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Book of Abstracts

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The RD50 testbeam

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The highlights from the October testbeam will be presented.

Defect and Material Characterization / 1

Nitrogen impact on vacancy aggregation in silicon single crystals

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Topsil is a world leading producer of ultrapure FZ Si wafers including the high resistivity material suitable for manufacturing of particle detectors. The company priority is to develop and supply the device-grade material with new, better properties. One of the directions is to study effect of nitrogen doping on density of voids in FZ Si crystals. In view of results reported in literature the presence of nitrogen at the concentration above 1E14 cm-3 suppresses the formation of voids related to vacancy aggregates generated during the crystal growth process. Topsil and Polish-based Institute of Electronic Materials Technology (ITME) have teamed up in a scientific project scoped to gain additional insight into nitrogen behavior in float zone silicon. The project, entitled NitroSil, is aimed at exploring the possibility of making of a new kind of silicon for high energy particle detectors with prolonged lifetime. The new high resistivity FZ Si will be enriched with nitrogen at the concentration above 1E15 cm-3 close to the solubility level. Similarly, like in the case of as grown vacancy aggregates, nitrogen is expected to react with vacancies formed during the irradiation diminishing the density of irradiation-induced vacancy clusters. The studies to be performed concentrate on verification of the nitrogen influence on the concentrations of electrically active vacancy aggregates formed due to irradiation of FZ Si with high energy particles.

Defect and Material Characterization / 2

First results on properties and concentrations of radiation defect centers in nitrogen-enriched, high-resistivity FZ silicon

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High-resolution photoinduced transient spectroscopy (HRPITS) has been used to determine the properties and concentrations of radiation defect centers produced by the irradiation with 23-MeV neutrons in monocrystalline, nitrogen-enriched, high-resistivity silicon, grown by the float zone (FZ) method. The nitrogen concentration in the material ranged from 9E14 to 2.5E15 cmˆ-3. The material was irradiated with three 1-MeV equivalent neutron fluences: 1E14, 5E14 and 1E15 cm-2. A number of irradiation-induced defect centers with activation energies from 30 to 550 meV were resolved. The changes in the concentrations of detected centers with increasing the neutron fluence are presented. The results indicate that doping with nitrogen may have an effect on the concentrations of radiation defect centers. In particular, the concentrations of radiation centers with the activation energies of 30 meV, 310 meV, 360 meV, 380 meV, and 460 meV are found to be significantly lower in the material with a higher nitrogen concentration.

LGAD / 3

Bulk defect investigations for proton irradiated sensors

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For irradiation experiments, protons with energies ranging from 23 MeV to 23 GeV are often used instead of a mixture of charged hadrons, their radiation induced damage to the silicon being rather similar. However, in oxygen rich silicon, NIEL violation con- cerning the full depletion voltage has been observed. In this presentation results from investigations on bulk defects in silicon pad-sensorswill be presented after irradiations with 23 MeV, 800 MeV and 23 GeV protons.

TCT techniques and HVCMOS / 4

E-TCT with laser beam directed parallel to strips

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In usual E-TCT measurements focused IR (1064 nm) laser beam is directed to the edge of the detector so that the laser beam is perpendicular to the direction of the strips. In this presentation results of E-TCT measurements with laser beam directed parallel to the strip will be presented and compared with »standard« E-TCT. Measurements were done with HPK mini strip detectors irradiated with neutrons.

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Design and Fabrication of an Optimal Peripheral Region for the LGAD

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An optimal design of the peripheral region prevents the Low Gain Avalanche Detectors (LGAD) from undesirable malfunctions, which may compromise the accomplishment of their outstanding possibilities as charge particle detectors for High Energy Physics experiments. Without a proper design, LGAD detectors may suffer from premature breakdown or high leakage current levels, which hinder the signal production, as well as enlarging the noise.

This work deals with the technological aspects of a suitable LGAD design. The impact of different design strategies for the device periphery is evaluated through simulation. As a result of the conclusions extracted from this work, a new optimized LGAD process has been devise at the IMB-CNM. Details of the new LGAD production are included in this presentation.

