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Update of annealing measurements on heavily irradiated p-type Si sensors

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OUTLINE

- Accelerated annealing studies (@80^{o}C) have been completed in term of CCE of signal induced by mip-like electrons on p-type substrate miniature detectors after 1.1, 3.5 and 7.5 10^{15} pcm^{-2}.

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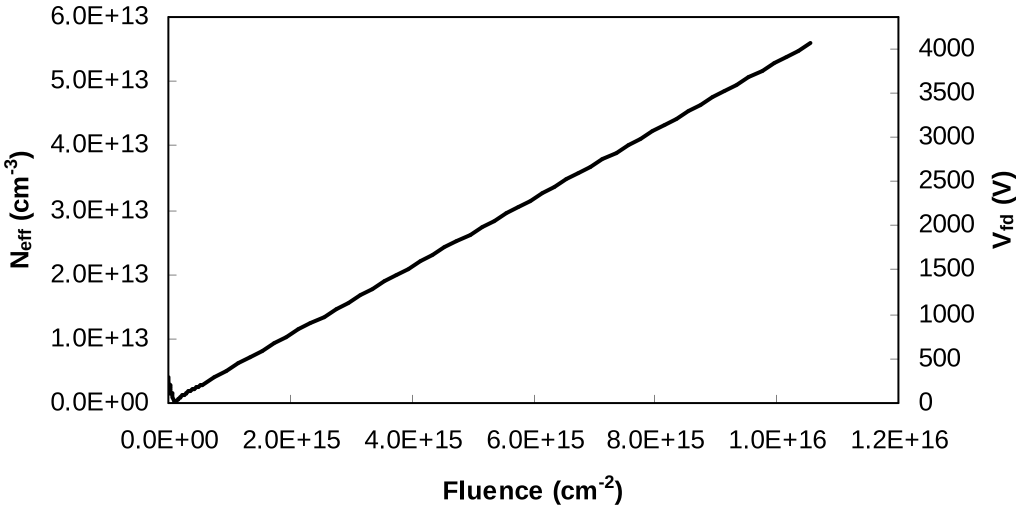
V_{FD} as a function of the proton fluence (at minimum after beneficial annealing)

The irradiated devices have been studied in term of CCE after the different irradiation doses and at the end of the beneficial annealing period. The results have been previously presented. They were extremely encouraging in term of the collected charge, especially compared with the expectation derived by the extrapolation of the V_{FD} at those extreme doses.



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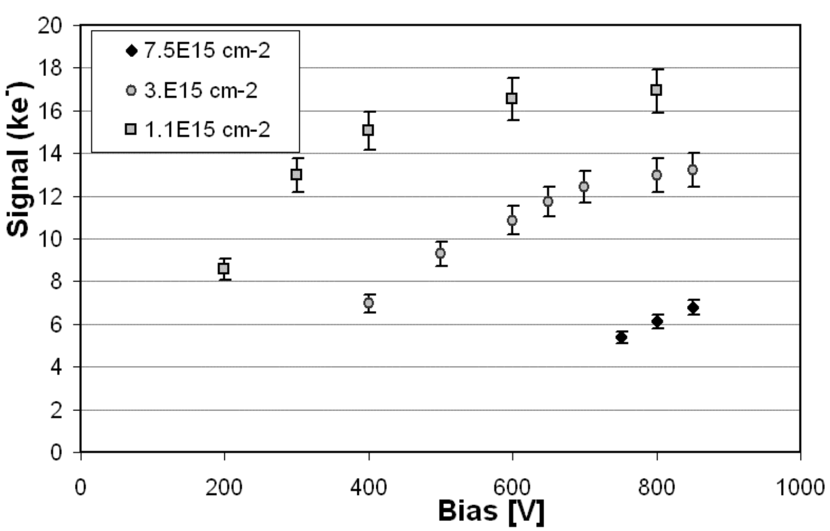
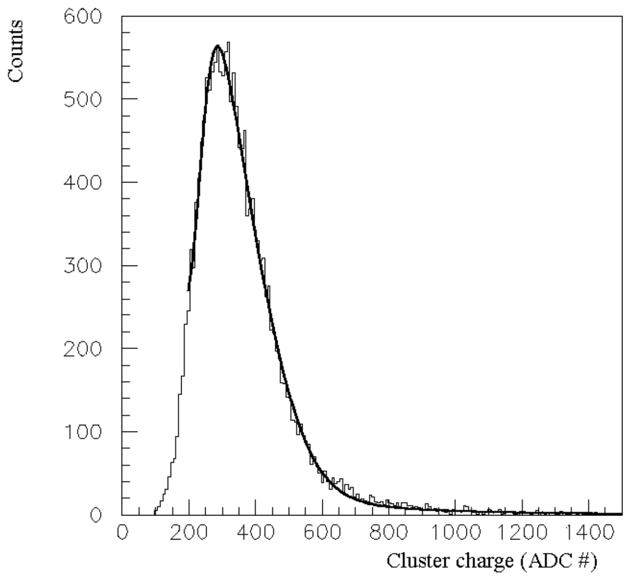
The V_{FD} after $7.5 10^{15}$ p cm^{-2} is expected at about 2800V for oxygen enriched n-type substrates. A bias voltage of 900V gives a depletion depth of about 160µm, that would yield a bit less than 12000 electrons in absence of trapping! The charge collected by the miniature p-type detectors is of ~7000 electrons, with a charge loss of 40%, which is remarkably good for that level of radiation.





