HELSINKI INSTITUTE OF PHYSICS

LUT University

Gamma, neutron, proton irradiated p-type silicon MOS capacitors with aluminium oxide

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Outline

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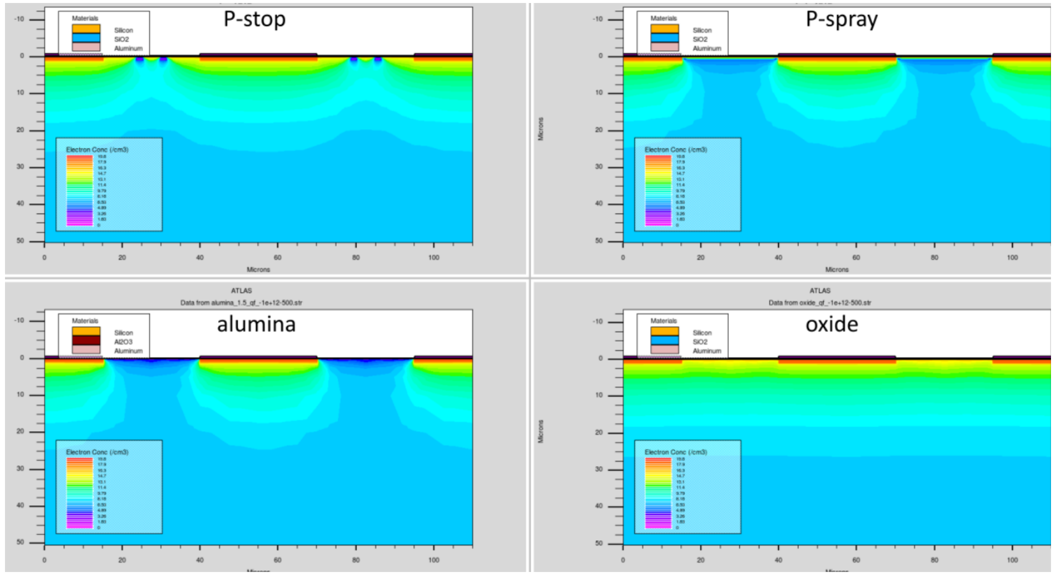
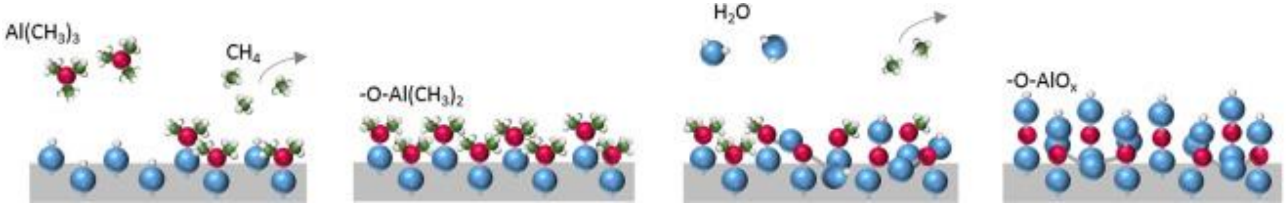
Motivation

- SiO_2 positive oxide charge->Electrical insulation between pixels for p-type silicon-> p-type implant between pixels-p-stop, p-spray-> additional implantation and high-temperature process steps
- An alternative is to use a different oxide with negative charge->aluminium oxide (Al_2O_3): good dielectric properties, high negative charge
- Atomic Layer Deposition Al_2O_3 :low temperatures, high uniformity of layers, very thin layers with good accuracy
- C-V measurements in order to investigate the interface charges and surface damage of alumina films after irradiation with different particles





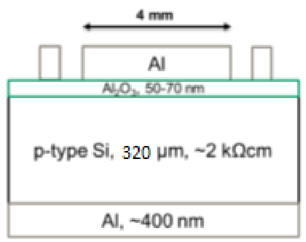
Samples

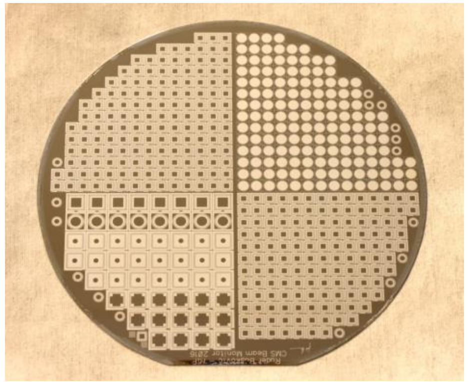
- Micronova Nanofabrication Centre , Espoo, Finland
- ALD Al2O3 with O3 precursor
- oxide thickness 80nm
- 4–8 kΩcm resistivity
- Frequency 1kHz
- Hysteresis :due to ionic mobile charges in dielectric film