Segmented Sensors, Test Beams and Detector Systems / 6

Ongoing activities at CiS

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At this time, the CiS research institute is engaged in developments of radiation detector technologies on several different fields. Current projects are dealing e.g. with defect engineering, active edge sensors, large area thinned sensors and sensor-chip packaging technologies.

For large area sensors, the need for smaller thicknesses can be approached by etching cavities to the sensors back side while guaranteeing stability on wafer level by thick frames at the edges. First tests with Membranes up to 4x4cm² in size will be shown.

Several approaches to realize active edges for radiation detectors are under development. As a first step, we started TCAD-simulations to optimize the layout and technology parameters.

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Study of Low-dose Radiation Resistance of Sidewall Passivation on p-type SCP Devices

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We have been investigating Scribe-Cleave-Passivate (SCP) method of making slim edges on silicon sensors. For n-type devices commonly used dielectrics, such as silicon oxide and nitride, work well and they are radiation resistant. For p-type devices we used alumina (Al_2O_3) for this purpose due to negative interface charge it forms on the border with silicon surface. Our initial radiation tests

revealed its potential weakness for low ionizing doses. We investigated this issue with MOS structures with alumina that were irradiated them with gammas and protons. As reported at the last RD50 meeting, we found that interface charge evaluated with the structures evolves with radiation dose in a different manner depending on the details of the processing. We used this knowledge to fabricate 5 groups strip sensors with SCP slim edges. The different groups had different sidewall passivation methods. This included the methods used in the MOS structure studies as well as further process variations that can affect the performance. We irradiated the sensors with gammas at BNL. We will report on the their measurements and present our conclusions on the factors affecting the radiation hardness of the silicon surface passivated with alumina.

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Status of Silicon Strip Sensor Measurements at Liverpool

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Dedicated RD50 charge multiplication sensors were annealed at room temperature and charge collection measurements were performed after several annealing steps. The multiplication sensors feature different structures specially designed to take advantage of multiplication after heavy irradiation. These devices were produced by Micron Semiconductor Ltd and irradiated with neutrons to fluences of 1e15 and 5e15 neq/cm^2. Some of these sensors were used to investigate the collected charge during constant biasing of the sensor.

Miniature silicon strip detectors (˜1x1cm) with different thicknesses from Hamamatsu K.K. and Micron Semiconductor Ltd. were irradiated at Birmingham and Ljubljana with doses up to 2e16 neq/cm^2. IV measurements were performed at different temperatures for the determination of the effective energy Eg and the current related damage rate alpha.

TCAD and Surface Damage / 9

Investigation of the insulator layers for segmented silicon sensors before and after X-ray irradiation

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For the proper simulation and understanding of segmented silicon sensors the surface boundary conditions and the charge density distribution in the SiO2 layer (and other insulator layers if present), as well as at the Si-SiO2 interface have to be known. It has been observed previously, that the boundary conditions on the sensor surface change with relative humidity, RH. A simulation example of time dependent surface potential of an AC coupled n+-p sensor with p-spray will be presented.

We therefore have measured the surface conductivity of SiO2 at room temperature for RH values between 30 and 46 using a Gate Controlled Diode fabricated on n-type high-ohmic Si, and for RH = 50% using a MOSFET. For determining the effective oxide-charge density, Neff_ox, which is required for sensor simulations, as function of ionizing dose and biasing conditions, capacitance-voltage-frequency (C-V-f) measurements on MOS
capacitors (MOS-C) irradiated up to SiO2 doses of 1GGy by 10 keV X-rays were performed previously. Large hysteresis effects were observed when the voltage was ramped from accumulation to deep inversion and back. We interpreted these shifts
as evidence for field-enhanced injection of charges from the Si into the SiO2. Here we present C-V-f measurements on MOS-Cs fabricated on <100> and <111> high-ohmic Si, without irradiation and after X-ray irradiation to 1 GGy. In order
to determine the time- and field-dependence of the injection of positive charges from the Si into SiO2, the MOS-Cs have been biased at different voltages in inversion for different time intervals.

Summary:

The performance of segmented Si-sensors is influenced by the conditions at the sensor surface and at the Si-SiO2 interface.