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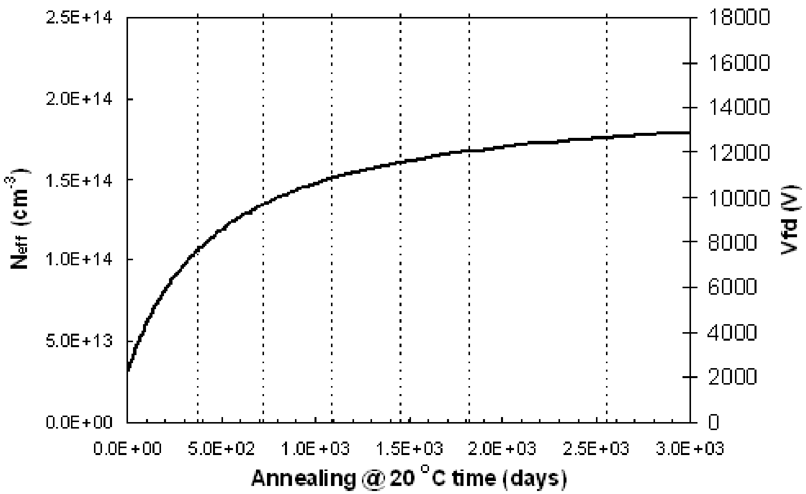

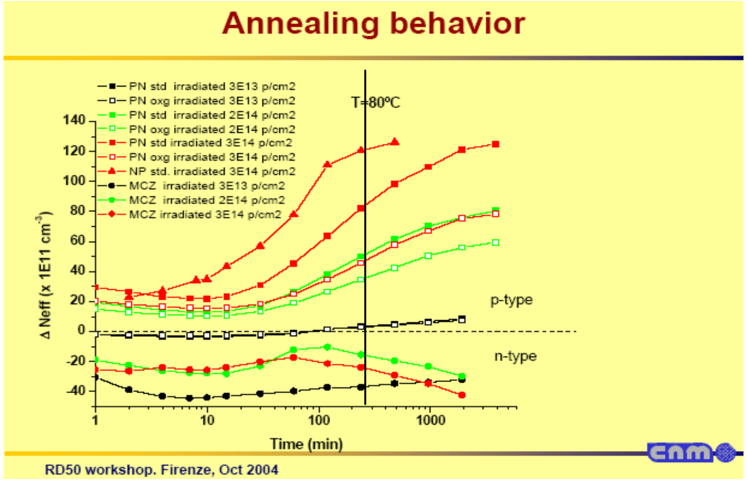

The V_{FD} worsens with time after irradiation with strong temperature dependence. The evolution after irradiation has been modelled for the n-type detector as shown here (RD48 parameters) for devices irradiated to 7.5 10^{15} p cm^{-2}. Measurements of p-type devices (at much lower doses) have also be performed by CNM on diodes, and the trend is the same (actually worse) than for the oxy n-type.

The trend of with V_{FD} with time has been thought to make the detectors unusable if kept at room temperature for any significant time, making the detector maintenance in the experiments more difficult and expensive given the necessity of cooling also during shut-down periods.