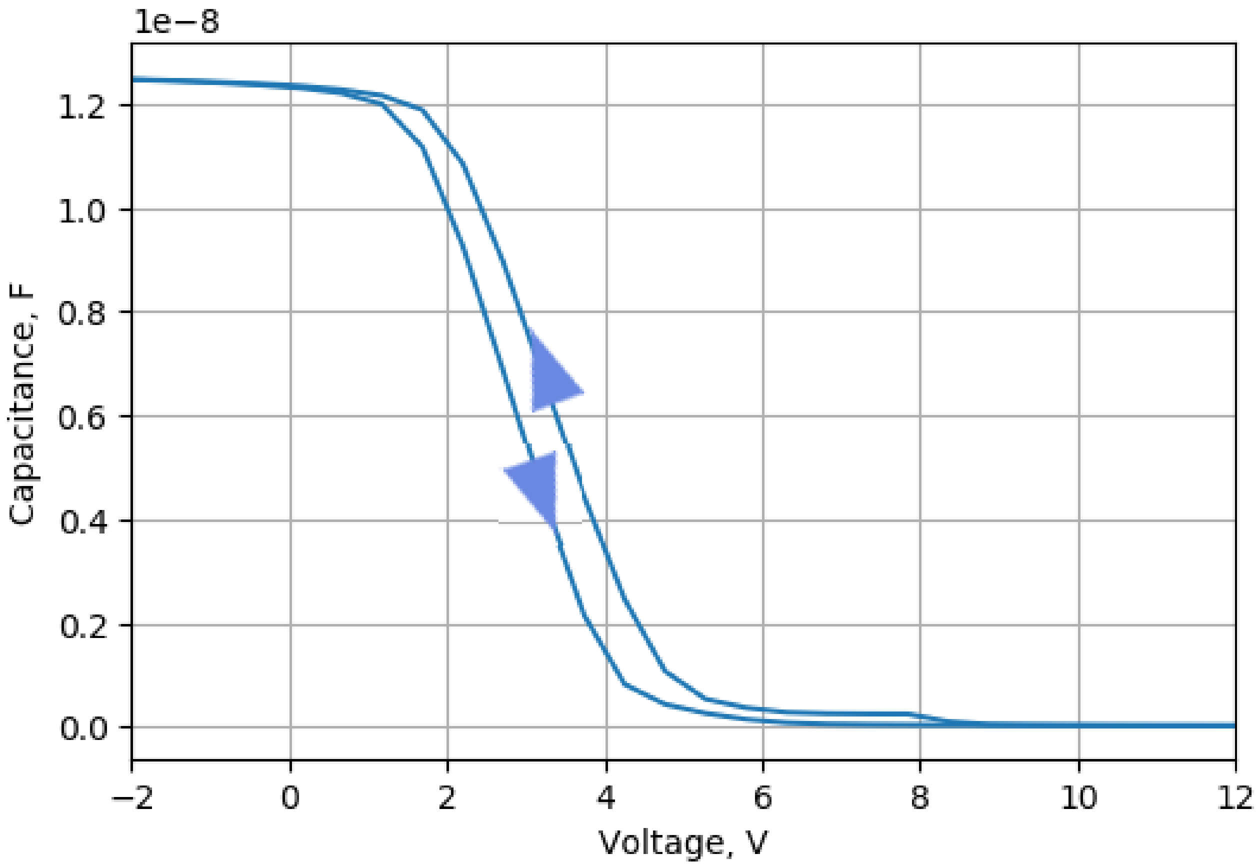
- The effective number of oxide charges:

$$N_f = -\frac{\Delta V_{fb} \times C_{ox}}{charge}$$

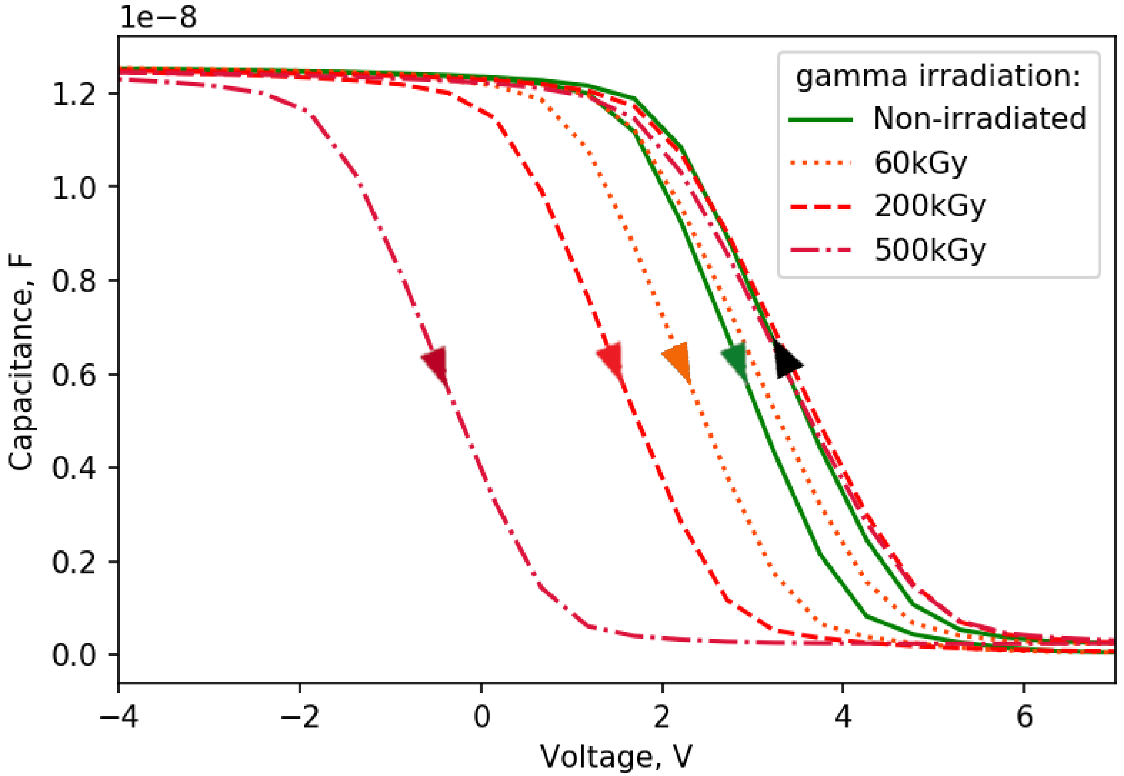
- From acc to inv: V_{fb}=2.99 ± 0.28 V
  $N_{f,eff}$=(1.73 ± 0.17)e12 cm^{-2}
- From inv to acc: V_{fb} =3.48 ± 0.49 V
  $N_{f,eff}$ =(2 ± 0.28)e12 cm^{-2}