TCAD and Surface Damage / 10

TCAD simulations of irradiated silicon sensors (Vidyo)

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The TCAD modeling of radiation damage for the silicon sensors not only provides understanding of the radiation damage, it is also helpful in the sensor design optimization. But radiation damage simulation of silicon sensors must be carried out by simultaneous incorporation of appropriate bulk and surface damages since both the strip and pixel sensors undergo these degrading effects. The use of either bulk damage or surface damage only can lead to wrong conclusions. In this work, simulations of irradiated silicon sensors incorporating the bulk and surface damages, using Silvaco TCAD, are discussed. The bulk damage is parameterized by two trap model while the surface damage is incorporated in the simulations using oxide charge density (QF) and interface trap density (Nit).

Defect and Material Characterization / 11

Point and extended defects in silicon induced by electron irradiation –dependence on the particle energy

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The defect formation, from point defects to clusters, is scanned by performing irradiation with electrons of five different energies ranging from 1.5 MeV to 27 MeV. The radiation damage induced by electrons has been investigated in terms of radiation induced defects, their evolution in time and impact on the electrical performance of silicon diodes. Our investigations demonstrate that extended defects start to form already for electrons with energy of 1.5 MeV. The direct impact of the trivacancy (V3) defect on the leakage current is confirmed. From this correlation, the capture cross section for holes of the V3 center in the single acceptor state is determined.In addition, similar to V3 small cluster, there are indications that there are other cluster related defects (the H centers) changing their configuration at ambient temperature and influencing the Neff. Preliminary results obtained by EPR and HRTEM will be presented as well.

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TCAD simulated surface damage in proton irradiated strip sensors: Investigation of interface traps vs non-uniform 3-level model

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Recent developments in the simulation work group suggest the possibility to reproduce the experimentally observed surface properties of
proton irradiated silicon strip sensors by the implementation of interface traps at the Si/SiO2 interface. This could offer an alternative for
the non-uniform 3-level model applied in Synopsys Sentaurus package, where a shallow acceptor level is added to the two deep levels of the proton
model (tuned by R. Eber from the PTI-model) exclusively close to the device surface (e.g. 2 μm). A study of the position dependency simulations of
CCE, that also provide strip isolation information via observed charge sharing, and interstrip capacitance between the two approaches and measurements
from test beam for the fluence range $3 \times 10^{14} - 1.4 \times 10^{15}$ n_{eq} cm^{-2} will be presented. Also first simulations of the hit position dependency of the signal in a 3D double-column sensor will be discussed.

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Surface Properties of Proton and Gamma Irradiated End-Cap Strip Mini Sensors

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The electrical characteristics of different types of end-cap miniature silicon strip sensors, ATLAS12A, were evaluated before and after proton and gamma irradiation. We report on the bulk damage aspects, including the increase of leakage current and evaluation of the full depletion voltage as well as the surface damage, including the decrease of inter-strip resistance, changes in inter-strip capacitance and the effectiveness of punch-through protection structure. It was verified that different geometries of end-cap sensors do not influence their stability; the sensors should provide acceptable strip isolation and new gate PTP structure functions well, even at the highest tested proton fluence 2E15 neq/cmˆ2.

TCT techniques and HVCMOS / 14

Edge-TCT characterization of irradiated HV-CMOSv3 sensors

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In high voltage monolithic detectors built on HV-CMOS technology the, usually small, n-well collecting diode is replaced by a long and deep n-well built on a low resistivity p-type substrate. The extended deep n-well allows partial depletion of the lightly doped region lying underneath. Charge collection in the depleted region is by drift. Some other charge may also appear in the depleted region after diffusion from the undepleted bulk. Since charge is promptly collected by drift, it is expected that these detectors will be radiation harder than monolithic detectors where collection is by diffusion only. Edge-TCT measurements of unirradiated and neutron irradiated 1×10^{15}, 7 $\times10^{15}$ and 2 $\times10^{16}$ n_{eq}/cm^2 samples were conducted. They show a charge collection degradation (preliminary) of $\approx$10% for 7 $\times10^{15}$ and 50% for 2 $\times10^{16}$ n_{eq}/cm^2 (reference measured at room T, irradiated measured at 0°C).