But how does the CCE correlates with the annealing as measured with the CV methods?

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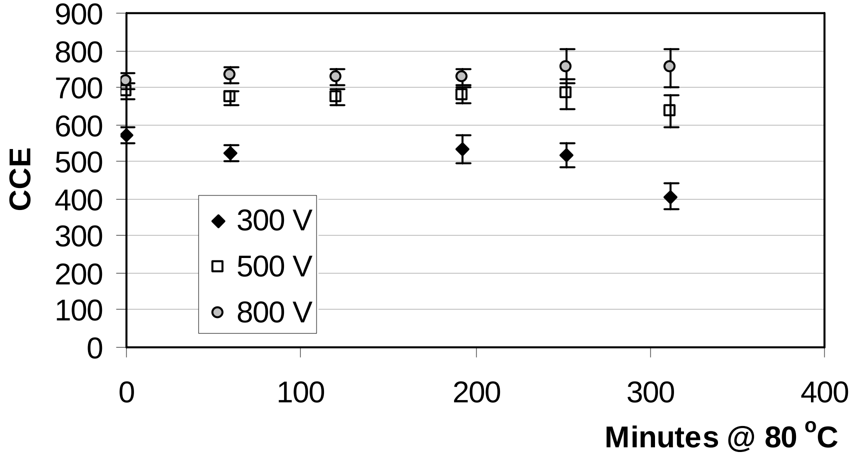
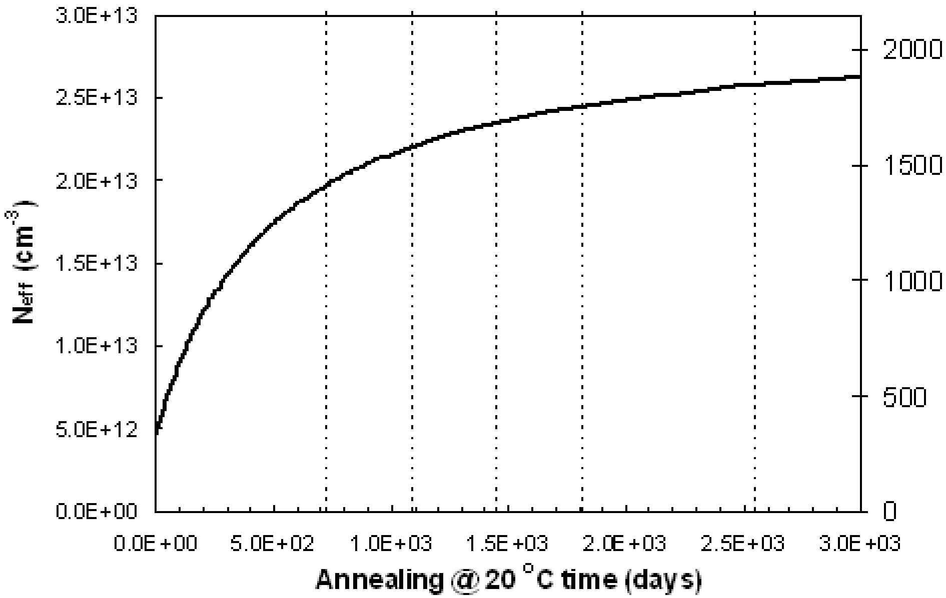
P-type detector irradiated to 1.1 10^{15} p cm^{-2}

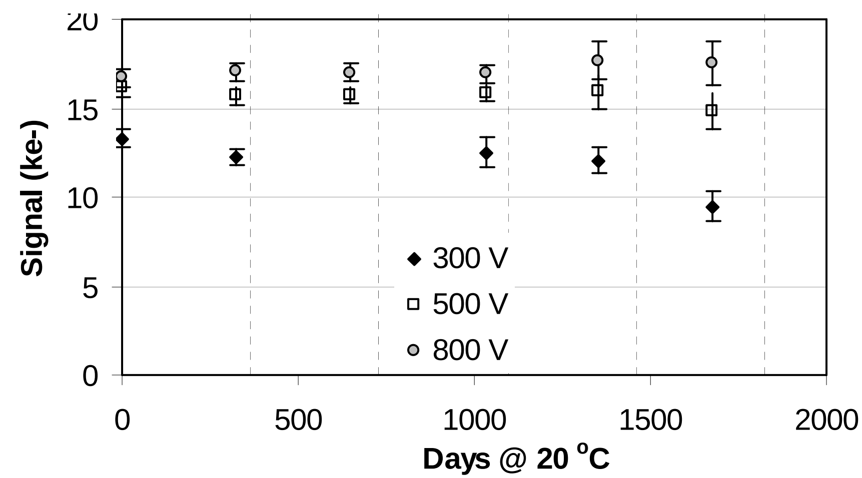
Comparison of the CCE changes with time at 80 °C with the expected V_{FD}