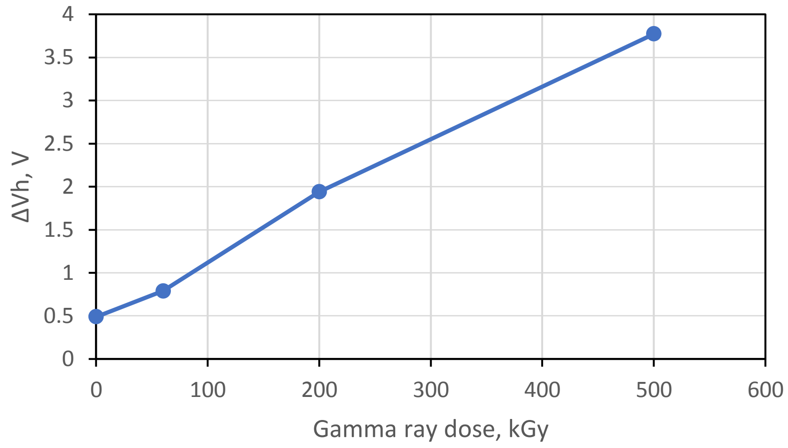


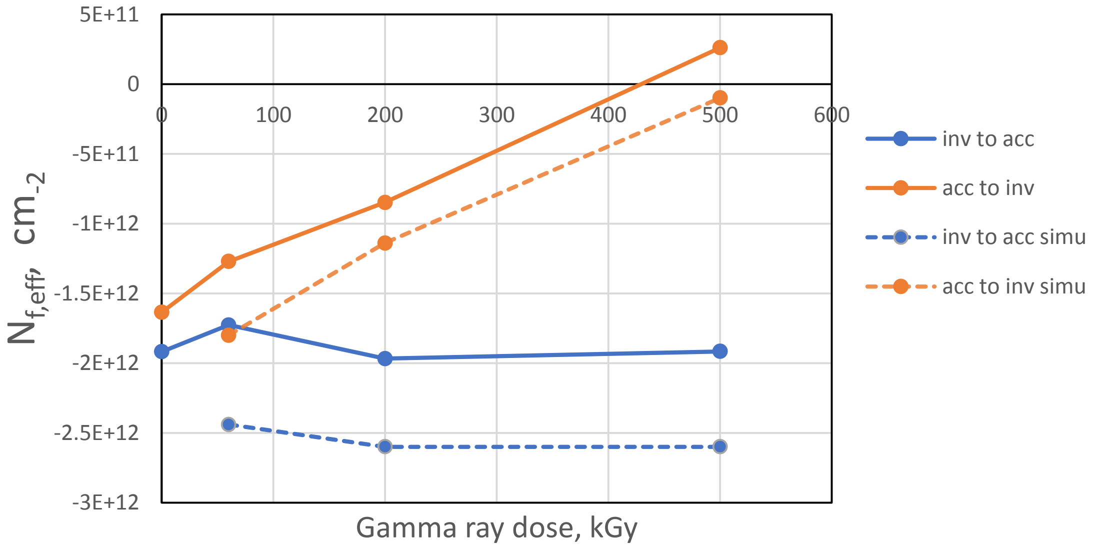




Gamma irradiation



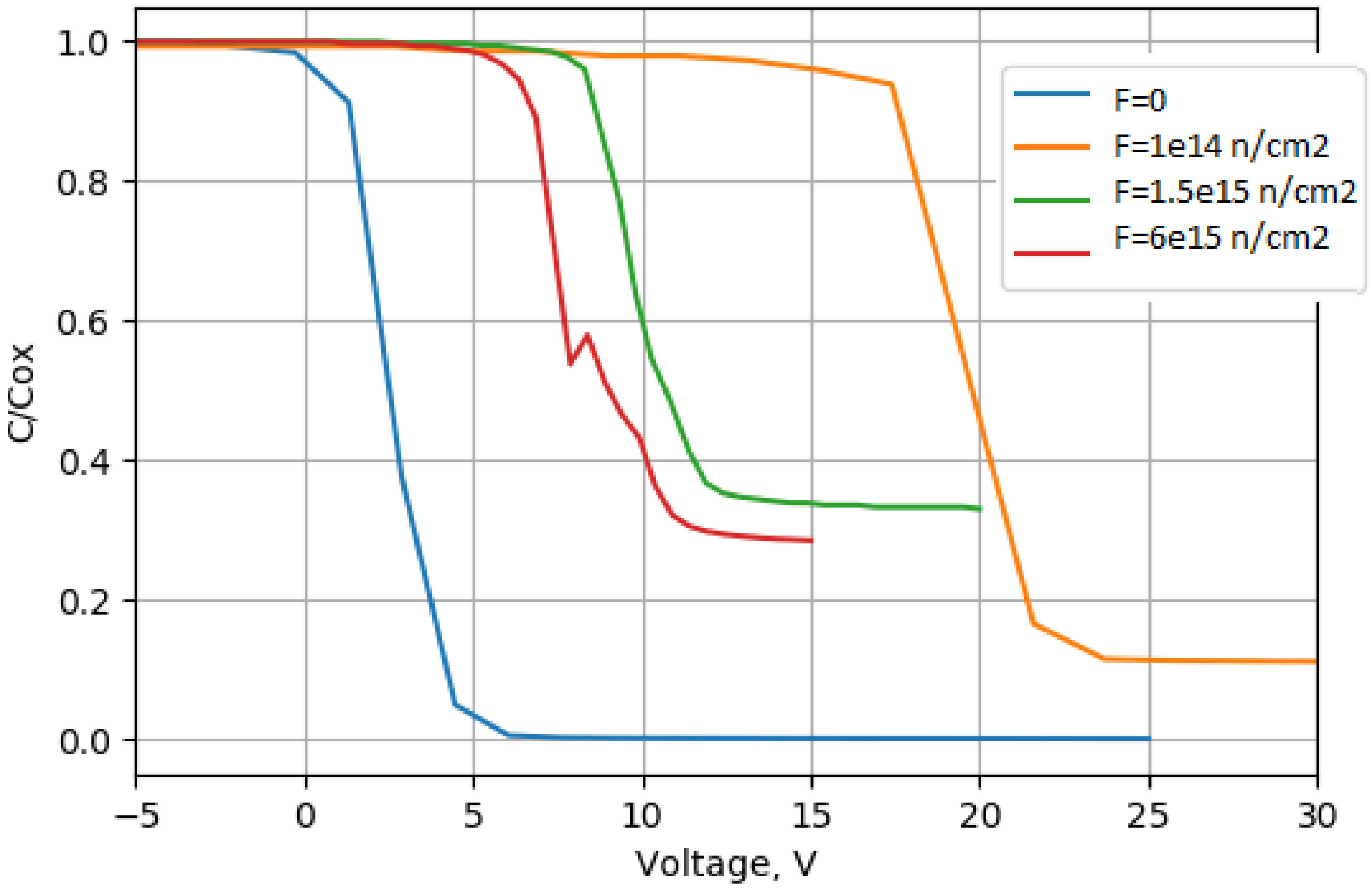




- from a Co-60 source at the Radiation Chemistry and Dosimetry Laboratory at the Ruder Boškovic Institute in Zagreb, Croatia
- For the acc to inv sweep: strong effect on V_{fb} -> build up of positive charge
- For inv to acc: negligible effect on V_{fb}
- Linear increase of ΔV_h with dose ($\Delta V_h = V_{fb\_inv\_to\_acc} - V_{fb\_acc\_to\_inv}$)