TCT techniques and HVCMOS / 15

Edge-TCT studies of irradiated HVCMOS sensor (an update)

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A HVCMOS sensor (HVCMOS2FEI4) was investigated before and after the irradiation with Edge-TCT. Key properties of the charge collection in p substrate were determined by different analysis methods. It was found that diffusion contribution to the the charge collection is reduced, but the depleted region is not affected much after relatively low fluences of up to 5e14 neq/cm2.

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Measurements on segmented LGAD devices

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The Low Gain Avalanche Detector (LGAD) is one of the technologies currently under development for radiation hard trackers.

The concept is to generate a high electric field region inside the semiconductor material. Charge carriers crossing this region may acquire high enough energy to generate secondary ionization initializing a multiplication cascade and enhancing the charge collected on the electrodes.

So far the LGAD technology has been studied on diodes. Recently a production run including segmented devices has been produced by CNM.
We analysed strips and pixel detectors from wafer 12 and 14 of run 6827 (i.e. 285 µm thick float zone with shallow and deep implantation of the n+ cathode, respectively).

The results of TCT measurements on strips to study the sensor response uniformity over the strip surface and of charge collection measurements on pixel devices after exposition to a 90-Strontium beta source will be presented and discussed.

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MODELING OF DLTS RESPONSE FOR SILICON DIODES WITH SPHERICAL AND ELLIPSOIDAL DEFECT CLUSTERS

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The concept of defect cluster is widely used to interpret effects of neutron irradiation on electrical characteristics of semiconductor crystals and devices. To predict these effects one needs to know the types of defects inside the clusters (donors or acceptors), their spatial distribution and energy levels and also the cluster size and shape. In early papers by Gossick (1959) the electrical characteristics of neutron irradiated silicon were mainly analyzed using different variants of clusters with spherical symmetry. However, it seems that silicon clusters should have a more prolate form. This work presents results of numerical simulations of prolate cluster effects on the DLTS signal of divacancies in silicon.
Numerical modeling was performed using the finite element method. The results of the simulation were compared with experimental data obtained by DLTS method in order to identify unknown parameters of the cluster, particularly, the number of divacancies in the cluster.
From comparison with available experimental data, it has been shown that prolate cluster model gives more reasonable values of divacanciy number in a single cluster than it does the model of spherical cluster.
However, an ambiguity in interpretation of DLTS data remains. A model has been shown demonstrating that also paired divacancies give good results to explain the available DLTS data for neutron irradiated silicon.

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Investigation of highly irradiated n+-in-n planar ATLAS pixel sensors

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Several FE-I3 sized n^+-in-n single chip sensors have been irradiated to fluences up to $2 \cdot 10^{16} n_{eq}/cm^2$ which may possibly be reached in the inner ATLAS pixel layers in HL-LHC. To determine the scaling behaviour, the leakage current was measured depending on the voltage or on the temperature for individual sensors.

In addition to these measurements an FE-I3 n^+-in-n single chip assembly irradiated to a fluence of $2 \cdot 10^{16} n_{eq}/cm^2$ was annealed in small steps to an overall time of 700 \,min at $60\,^{\circ}\mathrm{C}$. The impact on the leakage current and the collected charge was characterized.

The results obtained from this two studies are presented.

TCAD and Surface Damage / 19

Alternative technologies for Low Resistance Strip Sensors at CNM

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Results from the newly fabricated Low Resistance (LowR) Strip Sensors will be presented. In this third batch fabricated at CNM-Barcelona, new technological solutions have been implemented to obtain the needed low resistivity in the strips in order to obtain a full protection versus beam losses. As a first technological alternative, a Titanium Silicide (TiSi2) layer has been created on top of the silicon implant to create a low resistance path along the strip. In the second alternative, a highly doped polysilicon layer has been deposited on the strip, also to obtain a low resistance path. The tests show that the sensors are working satisfactorily, and that the low resistance along the strip has been achieved with strip resistances around 1.5 kOhms for the TiSi2 sensors, and 1.8 kOhms for the poly sensors. This suppose more than one order of magnitude reduction in the strip resistivity, which indicates that the additional protection from beam losses will be also achieved with these solutions. This will have to be confirmed with laser tests.