Initial V_{FD} ~ 420V

Final V_{FD} ~ 1900V







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P-type detector irradiated to 3.5 10^{15} p cm^{-2}

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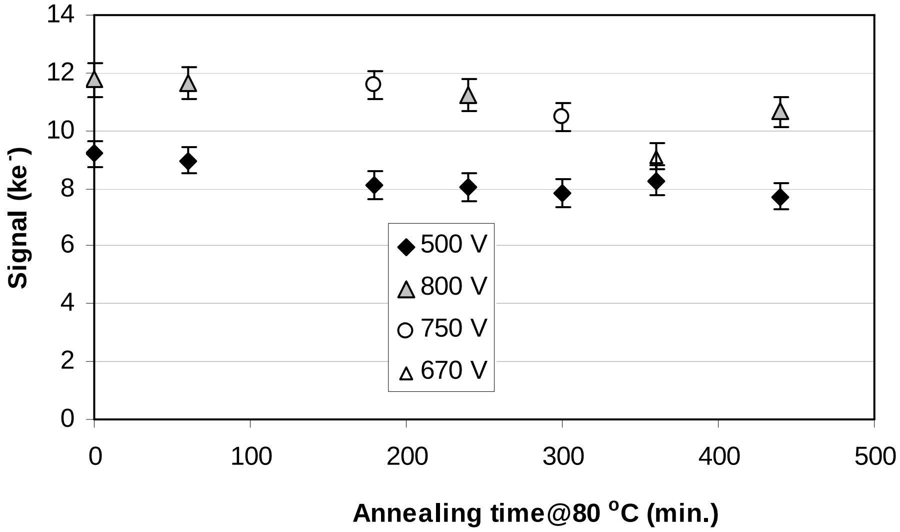
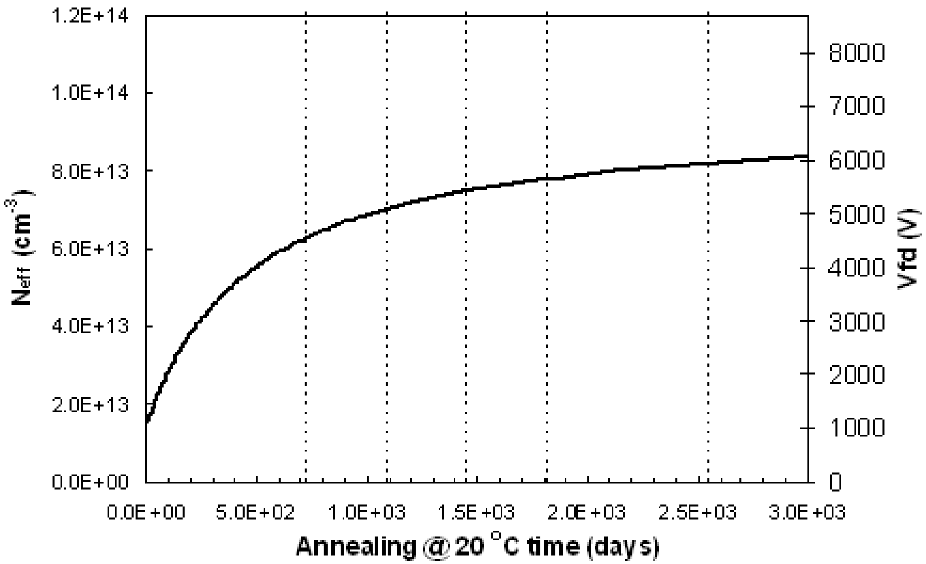
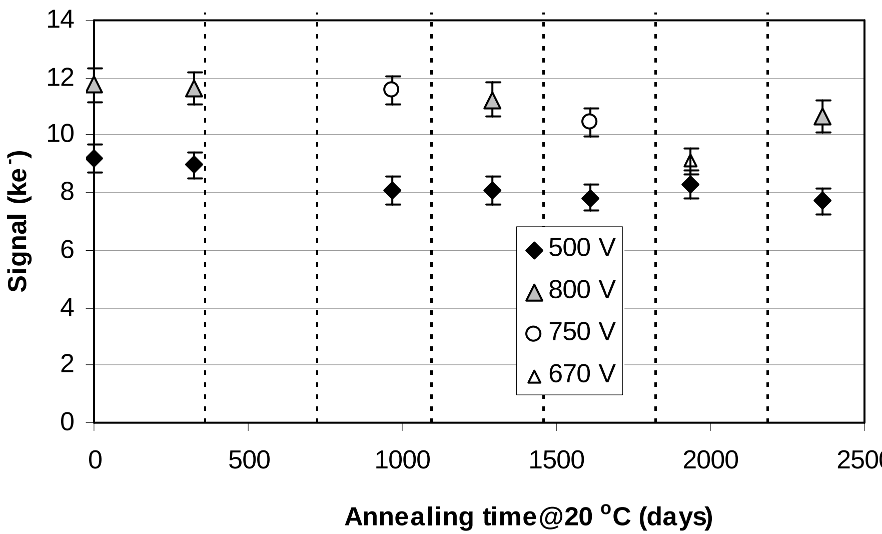
Comparison of the CCE changes with time at 80 °C with the expected V_{FD}