- TCAD reproduction of V_{fb} with variation of N_f

Neutron irradiation

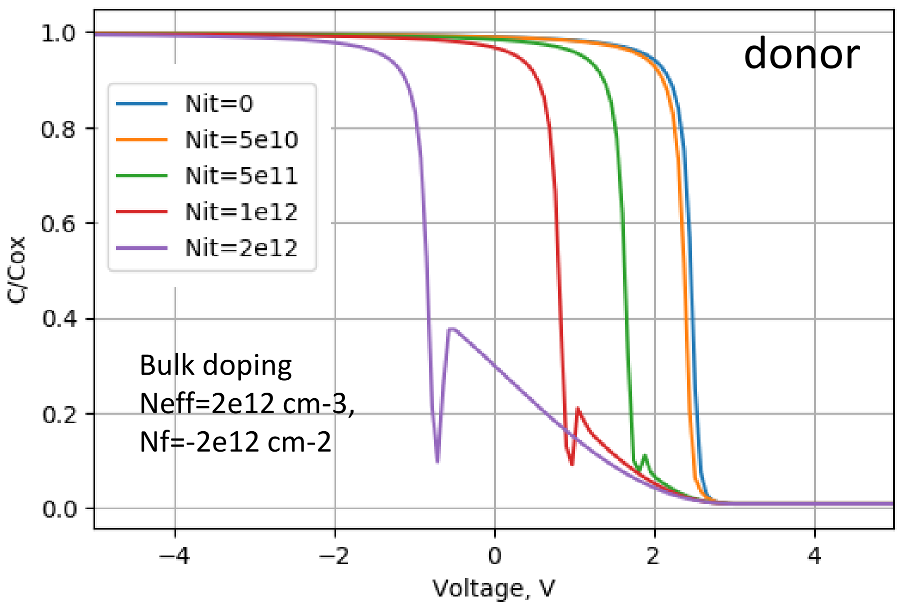
- in the Triga reactor at Ljubljana, Slovenia
- F=0->1e14 n/cm^2 : strong effect on V_{fb} -> build of negative oxide charge
- 1e14 n/cm^2 ->6e15 n/cm^2 : strong effect on V_{fb} -> build of positive oxide charge
- 1e14 n/cm^2 ->6e15 n/cm^2 : non-linear depletion slope, dip
- C/C_{ox} ratio: Increase of bulk doping N_{eff}