Defect and Material Characterization / 20

Photoconductivity spectra as a tool for Si material stability control.

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Investigation of different types of Silicon wafers (a few series of MCZ,FZ, epi) allow to reveal the properties of sample that are related with a possible origin of the material stability. It was observed two effects that are seen to be related to the performance of detector fabricated from this material: 1) There are three types of Si. In two groups it was observed a difference in the existence of the levels that cause the long relaxation the free carriers, i.e., accumulation of non-equilibrium carriers,

but in one group these levels were excited by photons less than 0.8 eV, in another group by photons less than 1.1 eV. In a third group this effect was absent.
2) The spectral dependence of extrinsic response was dependent on temperature in one group, and the characteristic parameters of spectra were independent on temperature in another group.
The differential photoresponse method of deep level analyze was proposed and the parameters of levels were determined in the silicon that has the excitation accumulation effect.
It was demonstrated that deep levels near to valence band are differently involved in electron-phonon interaction. The crystals in which electron-phonon interaction is efficient has a feature to demonstrate the defect transform induced by nonequilibrium carrier recombination or trapping.
The same type levels were observed by photoresponse spectra measurement excited by short pulses emitted by a tunable laser.
The measurement of photoresponse spectra in the test crystals could be used for the selection of silicon crystals that are more stable and less pronounced trapping effects.

Summary:

It is proposed to use the photoresponse spectra measurement at low temperature to recognize an existence of deep levels characterized by strong electron-phonon interaction and of traps responsible for a long memory of excitation.

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New Technological Capabilities at CNM

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In this talk, we will present some technological capabilities that could be of interest for the RD50 community. In this sense, the first results from new PiN diodes integrated on 6-inch N-silicon wafers will be shown. To perform this 6-inch technological process we have upgraded the standard CNM 4-inch process to the new wafer size. Additionally, we will describe the works performed to increase the layout edition capabilities to achieve a full-sensor automatic layout generation using Python. Finally, we will present a description of the technological and electrical characterization resources for silicon detectors at our labs, in particular we will explain our Reverse Engineering procedures that allow a deeper insight on the physical and geometrical properties of the fabricated devices.

Welcome / **22**

Welcome

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Defect and Material Characterization / **23**

Discussion on Defect and Material Characterization

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TCT techniques and HVCMOS / 25

TRACS: Transient Current Simulator

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TRACS: Transient Current Simulator

An extensible open-source C++ software for the simulation of the drift dynamics of electrons and holes drift in semiconductor detectors of complex geometries has been developed in order to understand transient currents and charge collection efficiencies of arbitrary charge distributions. The simulation makes use of Ramo's theorem to obtain induced currents in the electrodes. Efficient open source C++ numerical libraries are used to obtain the electric and weighting field using finite-element methods and to simulate the carrier transport. A graphical user interface is also provided. The tool has already been proved useful to model laser induced transient currents.

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Discussion on LGAD and Fast Timing

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Characterization after neutron irradiation of Silicon Diodes for the CMS High Granular Calorimeter (HGCAL)

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The CMS collaboration is planning to upgrade the forward calorimeters as these will not be sufficiently performant with the expected HL-LHC (High Luminosity LHC) conditions. One of the proposed calorimeter options is the High Granularity Calorimeter (HGC). It is realized as a sampling calorimeter with layers of silicon detectors that feature very high longitudinal and lateral granularities and a coarser segmentation backing hadronic calorimeter based on scintillators as active material. For the electromagnetic calorimeter (EE) 420m2 of silicon detectors and for the Front Hadronic calorimeter (FH) 250m2 of silicon detectors with a total of 5.1M channels are anticipated. The sensors are realized as pad detectors of a size in the order of 1 cm2 with an active thickness between 100 and 300 um depending on the position respectively the expected radiation levels. We

present our first results after irradiation of 300μ, 200μ and 100μ n-on-p and p-on-n devices that have been made up to fluxes of 1.5E16 n/cm2 at Ljubljana and have been measured at Hamburg.