Initial V_{FD} ~ 1300V

Final V_{FD} ~ 6000V







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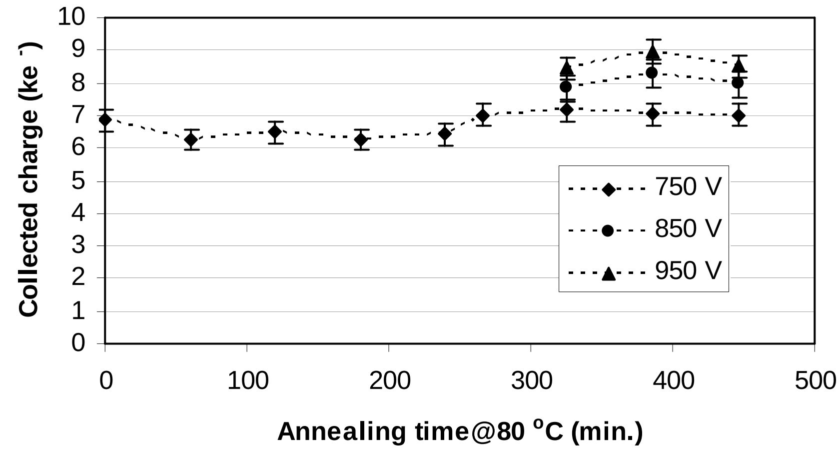
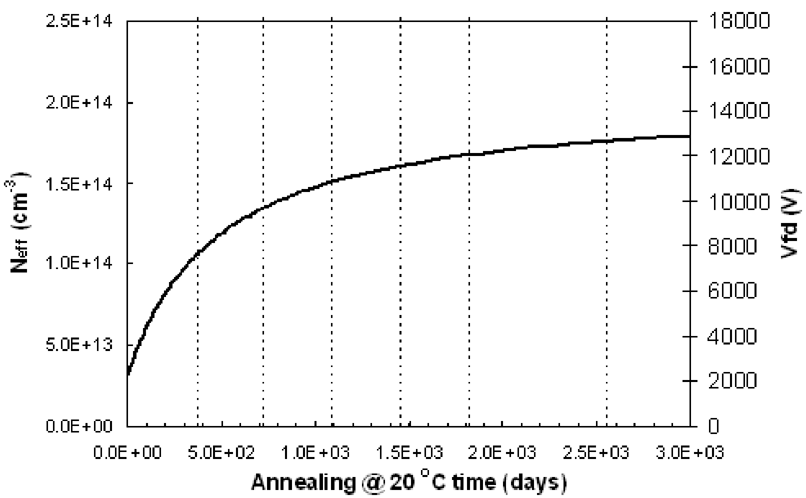
P-type detector irradiated to 7.5 10^{15} p cm^{-2}

