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Development of thinned silicon sensors on 8” wafers

Cooperative Research and Development Agreement

Final Report

CRADA Number: FRA-2015-0015

Fermilab Technical Contact: Ron Lipton

Summary Report
20 December 2019

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In accordance with Requirements set forth in Article X.A(2) of the CRADA document, this document is the final CRADA report, including a list of Subject Inventions, to be forwarded to the Office of Science and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

CRADA number: FRA-2015-0015

CRADA Title: Development of thinned silicon sensors on 8" wafers

Parties to the Agreement: Nhnanced Semiconductors, Inc. and Fermi Research Alliance, LLC

Abstract of CRADA work:

Sensors fabricated from high resistivity, float zone, silicon material have been the basis of vertex detectors and trackers for the last 30 years. The areas of these devices have increased from a few square cm to >200 m² for the existing CMS tracker. CMS and ATLAS upgrades will each require more than 200 m² of silicon and the CMS High Granularity Calorimeter (HGC) will require more than 600 m². Cost and complexity of assembly of these devices is related to the area of each module, which in turn is set by the area of the silicon sensors. A move from 4" and 6" wafers (the only sizes currently available) to 8" diameter in volume production has the potential for savings of tens of millions of dollars in the detector upgrade programs at the Large Hadron Collider (LHC) and future experiments. In addition to large area, the devices must be radiation hard, which can be achieved by the use of sensors thinned to 200 microns or less. The combination of wafer thinning and large wafer diameter is a significant technical challenge, and is the subject of this work.

Summary of Research Results:

During this CRADA we fabricated 3 rounds of 8" sensor designs, with design contributions from collaborators at Argonne, SLAC, LBL. These designs included test structures, sensors for CMS pixel and tracker, sensors for ATLAS tracker and various x-ray imaging sensors. We explored a variety of test structures for sensor guard rings as well as process splits to determine the best implantation parameters. The process flow was modeled using TCAD tools at Fermilab. The three major runs included three process variants Silicon-on-Insulator (SOI) on a thick substrate [R2], SOI with the thick handle removed [R3], and Si-Si bonded wafers [R4]. Our results include:

- A single guard ring provides the highest overall breakdown voltage for simple structures;
- R3, the SOI sandwich with handle wafer removed provided the best overall results it also demonstrated satisfactory AC coupling capacitors and resistors;
- R4, the SiSi run, suffered from poor oxide quality and large leakage currents;

- The R3 wafers performed as expected after irradiation, with some indication of excess noise above 250 volts.

The overall performance of the R3 wafers met most of the specifications of the CMS and ATLAS experiments. A viable process was demonstrated. After R3 the Austin Novati foundry was sold and the process would have to be requalified at the NHanced foundry in North Carolina.

Related Reports, Publications, and Presentations:

200 mm Sensor Development Using Bonded Wafers – in preparation

Silicon sensor fabrication on 8" wafers – CPAD 2016

Development of Thin Active Region Sensors on 8" Wafers for for Particle Physics – IEEE 2016

+ many reports at CMS meetings

Subject Inventions listing:

None

Report Date: 20 December 2019

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