**Long-term humidity exposure of ATLAS18 ITk Strip sensors**


1Santa Cruz Instituto for Particle Physics, 2Simon Fraser University and TRIUMF, 3KEK, 4IMB-CNAM (Catholic)

**Abstract**

The ATLAS collaboration is upgrading its detector for High-Luminosity LHC operations scheduled to start in 2029. This involves making a new all-silicon tracker, called Inner Tracker (ITk), with instrumented strip-area of 165 m2.

The strip sensor type is in-on-p, chosen because of its radiation hardness and a relative fabrication simplicity. So far it has not been used in large-scale experiments. Many years of R&D investigations and pre-production experience showed that it works well, with the specification of the maximum operational voltage of 500 V. The sensors, however, show sensitivity to the humidity, e.g., reduced breakdown voltage at relative humidity (RH) values of about 40% and above. This is an issue for testability, but not real operations, where RH is very low. Therefore, the collaboration adopted the strategy of dry storage, testing, and shipment for sensors and related internal components: modules, staves, and petals. A few days long exposure to ambient air during assembly was shown to be tolerable.

The dry handling strategy becomes much more difficult to implement during the tracker integration, when barrels and disks are put together in large-size cleanrooms with RH range between 50 and 70%. The duration of each of numerous integration steps is several weeks, followed by testing. The effect of such long humidity exposures on the sensor properties was unknown. Therefore, we commenced a study of repeat sensor exposures to 75% RH. We chose 32 sensors for the study from different delivery batches with different pedigrees in terms of initial performance on reception and recovery procedures used. Progressively longer exposures ranged between 4 and 266 days in duration. The cumulative exposure time was up to 2 years. No performance deterioration was seen, as evaluated by the visual inspection, IV characteristics, and other checks. We report the details of the tests, results, and implications.

**INTRODUCTION**

The ATLAS ITk Strip Sensors are in the middle of the full-scale production. The design version called ATLAS18 satisfies the project Specification Requirements [1]. The sensors have a feature that the breakdown voltage (Vbd) is dependent on the ambient humidity. Typically, Vbd is reduced at the relative humidity (RH) levels of 40-50% [2-3]. This is not a problem for operations, where a very dry environment is anticipated.

During the sensor tests where humidity matters, such as IV, CV, and Long-Term Stability (LTS) tests, RH is maintained under 10% [1]. This is straightforward to achieve in relatively small enclosures required for sensor, module and stave/petal tests, using either desiccant units or external gas line hookup to dry air or nitrogen. The setups for the large-scale tracker objects, such as disks and cylinders, are different. They need large chambers; volumes, which are impractical to keep dry at all times. Therefore, it is important to investigate a question of the long-term sensor tolerance to the ambient humidity. Given the Specifications for the cleanrooms and the construction plans, we forecast the question of whether after a several months long exposure to RH of 50% to 70%, would the ATLAS18 sensors still have the acceptable Vbd > 500 V, as shown by the IV tests performed in a dry environment (RH<10%)?

**Sensor Samples and Exposure Setups**

The sensor selection:
- At first, 8 devices from 5 pre-production batches. Their operation started in March 2021.
- In July 2022, additional 16 devices from 13 production batches were added. Their selection targeted sensors after performance recovery methods applied, UV irradiation or “baking” [4].

The setups:
- For the first 3 months, the "flattened" setup used. It was not scalable to the larger quantity of sensors.
- A dedicated hermitized cabinet was commissioned and used for the rest of the exposure, to scale up the total number of sensors to 24. They were arranged in vertical holding structures.
- To control the humidity, Oasis Humidor unit was used with a set point at 75% RH, above the expected humidity range. The setup temperature varied between 19 C and 23 C.

**Additional Tests:**

**LTS**
- After the last humidity exposure we performed a Stability test as an additional check on the sensor operation. The current variance during the standard 40-hour test was well within the specification of ≤15%.

**Humidity dependence:**
- During some of the testing periods we varied the humidity environment in the test enclosure to re-assess the influence of the humidity on Vbd. As expected, Vbd typically is reduced at higher RH values, although non-uniformly.

**CONCLUSIONS**

We investigated the ATLAS ITk Strip Sensors susceptibility to long-term humidity exposure. This performance analysis was done on the large-scale assembly of the final tracker parts, which will be exposed to the high ambient humidity for several months at a time. The target RH of 75% was intentionally maintained above the 50%-70% specification for the final assembly rooms. The longest single exposure was 266 days, and the longest cumulative exposure was 3 years. The following features were observed:

- The breakdown voltages tested in dry atmosphere did not change during the exposures.
- There was an expected dependence of Vbd on RH in humid environment.
- LTS tests after all the exposures showed typical good results.
- In repeat inspections we have seen no sign of corrosion.

We attribute the results to the high sensor quality and dedicated passion/tor feature designs to reduce the humidity sensitivity.

**References**

1) Y. Unno, et al., “Specifications and Pre-production of a new Large-Format Strip Sensors fabricated in each Silicon Wafer,” ATLAS18, for the Tier 3 User of ATLAS detector for high-luminosity LHC operation.” 2023, INFN 17, 05296


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