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Signal and Charge Collection Efficiency of n-in-p strip detectors after proton and neutron irradiation to HL-LHC fluences

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For the upgrade of the silicon strip tracker of the ATLAS experiment a detailed study was conducted on silicon strip mini sensors. About 20.000 silicon strip detector modules are foreseen to be built for the upgrade of the inner tracker in 2023. Various tasks in prototyping are currently ongoing. For the test of possible sensors a large number of n-in-p mini strip sensors from Hamamatsu Photonics, so called ATLAS12A were investigated before and after irradiation with gammas, protons and neutrons to fluences of up to 2*10E15 neq/cm2. Charge collection measurements using beta sources and laser measurements were performed at different institutes. A summary of the test will be presented including a comparison of results before and after annealing. In addition, the charge collection of ATLAS12A sensors will be compared to results obtained with ATLAS07 sensors.

LGAD / 30

Measurements on thin LGAD Sensors

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We will show measurements and simulations on thin LGAD sensors
and discuss the prospect for ultra-fast timing.

LGAD / 31

Effects of irradiation on LGAD devices with high excess current

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Silicon n-p diodes with heavily doped p layer underneath the n implant were designed to benefit from charge multiplication process already before irradiation. The leakage current of the devices produced varies by few orders of magnitude. Its origin it is not clear yet, but it has an impact on the device performance after the irradiation. The excess holes trapped at the deep traps cause the changes in the space charge and consequently in multiplication. The devices were investigated after different type of irradiation: 200 MeV pions, 800 MeV protons and reactor neutrons.

LGAD / 32

Long-term HV stability of the collected charge in charge multiplication sensors

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Charge multiplications (CM) detectors have been proposed as candidates for radiation tolerant detectors for the High-Luminosity upgrades of the ATLAS and CMS experiments. An open question in the implementation of such sensors has been how the signal in the CM mode evolves over long-time periods under high-voltage conditions and voltage cycling, as would be relevant in applications at the LHC.

We present measurements of the collected charge on CM detectors over large time scales (days to weeks) under high voltage biasing conditions. Severalirradiated detectors show a significant decrease in the collected charge after a few days while being held at a high bias voltage. Partial recover of the signal is possible after turning of the high voltage for a short time, although the maximum signal is never recovered. The measurements call into question the viability of CM sensors options for radiation-hard sensors for the HL-LHC.

TCT techniques and HVCMOS / 33

Two Photon Absorption and carrier generation in semiconductors

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Silicon is transparent to low intensity laser light with wavelength bigger than 1100 nm: Photon wavelength is beyond the energy gap so there is no possible linear quantum absorption.

Only at the focal point, light intensity can be high enough to switch to simultaneous absorption of two photons with half the gap energy each. This nonlinear absorption opens up a new technique for pair generation in semiconductors, particularly in semiconductor devices. The carrier generation is limited to the focal point, due to the intensity dependence of the absorption cross section, with the remnant device transparent to laser light beyond 1100 nm. With high precision optics, the focal

point can be moved inside the device, effectively moving a carrier generation small volume along the device. That small carrier volume can be used to probe the electric field inside the device.

Summary:

On the physics of two photon laser light absorption in semiconductor devices and its use for electric field probing with a movable small carrier generation volume.

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An Introduction to Edge-TCT measurements on irradiated HV-CMOSv3 sensors

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Passive $100 \times 100\,\mu$m test diodes in an unirradiated and an $1 \times 10^{15} Neq\,cm^{-2}$ irradiated HV2FEI4v3 HV-CMOS silicon sensor were analysed using the edge TCT technique. The observed signal had fast and slow contributions, that were interpreted as drift and diffusion. The former peaked in a region, that was interpreted as the depletion region, while the latter peaked further in the bulk material. Raising the bias voltage increased the depth of the former region, while pushing the latter region further into the bulk. The irradiated sample lost signal strength mainly in its slow part compared to the unirradiated sample, while its quick signal remained largely unaffected. As only the signal interpreted as drift is fast enough to be useful in LHC operation the investigated sensors could be considered radiation hard for this purpose. This gives further promise to the HV CMOS technology for high energy physics applications.

