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Laboratory and testbeam results for thin and epitaxial planar sensors for HL-LHC

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The High-Luminosity LHC (HL-LHC) upgrade of CMS pixel detector will require the development of novel pixel sensors which can withstand the increase in instantaneous luminosity to $5 \times 10^{34} cm^{-2} s^{-1}$ and collect ~3000 fb^{-1} of data. The innermost layer of the pixel detector will be exposed to doses of about $1 \times 10^{16} neq/cm^2$. Hence, new pixel sensors with improved radiation hardness needs to be investigated. A variety of silicon materials (Float-zone, Magnetic Czochralski and Epitaxially grown silicon), with thicknesses from 50 μm to 320 μm in p- and n-type substrates have been fabricated at one company (Hamamatsu Photonics K.K.) using single-sided processing. The effect of reducing the sensor active thickness to improve radiation hardness by using various techniques (deep diffusion, wafer thinning, or growing epitaxial silicon on a handle wafer) have been studied. The results for electrical characterization, charge collection efficiency, and position resolution of various n-in-p and n-in-n pixel sensors with different substrates and different pixel geometries (different bias dot gaps and pixel implant sizes) will be presented.

Summary

A variety of pixel technologies (3D technologies, diamond, HV-CMOS) are being proposed for the HL-LHC upgrade of CMS experiment. These technologies offer improved radiation hardness but are expensive and difficult to produce compared to planar sensors. In order to continue using planar sensors for HL-LHC upgrade of CMS, radiation hardness needs to be improved. The radiation hardness of planar silicon sensors can be improved by reducing the active thickness of the bulk (50 μm to 120 μm), while collecting good charge above the chip threshold. Various techniques have been used to reduce sensor active thickness (deep diffusion, wafer thinning, and growing epitaxial silicon on a handle wafer). Epitaxial technology allows reducing the sensor active thickness down to 50 μm. Using the new CMS Phase 1 Upgrade readout chip allows reducing the threshold to about 2,000 electrons. Thus, extremely thin epitaxial sensors can be used which improves radiation hardness by reducing charge trapping. Charge multiplication effects have been reported in epitaxial sensors after heavy irradiation, which can improve radiation hardness. We report laboratory and testbeam measurements results for various thin n-in-p sensors with both p-spray and p-stop isolation. The results for electrical characterization, charge collection efficiency, and position resolution will be presented.

Also, a variety of bulk sensor materials (Float-zone, Magnetic Czochralski and Epitaxially grown silicon), with thicknesses from 50 μm to 320 μm in p- and n-type substrates have been fabricated at one company (Hamamatsu Photonics K.K.) using single-sided processing. Parylene-N is used to prevent arcing between sensor and readout chip. Radiation hardness of parylene have been investigated after heavy irradiation. In order to study the effect of pixel implant size and bias dot gap, six different pixel geometries have been investigated. The results for electrical characterization, charge collection efficiency, and position resolution of various n-in-p and n-in-n pixel sensors with different substrates and different pixel geometries (different bias dot gaps and pixel implant sizes) will

be presented.

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