Development of long and high-density data bus for sPHENIX INTT detector

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The intermediate tracker (INTT) is a silicon strip barrel detector for the sPHENIX experiment.[1)] INTT is implemented in a tight space between an inner silicon detector (MVTX) and the outer TPC, and the readout electronics are placed 120 cm away from the detector. The data bus of INTT must satisfy the following requirements:[2)] (1) flexibility, (2) length of at least 120 cm, (3) high-density signal line (128 lines/5 cm), and (4) high-speed signal transfer (by LVDS). It is challenging to meet all the requirements because high-speed signal transfer and a long data bus are contradictory.

To investigate the technical feasibility of the data bus, we made a prototype of the long and high-density data bus using flexible printed circuit (FPC), which is a film based PC board. A liquid crystal polymer (LCP) was chosen as the film material to reduce signal loss due to the small dielectric tangent. The prototype is a three layer structure in which the middle signal layer is sandwiched by the top and bottom ground layers for a differential impedance (Z_{diff}) of 100 Ω. Figure 1 shows an FPC sheet containing five sets of the signal layer before laminating the top and bottom layers.

We evaluated the electrical and mechanical characteristics of the prototype. As a result, we found that the signal attenuation and return loss are −3 dB and −20 dB, respectively, and Z_{diff} is 90 Ω. The thiner line is preferable for 100 Ω, but more difficult to produce without troubles. The signal distortion was visually tested using the eye diagram. The eye is clearly open as shown in Fig. 2 (left). We also found that the accuracy of the width of the signal lines is ±3 μm from the measurement of the line widths for 40 lines on the FPC as shown in Fig. 2 (right). These results show that the prototype meets the requirements within the scope of the specification.

However, two issues are found in the prototype FPC. One is that the peel strength of the laminated layers is weak, and the other is that it is difficult to produce the through holes for long FPC. We studied several ways to improve the peel strength. The current status is reported in Ref. 3).

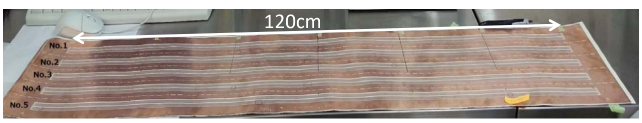

Fig. 1. LCP sheet of the signal layer for the prototype.

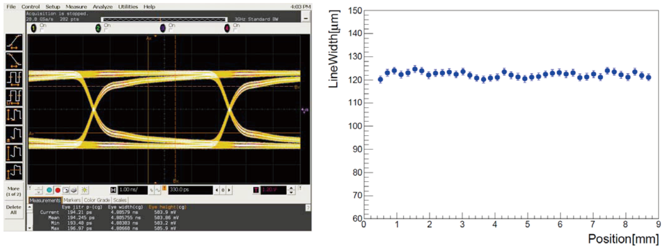

Fig. 2. Characteristics of the prototype FPC. (Left) Clear opening of eye diagram (Right) small variation of the line widths.

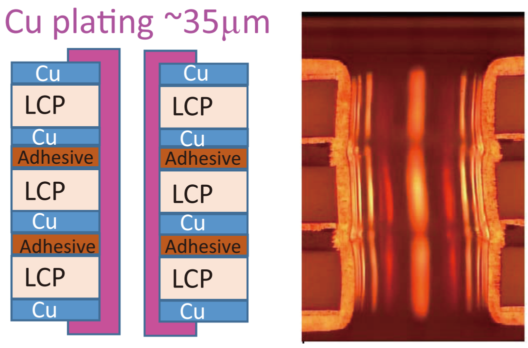

Fig. 3. Result of the Cu-plating for the four layer FPC. (Left) Schematic view of the laminated structure of FPC with Cu-plating. (Right) Result of Cu-plating.

The through hole is produced by drilling a hole on the FPC and Cu-plating the surface of the hole through an electro-chemical process. This requires a big chemical bath to soak the entire FPC. We looked for a company that has a bath big enough for INTT data bus. Along with the company, we tested the Cu-plating on the through hole for the 4 layer FPC. Figure 3 shows the Cu-plating result, which was successful. We will investigate the reliability of the through hole with a thermal shock test as a next step.

We evaluated the feasibility of the long and high-density data bus using FPC. Most of the issues were solved, and some technical issues found in the study are under further investigation. Based on the knowledge from the prototype, we are making the production version of the data bus for INTT. The production version will be tested in 2019.

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