INTT Ladder NIM Major Modification for resubmission

RIKEN/RBRC

Itaru Nakagawa

2025/7/20

Definition of Cell and Block

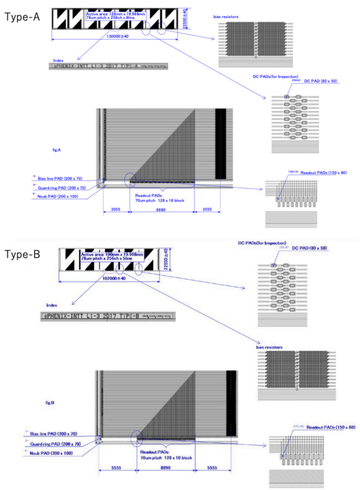


Figure 5: The layout design of the type-A (top) and type-B (bottom) silicor

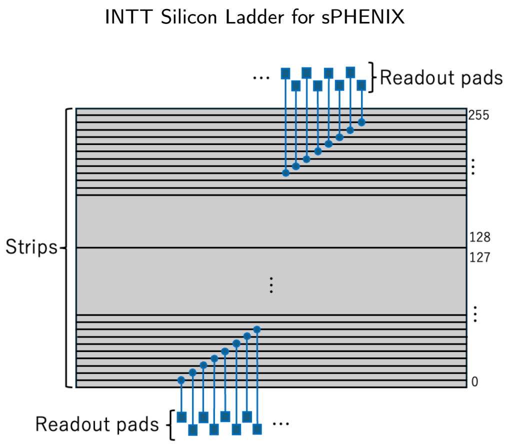


Figure 6: The schematics of the double metal structured strips and their readout lines [10].

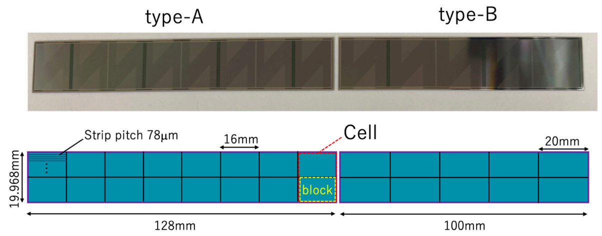


Figure 5: The photo of type-A and type-B silicon strip sensors (top). The layouts of the cell and the block are defined in the schematic drawing (bottom). The dimensions are presented for the active area of sensors [13]. The strip pitch is not scaled in the drawing.

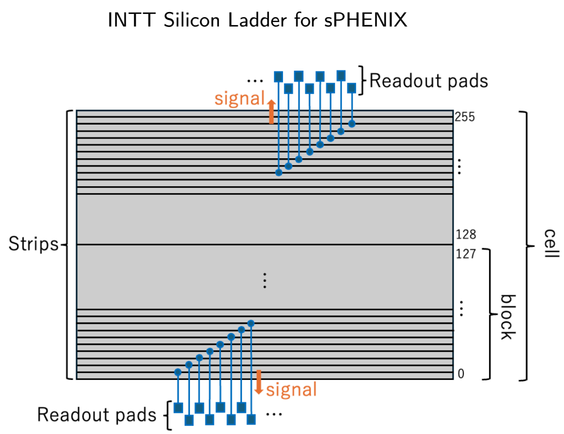


Figure 6: The schematics of the double metal structured strips and their readout lines [13].

How good the heat conductivity?

