Analysis of humidity sensitivity of silicon strip sensors for ATLAS upgrade tracker, pre- and post-irradiation

ABSTRACT

- During the prototyping phase of the new large area ATLAS ITk silicon strip sensors, the community observed a degradation of the breakdown voltage when the devices with final technology options were exposed to high humidity. In 2020, the ATLAS strip sensor community started the pre-production phase, receiving the first sensors fabricated by Hamamatsu Photonics K.K. using the final layout design. The work presented here is focused on the analysis of the humidity sensitivity of production-like sensors with different surface properties, before and after irradiation.

DEVICES UNDER TEST

- Special batch fabricated by Hamamatsu Photonics K.K., implementing variations during the fabrication process to obtain different surface characteristics, such as “special treatment” (Type A, production-like), “additional treatment” (Type A’), “special masking” (Type B), “thicker passivation” (Type C) and “p-spray addition” (Type D high and low). Several sensors tested for each type.

RESULTS PRE-IRRADIATION

- Humidity Sensitivity and training effect: All sensor types tested at low (<10%), cleanroom (35-45%) and high (50-60%) humidity. After high humidity exposure, test repeated at low humidity several times to study the benefits of the “training”. Type D low shows the better performance at cleanroom and high humidity. Type C the fastest recovery.
- Short-term (40h) high humidity exposure: All sensor types tested at low (<10%) and high (50%) humidity. Then, exposed 40h to high humidity and re-tested at high and low humidity. All sensor types showing similar breakdown at high humidity before and after exposure.

RESULTS POST-IRRADIATION

- Prototype sensor irradiated with protons up to 5e14 neq/cm2 was tested at different humidity levels, showing no sensitivity after irradiation.

CONCLUSIONS

None of the different processing splits seems to completely mitigate the humidity sensitivity, but some surface characteristics can improve the breakdown voltage dependence and recovery:

- ✓ A low dose of p-spray (Type D low) substantially improves the breakdown voltage deterioration at cleanroom and high humidity. P-spray could prevent the accumulation of hydrogen ions in presence of humidity, reducing the sensitivity.
- ✓ Sensors with thicker passivation (Type C) show the fastest performance recovery after humidity exposure.
- ✓ All sensor types show similar breakdown voltage before and after 40h of humidity exposure, also showing a fast recovery in low RH.
- ✓ Prototype sensor irradiated with protons shows no sensitivity to humidity changes, suggesting a progressive improvement during irradiation. Sensors with different surface characteristics and irradiated to different fluences are currently under test, and results will be incorporated to the manuscript.

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