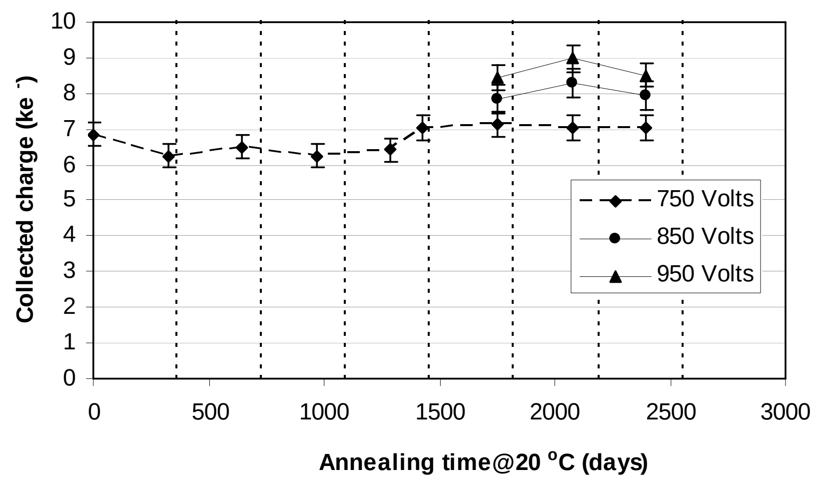
Comparison of the CCE changes with time at 80 ^{o}C with the expected V_{FD}

Initial V_{FD} ~ 2800V

Final V_{FD} > 12000V







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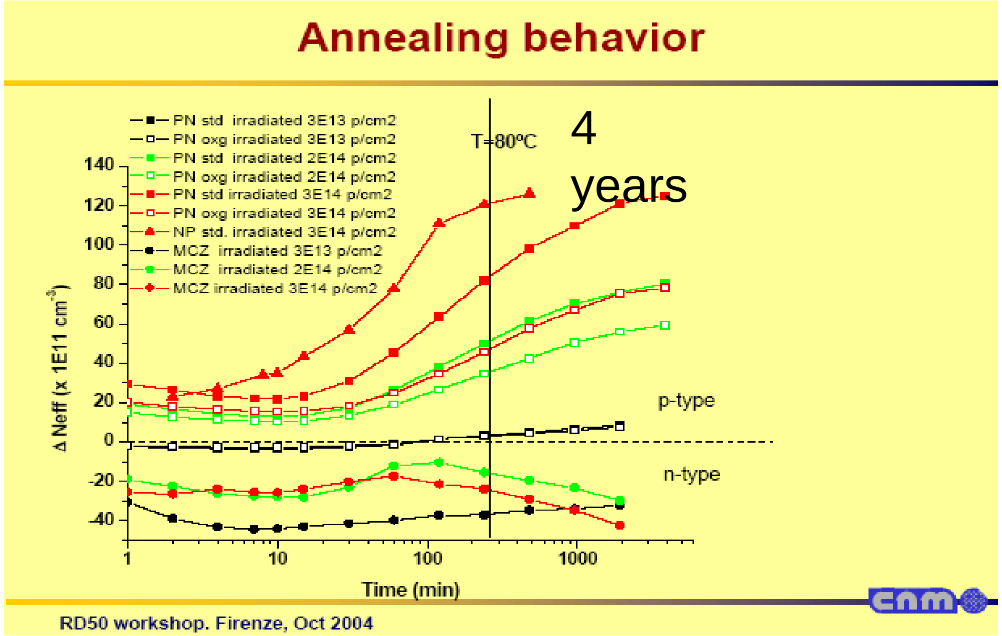
Pad diodes made of similar material, irradiated to 3 10^{14} p cm^{-2}, show a six times increase of V_{fd}, after 4 years of annealing time @ 20^{o}C.



