

## Latest development of HPK/KEK $n^+$ -in-p planar pixel sensor modules for HL-LHC and understanding their performance with TCAD simulations

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We have been developing planar-process pixel sensors in p-type 6-in. silicon wafer for an application in ATLAS detector for the luminosity upgrade of the large hadron collider (HL-LHC). Our motivation is to develop a highly radiation-tolerant and cost-effective pixel sensor for covering large area of the pixel detector. In the 1st prototype pixel sensors, after irradiation and beamtest, inefficient regions in detecting passing-through charged particles in pixel structures were identified, especially associated with the bias rail. New pixel structures were fabricated in the 2nd prototype sensors and are shown to improve the inefficiency greatly. The source of the inefficiency has been understood with technology CAD (TCAD) simulations and improvement in the new structures is being discussed.

The pixel modules are made by bump-bonding the sensors and ATLAS pixel readout ASIC FE-I4's by using SnAg solder bumps. The bumpbonding of thin (150  $\mu\text{m}$ ) sensors and thin (150  $\mu\text{m}$ ) ASIC has revealed an issue associated with the thickness. The issue seems to have been resolved by improving the flatness of the sensors and ASIC by depositing compensation in the backside or by improving the vacuum chucking jigs.

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