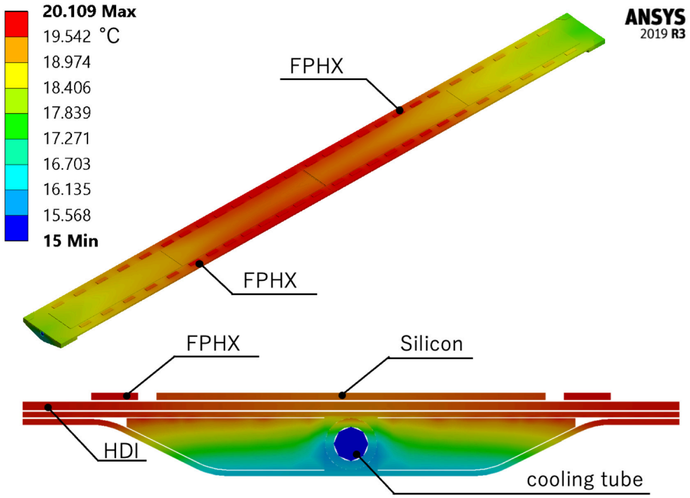
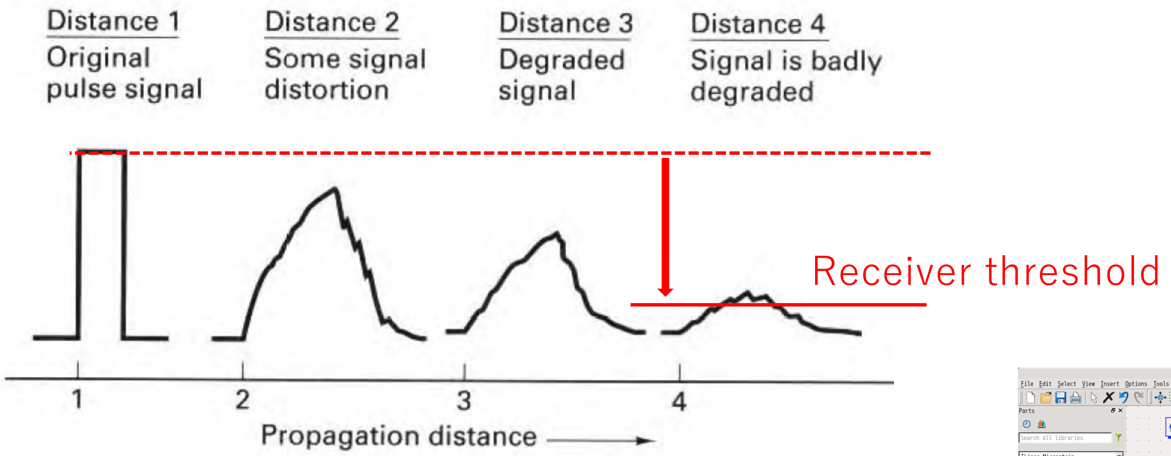


Figure 12: The simulated results of the thermal conductivity of the ladder. The top figure displays the top surface of the ladder, while the bottom figure shows the cross section of the ladder.

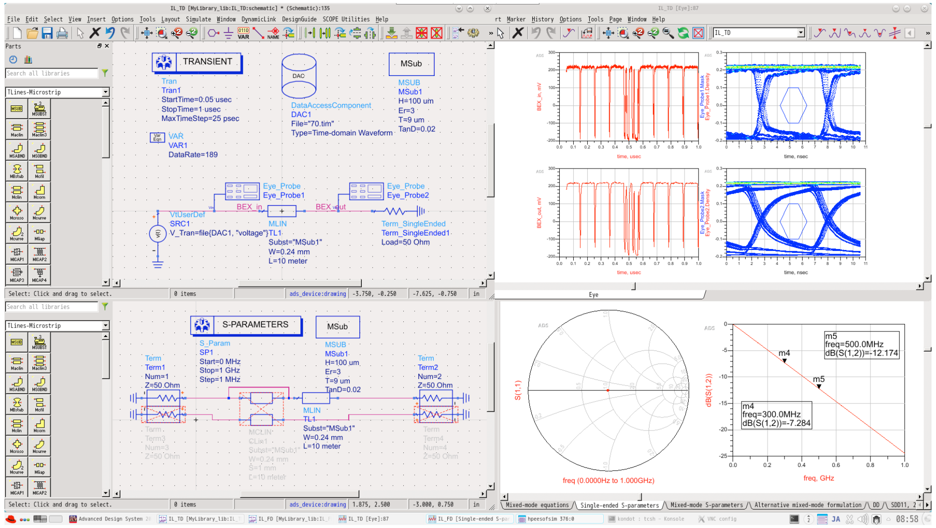
New figure added with supplemental explanation in the main test.

The overall thermal performance for the ladder was studied using an ANSYS 2019 R3 with the Steady State Thermal module[23]. Shown in Fig. 12 is the simulated results of the ladder with the following boundary conditions; 1) inlet water temperature = 15 °C, 2) flow rate 0.12 l/m, 3) natural convection at 20 °C room temperature, 4) 3 W total dissipation from the 52 FPHX chips. The chips in the middle of the ladder are hottest due to its shorter spacing between chips, but it is kept near room temperature. The temperature difference between the hottest spot and the cooling water is predicted to be $\Delta T = 5.1$ °C. The actual measurement of ΔT was well reproduced by this ANSYS simulation within 10%.

