2	10	0	5	Off
		c1-IIB9-1	20	-5	-1	On →Off
		c1-IIB9-2	20	-5	-5	On →Off
		c1-IIB10-1	40	-5	-5	On →Off
		c1-IIB10-2	40	-5	-2	On →Off
		c2-IIB10-2	40	0	-2	Off
		c1-IIB11-2	80	-5	-5	On →Off
QIV	-2	c2-IVB8-2	10	-5	-3	On →Off
		c1-IVB10-1	40	0	0	Off
		c1-IVA3-2	120	0	-3	Off
		c2-IVA3-1	120	-5	0	Off
		c2-IVA3-2	120	-5	-3	On →Off

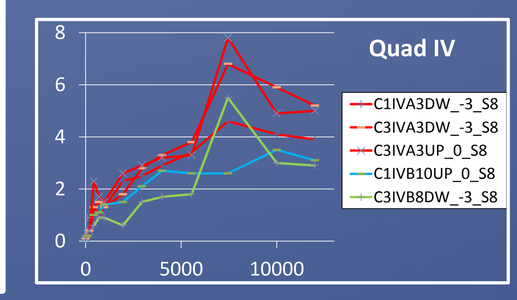
- Threshold voltage shift (V) vs Vgs (V)



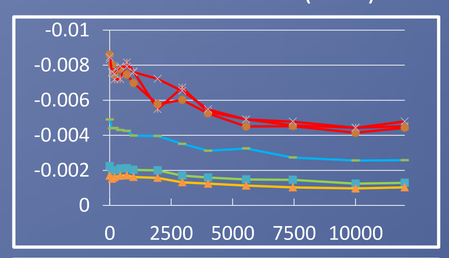
Subth size (V) vs Irradiation (Krad)

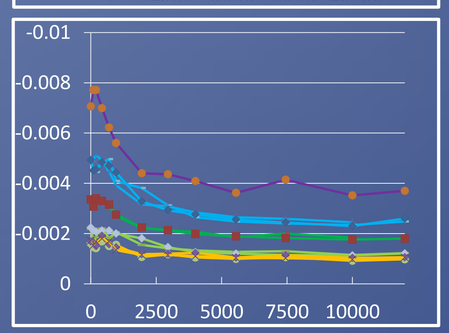


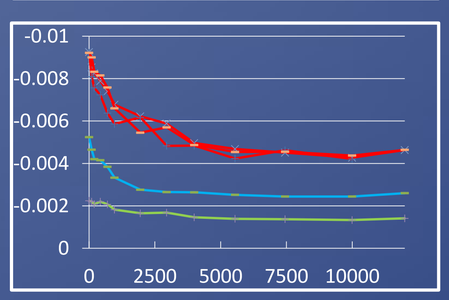


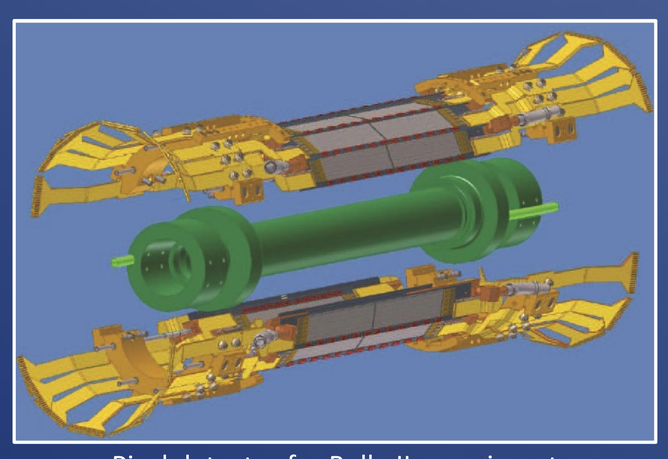


Gain vs Irradiation (Krad)

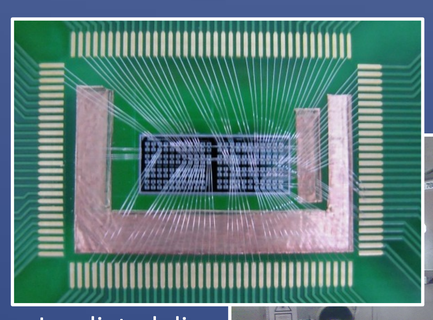








Pixel detector for Belle II experiment



Irradiated die

^{60}Co source

Biasing-Testing setup

SUMMARY

After being irradiated with a gamma source up to 10 MRad, thick oxide DEPFET-like transistors have shown a negative voltage shift of 18-23 V, reduced to 14-20 V after 28 days of annealing at room temperature. This voltage shift is foreseen to be compensated by changing the operation voltage in the switcher, the steering chip used for DEPFET matrix operation. In order to reduce the voltage shift, therefore the complexity of this chip, a new thin oxide technology is currently being developed in the DEPFET collaboration showing promising results in the first tests.

Despite the fact the gain was found to be 5 times lower than expected by the ratio W/L, the gain is reduced by a factor 2 after 10 MRad. The subthreshold size increased from 0.1 V before irradiation up to 2-6 V after the irradiation, released to 3-6 V after the annealing, the increase is proportional to the channel width.

References: S. Rummel, L. Andricek NIMA 623 (2010) 189–191