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TPA-TCT: A novel Transient Current Technique based on the Two Photon Absorption (TPA) process

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Transient Current Techniques (TCT) based on laser-induced currents produced by Single Photon Absorption (SPA) processes in the sensor substrate have been used extensively to study the electric

field distribution of irradiated silicon sensors. A new laser-based Transient Current Technique is introduced here for the first time where the free charge carriers are created in a Two Photon Absorption (TPA) process induced by a focused femto-second laser pulse with a wavelength of 1300nm. The fact that in a TPA process the absorption of the light depends on the square of the intensity of the light beam used for the current generation allows to create very localized TPA-induced electron-hole pairs and opens the possibility to carry out a 3D mapping of the sensor's electric field with micrometric resolution. A first proof-of-concept measurement is presented in this talk.

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Potential of Thin Films for use in Charged Particle Tracking Detectors

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Thin Film technology has widespread applications in everyday electronics, notably Liquid Crystal Display screens, solar cells, and organic light emitting diodes. We explore the potential of this technology as charged particle radiation tracking detectors for use in High Energy Physics experiments such as those at the Large Hadron Collider or the Relativistic Heavy Ion Collider. Through modern fabrication techniques, a host of semiconductor materials other than silicon are available to construct thin, flexible detectors with integrated electronics with pixel sizes on the order of a few microns. We review the material properties of promising candidates, discuss the potential benefits and challenges associated with this technology, and review previously demonstrated applicability as a neutron detector.

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First results on the timing resolution properties of LGAD

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In this contribution I will show the first test beam results obtained with CNM 300 micron thick detectors and compare them with laboratory measurements and simulations.

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Electric field and mobility in extremely irradiated silicon

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Electric field in silicon irradiated with neutrons up to 1e17 n_eq/cm^2 was investigated by edge-TCT. Methods for absolute determination of electric field were developed. From the v(E) dependence mobility degradation with fluence was extracted. A simple field structure was observed, consistent with a SCR and "ENB", a region that does not contribute to leakage current and the electric field is consistent with current transport across highly resistive silicon. The observed mobility change and the values of electric field indicate substantial reduction of trapping from linear extrapolation of low fluence values.

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Discussion on Full Detector Systems

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The new IRRAD facility at CERN

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Comparison of pixel detecftors AC and DC coupled to FE-I4 read-out

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After high hadron radiation fluences, the traditional DC coupling of pixel sensors to readout electronics can lead to noise and signal distortion problems, due to the significant current flowing from the sensor through the electronics. AC coupling can offer a more favorable way for feeding the signal to the pre-amplifier, provided that the coupling strength yields a good signal to noise ratio. This presentation shows that indeed the AC coupling is a possible solution for pixel sensors.

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Characterization of thin n-in-p planar pixel sensors and status of the new active edge pixel production

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N-in-p planar pixel sensors with an active thickness of 200 µm produced at CiS,
and 100-200 µm thin active/slim edge sensor devices, produced at VTT in Finland have been interconnected to ATLAS FE-I3 and
FE-I4 read-out chips and irradiated in Ljubljana, Los Alamos and KIT up to a fluence of 1.4×10ˆ{16} n_{eq}/cmˆ2.
Charge collection properties and tracking efficiencies are studied to investigate their possible applications in the inner layers of the ATLAS pixel detectors at HL-LHC.
An update on the status of the new production of active edge pixels at ADVACAM is given.

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Dopping profile Simulations and measurements

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N-in-N, N-in-P and p-Spray implants with varied parameters are simulated and compared with Secondary Ion Mass Spectroscopy measurements in an attempt to understand device characteristics and calibrate the simulation framework. A very good agreement is observed for the intermediate and high doses, while corrections are implemented for measurements performed through the screen oxide layer. Using 3D TCAD simulations, the entire range of possible parameter phase space has been covered, in an attempt to respond to demonstrate validity for different sensor nature.
An irradiation Campaign is undertaken and measured samples are currently under photon bombardment. Using extensive simulations couple with post-irradiation measurement, one could understand dopant behavior and irradiation defects in the bulk, while all samples will be laboratory measured to confirm any obtained result
A second irradiation under neutrons is also planned with the interest of distinguish different kind of defect in each case.

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Discussion on HVCMOS and TCT techniques

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Discussion on TCAD

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Mobility in irradiated silicon

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