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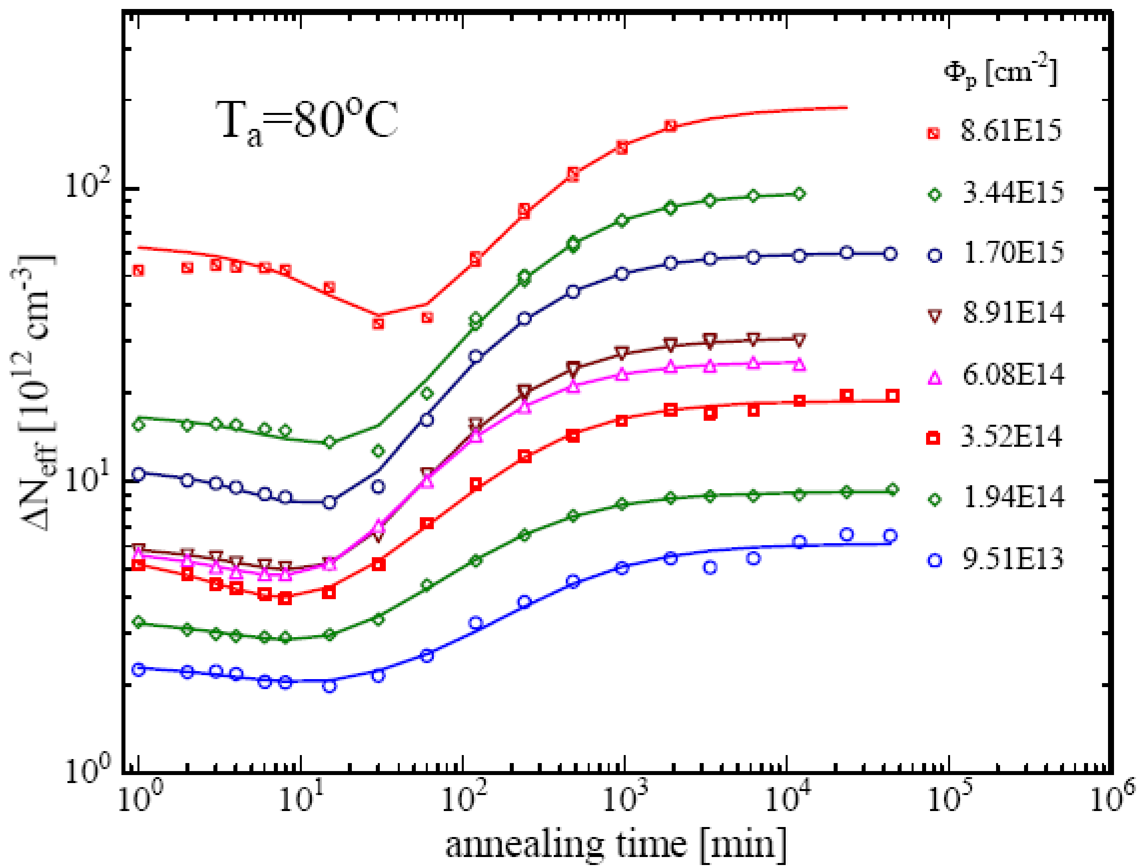
The only direct CV measurements available are on thin devices (50 µm thick). The corresponding VF_D value after 7 years equivalent annealing time at 20°C for a device irradiated to 8.6 10^{15} p cm^{-2} is >12000V (in agreement with the RD48 predictions).



Presented by E. Fretwurst at the 4th RD50 workshop, CERN 5th-7th May 2004.

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Conclusions

•It is noticeable that for the three different fluences, and at all voltages (even at the lowest voltage measured, namely 300 V after 1.1 10^{15} cm^{-2}, and 500 V after 3.5 and 7.5 10^{15} cm^{-2}), the collected charge doesn't decrease sensitively up to an entire year at R.T. This allows an easy maintenance schedule throughout the all experimental lifetime of the detector in sLHC experiments. The decrease of the CCE is observed only for the lower voltages after a few years at R.T. Basically, given the necessity of providing high voltages for the operation of silicon microstrip detectors in a sLHC-like environment, the annealing effects could be neglected. It must be stressed that the detector cooling during operation is necessary (the detectors must be kept at a temperature safely below the thermal run-away limit) to be able to apply the required high voltage.

•The relation of the CV measurement with the CCE seems to be lost whit heavy irradiation and long annealing time. A different approach (probing of the electric field?) that better describes the detector behaviour in these conditions should be envisaged.