Hot spot visual evaluation of breakdown locations in ATLAS18 I'TK strip sensors and test structures

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Abstract

An important characteristic of silicon-based particle detectors, like those used for the forthcoming ATLAS I’TK upgrade for the HL-LHC, is the leakage current. This characteristic is evaluated in the quality control stage of the new I'TK strip sensors performing an IV measurement, where the sensors are biased up to ~700V, typically showing low and stable leakage current. However, some sensors can exhibit a sudden leakage current increase during the IV measurement, so-called early breakdown, making the sensor unusable.

The analysis of these early breakdown conditions typically consists of visual inspection of the sensors using a microscope, as often this is caused by physical damage, be it a deep scratch, chipping on the edges of the sensor, or other damage. But up to this point, the association of the observed damage with the early breakdown is not definitive. Rather, this is an association by correlation, due to the limits of verification by observation with standard equipment.

A hot spot imaging setup has proven to be a valuable diagnostic tool to identify and understand these early breakdown conditions and elaborate on former understandings of these emissions. The regions responsible for the breakdown can be properly located by imaging the intra-red-light emissions produced by them in breakdown conditions. These regions of interest can also be imaged at magnification to evaluate the more precise structure of the breakdown to better understand the damage. The regions discovered, which have improved our understanding of breakdown damage and its symptoms, include scratches, chipping, static charge buildup and manufacturer defects in the ATLAS18 strip sensors and test structures.

The Setup

The Hot Spot setup was adopted into our existing sensor probing station. This consists of a dark chamber, dry air source, and several instruments for biasing and testing ATLAS18 sensors.

The Hamamatsu Orca Quest provided the primary imaging, featuring high resolution, sensitivity, and exposure time with exceptionally low noise levels. Some images will be noted as using another camera, the Teledyne Photometrics Retiga E7. These are very low noise scientific back illuminated CMOS (capturing hot electrons). The captures are primarily in the NIR and IR wavelengths.

The Exact Imaging of Breakdown using the Intra-red Light Emission

This section will explain findings on several samples. Samples are presented using illuminated captures with emission captures overlaid and colorized. Imaging typically requires breakdown current in the 10’s of µA to be visible, typically above 800 V. These pictures confirm that the breakdown is caused by something on the surface, for example static charge in a localized area, if not by apparent physical damages.

Results!

This sample had a very large breakdown area shown (Right) at 950V and 44µA of current. Microscope imaging (middle) of the area shows speckling in the damaged region which was later agreed to be the result of a wobbling damaging the active area.

This sample has a breakdown region that changed over time, left biased at 800V, 25µA. Two captures were taken 2 minutes apart (Middle) shown in red and blue showing an evolution in the breakdown region. Microscope imaging (Right) shows a speckling in the damaged area which was later assumed to be the result of a wobbling damaging the active area.

This sensor had instant breakdown conditions on reception for quality control. It underwent several procedures to attempt to repair it. Recently, the Retiga E7 was used to locate the damage. The wide-angle image (Left) showed an extremely dim illumination on the edge of the sensor, requiring several minutes of 2x2 binned exposure at 950V 24µA. Magnified imaging of the area (Right) shows a strip on the edge producing a faint glow, also requiring several minutes of exposure with 2x2 binning to capture. This sample proved extremely challenging imaging conditions (like instant breakdown) are still achievable.

The area observed with a microscope below shows a defect branching to and shorting the p-stop.

ATLAS18 R4 Wafer 505

This sensor initially passed quality control but started breaking down after the sensor was shipped and received. Breaking down at 220V and imaged at 830V 37µA, emissions were found in the middle of the area with no visible damage. Using a 1-hour 400nm UV light treatment (1), the breakdown no longer occurs until 790V and produces a much smaller breakdown region at the same location (Left) confirmed it was static charge buildup.

Reference

(1) Identification and Recovery of ATLAS18 Strip Sensors with High Surface Static Charge, Zainab Staats, in the same session/proceedings

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