Effect of Nit on CV-curve

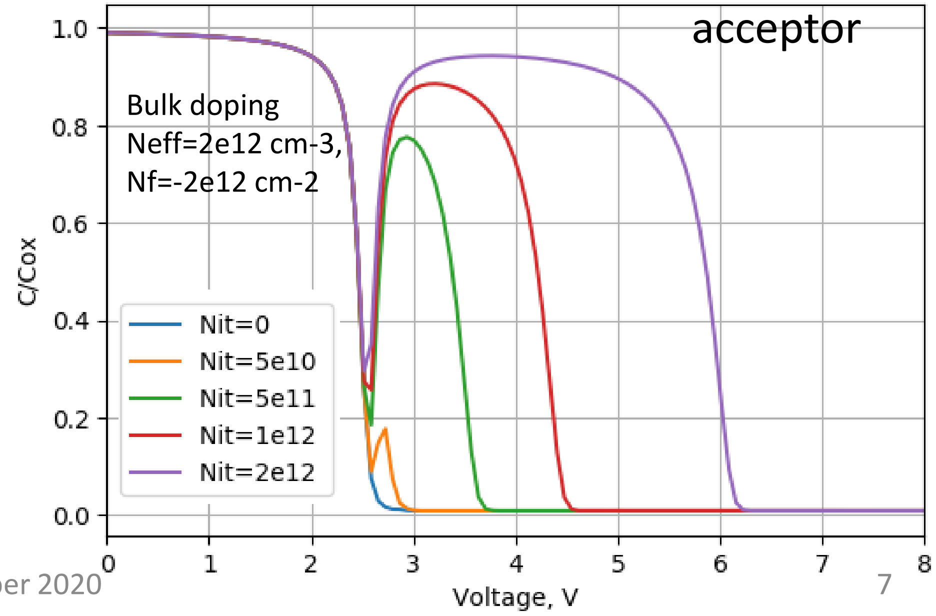
Donor interface-trap :

- Strong effect on depletion slope: donating electron-> positive charge build-up->eventually V_{fb} changes the sign
- Dip



Acceptor interface-trap :

- Strong effect on V_{fb} -> accepting electron-> negative charge build-up> change of V_{fb} to higher voltage
- Dip at initial voltage

