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Design, Production and Testing of ATLAS ITk Strip Bus Tapes

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The bus tapes required for ATLAS ITk strips are very challenging because of the data rates and lengths of the transmission lines. The impedances need to be very well controlled. The designs must allow for sensor operation at 500V. The required quality of the Ni/Au plating for wire bond pads is difficult to achieve for such large tapes. The tapes must be radiation tolerant and we have seen material that failed the tests. Custom Bus Tape Testing Robots have been produced to check all the electrical and dimensional requirements. Tapes are in production at CERN and Elgoline.

Summary (500 words)

The bus tapes required for ITk strips for the barrel and Endcap are very challenging. The tapes have very long (up to 1.4 m) differential lines with 100 um track and gap. These lines are used for transmission of data to and from modules to the End of Structure (EoS) card which is the interface to the off-detector electronics. Data transmission at 640 Mbps is challenging because there is significant attenuation along the lines and the impedance needs to be controlled to +/- 10%. The tapes provide low-voltage and high-voltage power for the modules. The detectors will be operated at up to 500V, it is essential to ensure sufficient separation between any exposed HV track and a ground. The dimensional tolerance on the tapes is 600 um. The tapes are an integral part of the grounding design.

Radiation testing showed that the coverlayer glue failed for the material used by a commercial manufacturer for barrel tapes for a dose of 500 kGy(Si). In parallel, prototype tapes at CERN using a different base material and cover layer were produced. The radiation tests of the material used for the CERN tapes were successful. Therefore, CERN has been selected as the preferred supplier for the barrel tapes.

Endcap tapes are being produced by Elgoline. The CERN tapes use vias to connect the two copper layers. The Elgoline tapes use laser ablation to create openings in the top polyimide layer to allow wire bonding to pads on the bottom copper layer. Obtaining high yields for such large flexible tapes with many narrow tracks is challenging. Achieving the desired 100 Ohm impedance requires very careful tuning of the width of the 100 um lines.

The Ni/Au plating of the pads to allow Al wire bonding is very challenging for large tapes. The laser ablation to allow connections to the bottom copper layer, impacts the surface finish for the bottom copper layer. A subsequent “jet scrubbing”process is used to obtain the correct surface finish. For the long barrel tapes, the Ni/Au plating was particularly challenging.

Extensive QC/QA is needed in production to ensure high yields. This includes measuring the copper thickness before etching an XRF measurements of the thickness of the Ni and Au layers in the bond pads. The impedance of a test trace in is measured. The mean pull force should be > 10 gm of wire bonds in sacrificial regions.

In order to ensure that all tapes that are used in ITk are fully functional, a custom Bus Tape Testing Robot (BTTR) has been designed and is in use at all tape testing sites. The BTTR contains two stages carrying cameras and an electrical probes that are used to connect pads for testing for open and short circuits. The BTTR also checks that high voltage leakage current is less than 20 nA. The BTTR measures fiducial locations to check the dimensional requirements.

Tapes are in production at CERN and Elgoline

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