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ATLAS SCT hybrid experience

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ATLAS semi-conductor tracker (SCT) has chosen the Cu-polyimide flex circuit, reinforced with a carbon-carbon substrate for its ATLAS SCT barrel modules. We report the successes, and problems encountered and solutions, during the course of production of 2,600 pieces of the hybrid.

Summary

The inner detector (ID), for tracking the charged particles in the 2-Tesla solenoidal magnetic field, of the ATLAS detector at LHC is made of 2 detecting media: silicon and gas. The latter is the transition-radiation tracker (TRT) in the outer regions. The former is further made of 2 types: the pixel for the inner region (PIXEL) and the microstrip detectors for the middle region (SCT). The detector unit of the central barrel region of the SCT is made from the so-called ATLAS SCT barrel module as shown in Figure 1. The strips run horizontally and 6 ASIC's, 128 channels each, sense the strips on the top and the bottom side of the module. The hybrid that carries the ASIC's is the ATLAS SCT barrel hybrid.

The hybrid is set in the centre region in the module such that the geometry allows clear overlapping of the adjacent modules along the strip direction, reducing the input resistance to the front-end transistor to 1/4 compared with the sensing at the end of the strips, thus reducing the input noise. The hybrid is only glued to the cooling tabs at ends and not glued to the surface of the sensors for the minimum damage to the sensors.
The hybrid for one module is made of one-piece of Cu-polyimide flex circuit, from the Input/Output (IO) connectors to the end of the circuit in the bottom side. The flex-circuit was bent 180 degrees for wrapping around the sensors from the top to the bottom side. The area of the ASIC's are reinforced with a carbon-carbon substrate for excellent thermal conductivity, strong mechanical strength, good electrical conductivity, and lightweight. The excellent thermal conductivity is required for removing the heat from the ASIC's. The strong mechanical strength is required for allowing the wire-bonding from the ASIC's to the sensors where no direct supporting underneath the ASIC's exists. The good electrical conductivity reinforces the electrical stability of the ASIC's operation, together with the intrinsic stability of the Cu-polyimide flex circuit. The lightweight means the low radiation length.
The ATLAS uses 2,112 SCT barrel modules in the experiment and required 2,600 hybrids including spares and losses. With 50 pre-series production hybrids, the final design and production readiness review (FDR/PRR) were carried out, with the results of mechanical, thermal, and electrical performances. At around the 10% of series production, the production advance review (PAR) was carried out for monitoring the quality and performance in the series production. The quality and performance of the pre-series and series production were as expected and no serious flaw or trouble was surfaced.
Whole through the production of 2,600 pieces, the Cu-polyimide flex circuit did not encounter a major problem. The design followed the industry's design rules maximally. Neither breakage of traces nor delaminating of the layers was encountered. There were two minor problems: one was the residue of adhesives and the other was the residue of the solvent on the surface of the circuit, such that these residues weakened the sticking of the wire-bonds. The wire-bond strength was monitored continuously and the weakening of the wire-bond strength fed back to the production process and the problem was quickly removed.

The major problem appeared in a small piece in the hybrid, the so-called pitch-adapter. Since the pitches of the strips (80 microns) and ASIC's (48 microns) were different, the fanning traces were made with pure-aluminium traces on glass substrates. Up to the PAR quantity, the wire-bond strength on these pitch adapter was as expected. At about 15% production, the wire-bond strength started to decrease gradually. Reduction of the strength also associated with the generation of the "whiskers"around the wire-bond feet. The problem was traced to the quality of the aluminium metalisation and the metalisation process was improved subsequently. At around 50%, and again around 70%, of the series production, the yield of acceptable generation of whiskers was decreased. In order to solve the problem, the series production was stopped for a few months each.
A through investigation of the problem traced the source of the problem to the deep inside the aluminium metalisation process. Also the yield varied depending on the wire-bonding machines, possibly due to the shape of the wedges and the frequency and power of the ultra-sonic. The key parameter of the problem seemed to be the hardness of the metalised aluminium. The hardness was revealed to be required harder than the pure-aluminium. However, when it became too hard, it did not allow the wire-bond to stick. The hardness was identified to be a function of the temperature at metal-deposition. After identifying the mechanism and tuning the temperature to be the right range, there were no more problems till the end of the series production.

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