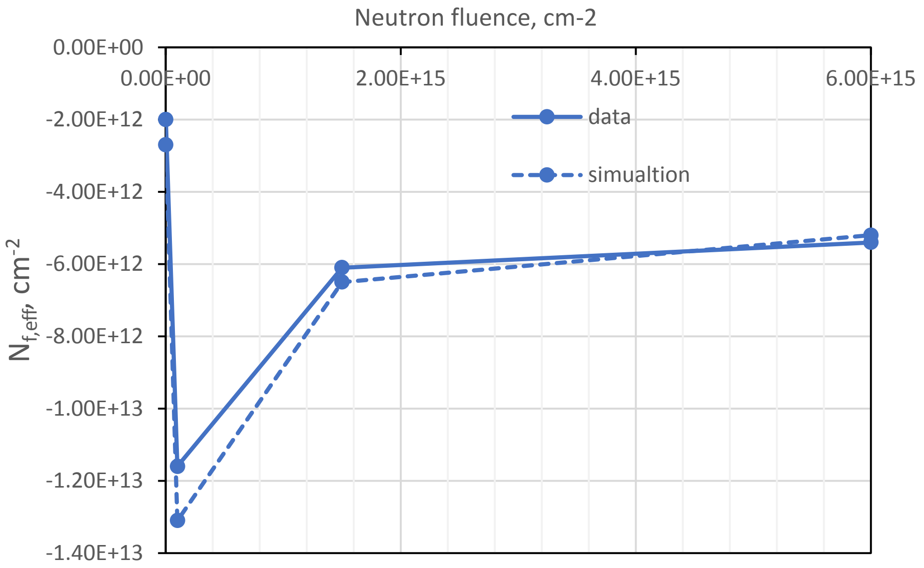


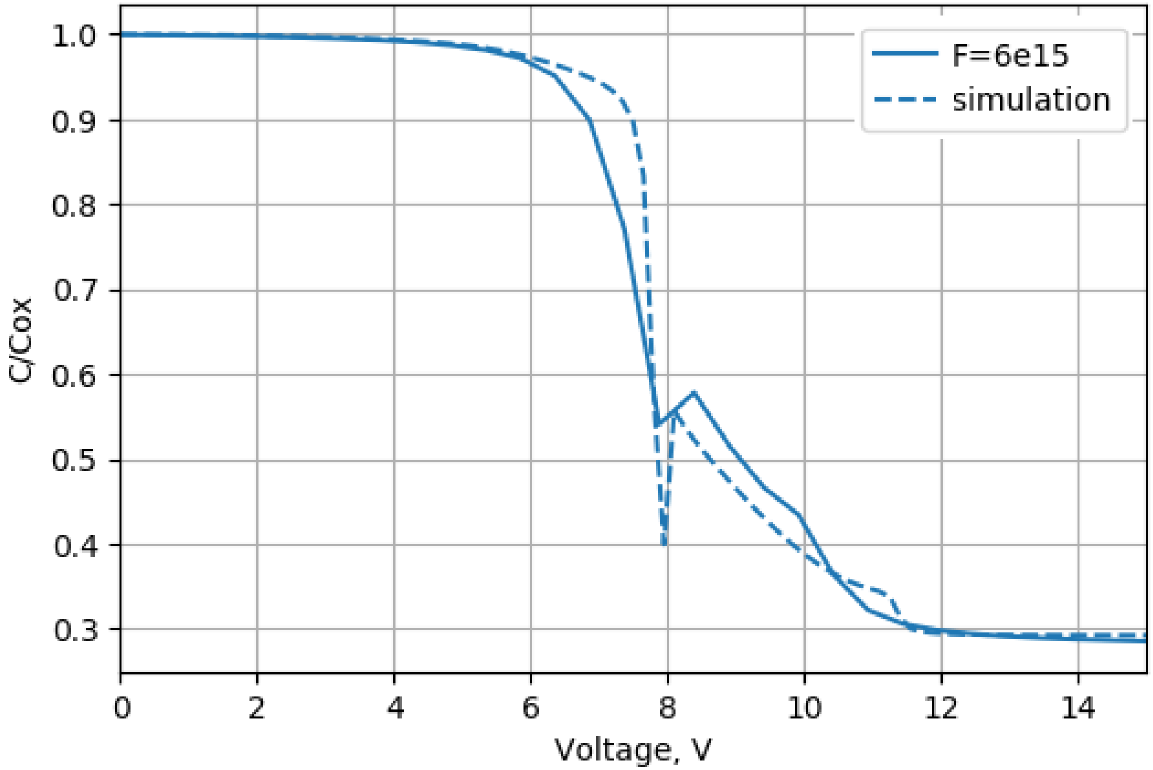
Effect of Donor Nit

- TCAD p-type Al2O3: N_{eff}=5e14 cm^{-3}, N_f=-7e12 cm^{-2}, N_{it}=1.8e12 cm^{-2}

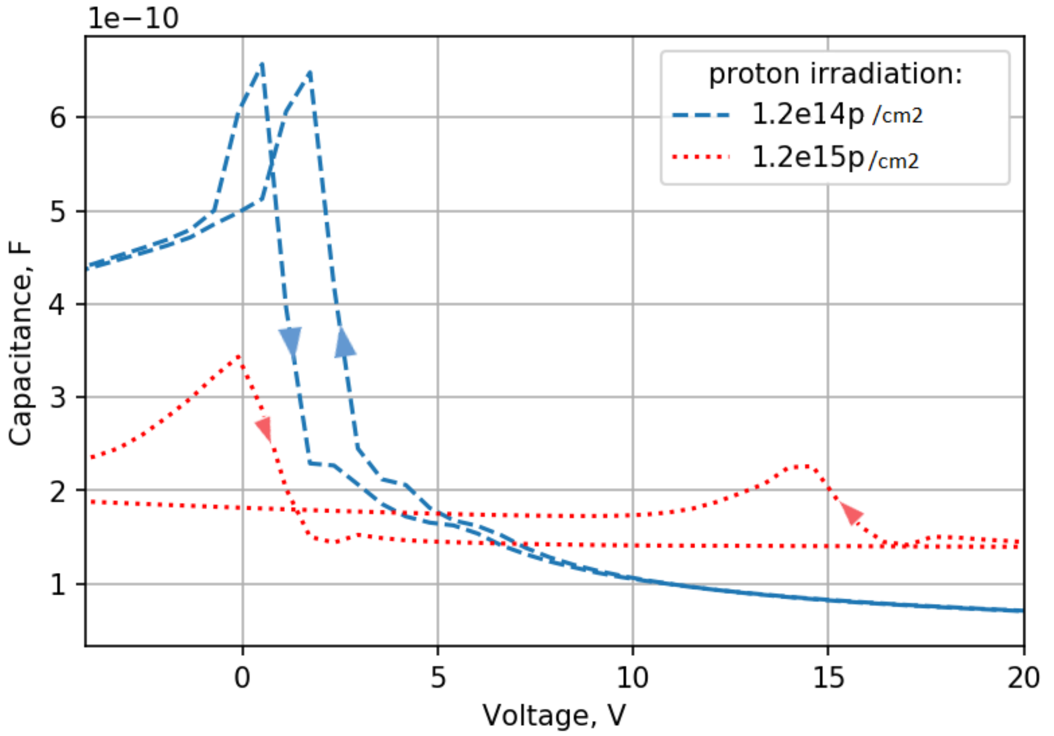
Type of trap	Level,eV	σe, cm²	σh, cm²	Density, cm^{-2}
Donor	Ev+0.6	1e-15	1e-15	1.8e12

