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RD50 Project proposal: Defect engineering in PAD diodes mimicking the gain layer in LGADs

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The proposed project is focusing on the acceptor removal process (ARP) in the irradiated gain layer of LGAD sensors, aiming to understand it and parametrize it for various content of B, C and O impurities and irradiation fluences, in order to find proper defect engineering solutions to maximize the radiation hardness of the gain layers. The studies performed so far on LGAds show that in the p+ layer of LGADs, the ARP can result in a complete disappearance of the gain at 1MeV neutron equivalent fluences higher than 2x1015 cm-2. As major obstacles preventing the achievement of enough knowledge for characterizing and proposing feasible solutions for improving the performance of the gain layers in LGADS are:
(i) the impossibility of performing the needed investigations after high irradiation fluences in the gain layer only, and determine the defects depth profile caused by B and C implantations in the p+ gain layer. This can be usually performed with DLTS when the applied voltage falls entirely only on the gain layer. However, in structures like LGAD, with Boron doped layers of different resistivity, the highly doped gain layer and the low doped bulk, DLTS cannot be applied. The only applicable method in LGAD structures is TSC which can evidence only overall signals generated by all the layers in LGAD devices, including possible also the contribution from the highly B-doped back contact, making the gain layer'ARP characterization not reliable. In addition, by TSC one cannot follow a depth profile of the defects containing implanted impurities. Therefore, a reliable, comprehensive characterization of the gain layer after large fluences cannot be performed on LGAD structures. To characterize the ARP in the gain layer of LGADs one needs special samples containing only the gain layer. Such samples are to be produced via the present common project within RD50.
(ii) the bistability of a B-containing defect with a donor level at about 0.27 eV from conduction band of Silicon (generally attributed to the BiOi complex), measurable in only one of the two configurations –the BiOiA(0/+). This leads to an underestimation of the defect generation rate, gBiOi, and to a discrepancy with the Boron removal rate, gB, as estimated from CV/IV characteristics and used further for modelling the ARP. In addition, there are long time variations of both gBiOi and gB once the samples are exposed even shortly to the ambient light when manipulate them prior to start of the measurements.
For an undoubtful characterization of the ARP process in the gain layer of the LGADs and understand the gain loss in such structures, special samples, mimicking the gain layer in the presence of different amounts of B, O and C impurities, has to be fabricated and studied. CZ and FZ silicon wafers are preferred to start with because the B and O impurities are homogeneously distributed in the bulk of the samples. The variation of C content will be achieved by implantation.

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