Development of long multi-layered flexible cable of silicon sensor detector for sPHENIX experiment

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The progress in the new development of the bus extender[1)] for the sPHENIX intermediate tracker (INTT) is reported. The INTT composed of silicon strip sensors. Due to a tight space budget around the collision area, the space to run signal cables for INTT is strictly limited. Thus, high density signal transfer cables are required to send signals from silicon sensors to the front-end readout electronics by 1.3 m. The additional requirements to the cable are flexibility and the impedance matching with circuits to be connected to. As defined in the Eqs. (1) and (2), one of the key essences is the signal line width and pitch.

$$Z_{\mathrm{dif}} = 2 \times Z_0 \exp\left(1 - 0.374 e^{-2.9\frac{S}{D}}\right) \tag{1}$$

$$Z_0 = \frac{60}{\sqrt{\epsilon_r}} \ln\left(\frac{4D}{0.67\pi(0.8W + d)}\right) \tag{2}$$

Here, Z_{dif} and Z_0 are differential and characteristic impedance, and ϵ_r is the relative dielectric constant. For given impedance, the narrower the line width, the thinner the cable can be. Thus we need to design the signal line width as narrow as possible for the cable to be flexible.

In order to judge the technological limit of a finest width and pitch of the signal line of long flexible print cables (FPCs), we measured a 1.3-m long sample FPC, as shown in Fig. 2, manufactured by the Print-Electronics Laboratory. The measurement was conducted for 32 signal lines whose width were designed to be 120 μm.

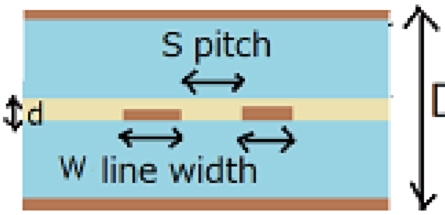

Fig. 1. Cross section of differential signal lines. S and W are line width and pitch, respectively. D and d are thickness between ground planes and thickness of signal layer, respectively.

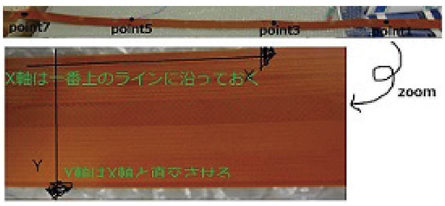

Fig. 2. Sample FPC

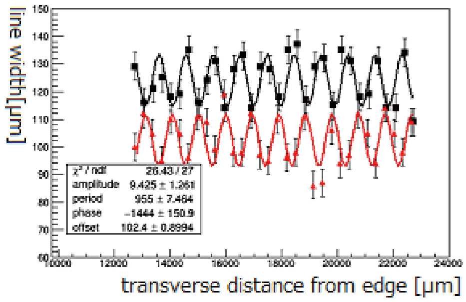

Fig. 3. Observed line width (y-axis) of the sample FPC (black) and its mask(red). The x-axis is the transverse distance from the edge of the sample FPC.

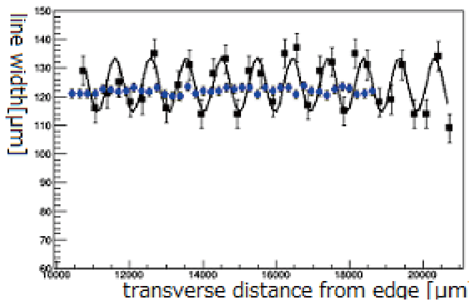

Fig. 4. Observed line widths of the new prototype FPC (blue) superimposed on these of the sample FPC.

The observed line widths are plotted in Fig. 3 (black symbols). As can be guided by the curve showing a sine function fitting, the observed line-width oscillates by 10 μm with a constant (< 1 mm) repetition. Most likely, the origin is propagated from the mask itself used at an exposure process. As shown by black symbols, almost exact pattern was observed in the mask. Therefore, we employed a higher precision mask printer to produce the next-round prototype FPC. The resulting line-width data are superimposed in Fig. 4 on top of previous measurements of the sample FPC. As is apparent from the Fig. 4, the new mask successfully provided much better precision (3 μm) of the line width. There found 10 μm offset in the line width between the FPC and the mask. This offset can be diminished by design the line width 10 μm narrower for the mask on purpose.

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References
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2) I. Nakagawa *et al.*, in this report.