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Study of the collection of charge carriers generated close to the Si-SiO2 interface of silicon strip sensors before and after 1 MGy X-ray radiation

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The collection of charge carriers generated in p+-n-strip sensors close to the Si-SiO2 interface before and after 1 MGy of X-ray irradiation has been investigated using the transient current technique (TCT) with sub-nanosecond focused light pulses of 660 nm wavelength, which has an absorption length in silicon at room temperature of 3.5 µm.

Depending on the applied bias voltage, bias history, humidity and irradiation, incomplete collection of either electrons or holes has been observed when illuminating the strip side of the sensor. The data are described by a model which allows a quantitative determination of the losses of holes, the losses of electrons and the width of the accumulation layer below the Si-SiO2 interface.

For non-irradiated sensors little or no charge losses are observed in equilibrium. However, immediately after changing the biasing voltage the sensors are in a non-equilibrium state:
Electron losses occur when the voltage is increased, and hole losses occur when it is decreased. For irradiated sensors electron losses are observed in equilibrium. When the voltage is ramped up the fraction of electrons lost increases, when it is ramped down it decreases.

The time it takes to reach equilibrium is a strong function of humidity: Several days in a dry and of the order 60 minutes in a humid atmosphere. The charge losses and their dependence on bias history and humidity can be qualitatively explained by the time it takes until the charges on the surface of the sensor are distributed in a way that the longitudinal electric field on the surface vanishes and a constant potential is reached. The difference in time it takes to reach the equilibrium is explained by the increase of the surface conductivity with increasing humidity.

The number of charges lost in one laser pulse decreases with the number of charges lost and thus accumulated in preceding pulses. The amount of charge which has to be accumulated until the charge losses vanish, and the time it takes that the initial charge losses are reestablished, have been determined with the laser operated in burst mode.

The observations for sensors from two vendors built from silicon with different crystal orientations and different coupling of the read-out strips to the p+ implants are qualitatively similar.

The relevance of the results for the operation of sensors is discussed.

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