Production of bus-extender for sPHENIX INTT detector

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sPHENIX is the second-generation heavy-ion collision experiment at the Relativistic Heavy-Ion Collider aimed at studying the properties of strongly coupled quark-gluon plasma. The intermediate tracker, INTT, is a silicon strip detector in sPHENIX that is used to perform precise tracking near the crossing point of colliding nuclei.[1)] A special cable for INTT called bus-extender is required to transmit large amounts of data from INTT to the readout electronics at high speed. The bus-extender is more than 1 m long and routed with a curving path. We developed the bus-extender based on flexible printed circuit (FPC) technology since no commercial cable is available.

The bus-extender is composed of four Cu layers including signal, power, and ground layers laminated with a liquid crystal polymer as a dielectric substrate. The signal layer contains 62 pairs of low-voltage differential signals within a 5 cm width of the cable, and their lines and spaces are both 130 μm.

We built prototype bus-extenders with a length of 1.3 m, as shown in Fig. 1, and evaluated their electrical and mechanical performance. The signal loss due to a long transmission line was 30%. The peel strength among the laminated layers was greater than 15 N/cm. These results are summarised elsewhere.[2)] From the results, the performance of the prototype is sufficient to satisfy the requirements. We completed the development and moved to the production stage.

The fabrication procedures are as follows: 1) the pattern of signal lines is printed by photolithography and etching, 2) all four layers are laminated by bonding sheets with pressure, and 3) through holes are opened and Cu-plated to connect the signal lines between the inner and outer layers. During the fabrication, we found that the yield rate was 30% because of short and open circuits of signal lines. Figure 2 shows two examples of short and open circuits found in the first fabrication procedure. This poor yield rate needs to be improved for the mass production since the yield rate directly impacts the production cost. We investigated why the short and open circuits were produced and found that the major cause of the problem is the contamination of tiny dust particles, which can interrupt light exposure and the flow of the etching solution. To solve the problem, we added two steps to the first procedure. One is to remove dust particles as much as possible using a silicon rubber roller. The other is to check the open/short lines after etching and to remove the bad signal layer in the later lamination process if found. With these new steps, the yield rate was improved to 75%. The visual inspection of signal lines after etching is useful to improve the yield rate further. An inspection system to search the bad lines semi-automatically is under development.[3)]

Fig. 1. Prototype bus-extender with a length of 1.3 m.

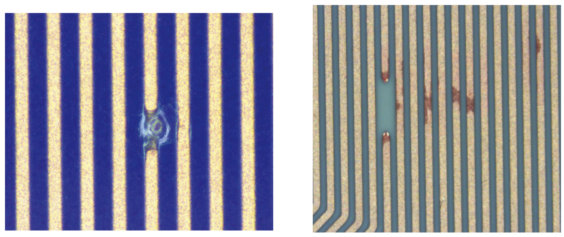

Fig. 2. Examples of short and open circuits after the photolithography (left) and etching (right).

In summary, the development of the bus-extender was completed, and new steps added to the fabrication procedure successfully improved the the yield rate. The mass production of the bus-extender will be started in January 2022 with the semi-automated inspection system.

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References

1) I. Nakagawa *et al.*, in this report.
2) T. Kondo *et al.*, submitted to IEICE Electron. Expr.
3) H. Imai *et al.*, in this report.