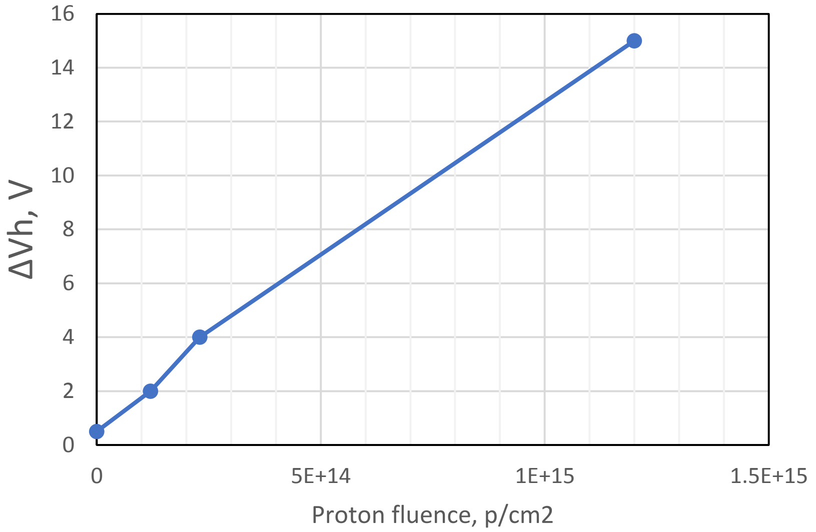
- Reproduction of dip and V_{fb} with interface donor-trap level: strong evidence that donor N_{it} dominates in alumina at high neutron fluences

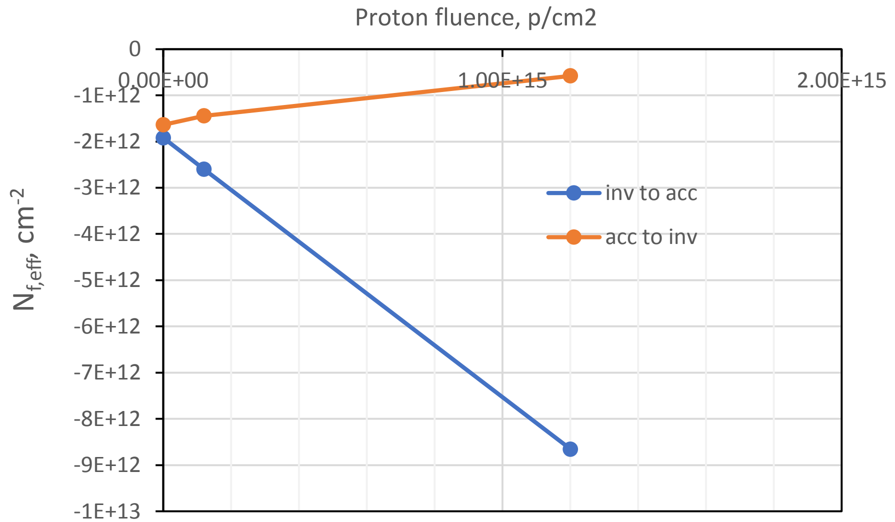




10 MeV Proton irradiation







- 10 MeV protons at the Accelerator Laboratory at University of Helsinki
- C_{ox} decreases with the increase in fluence-> displacement damage
- For the acc to inv sweep: effect on V_{fb} -> build up of positive charge
- Hysteresis ΔV_h linear increase with the dose -> mobile traps
- Simulation is in progress

Summary

MOS capacitors with Al_2O_3:

- Gamma measurement & simulation results suggest significant accumulation of positive oxide charge and mobile charges.
- Neutron measurement & simulation gives a strong evidence that donor N_{it} dominates over N_f in alumina at high neutron fluences
- Proton measurement results suggest build up of positive oxide charge and an increase in the number of mobile charges.

Thank you!