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Development of silicon planar P-I-N photodiode

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The objective of this work is to simulate, fabricate and characterize a silicon planar PIN photodiode. The planar PIN photodiode was selected due to its profound advantages compared to the vertical or surface illuminated photodiode. This research is a novel approach in using Silvaco ATHENA and ATLAS simulation software to design and characterize a planar PIN photodiode. Four devices with active area dimensions ranging from 2500 μm x 6500 μm to 4000 μm x 6500 μm with intrinsic region widths of 0.5mm, 1mm, 1.5mm and 2mm were designed. Breakdown voltage was at –500V with equivalent dark current at 45.7pA. The highest responsivity was achieved at 0.059A/W (total quantum efficiency, η=9.14%, V_r=0.5V, P=0.5mW and λ=800nm) and –3dB cutoff frequency of 0.5kHz. Increment in intrinsic region width reduces the photocurrent, quantum efficiency and the responsivity of the device. The device was fabricated on a n-type <100> silicon substrate using standard CMOS semiconductor processing with five photo mask layers. The fabrication involves RCA cleaning, dry oxidation, boron and phosphorous doping, photolithography, wet etching, metal deposition, metal lift-off, thermal annealing, dicing and planar polishing of the substrate material. Junction depth (x_j) of 1.09μm dan 1.61μm was obtained for the p+ and n+ junctions respectively. The dopant concentrations were $N_A = 8.19 \times 10^{20}$ cm^{-3} and $N_D = 2.02 \times 10^{20}$ cm^{-3}. Characterization of the prototype consists of dark/photo I-V, C-V as well as surface and planar responsivity measurements. Breakdown voltage of –0.8V with equivalent dark current of 0.77μA was achieved. Ideality factor approaching the value of 2 as well as similar shunt and series resistance values in the prototype indicates a bi-directional diode was fabricated. Further analysis on the intrinsic layer of the prototype exhibited high doping densities which contributed to the presence of leakage current as well as generation-recombination currents. The presence of these impurities was suspected to be due to the thin diffusion masking oxide layer.