Allowance of Signal Transmission Loss



Simulation by T. Kondo (TIRI)



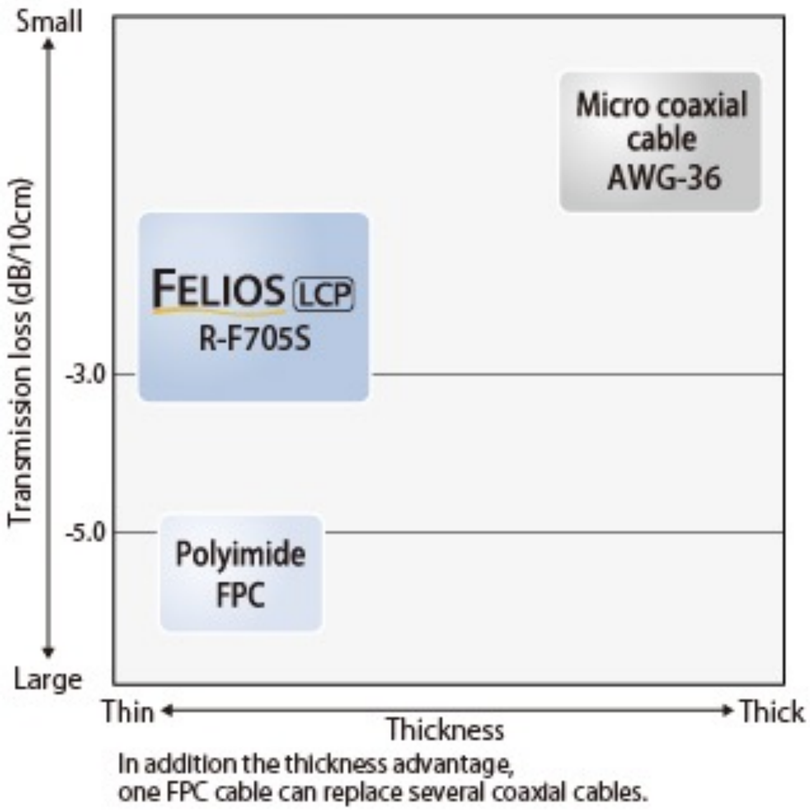
FPHX

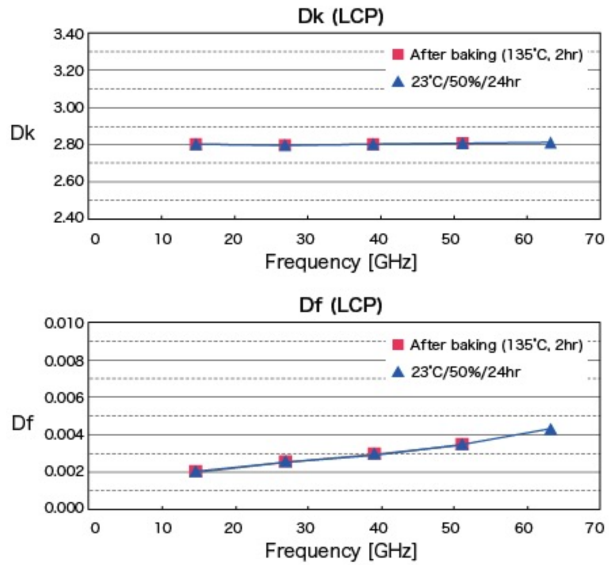
ROC

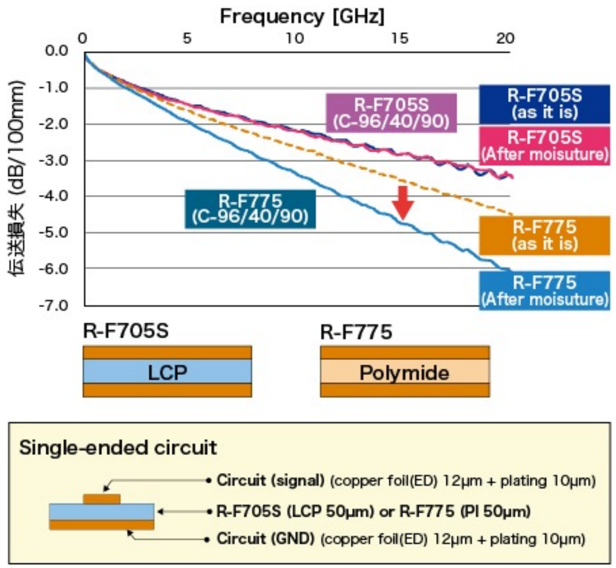
The allowance was estimated to be (-12dB) -75%.

https://industrial.panasonic.com/sa/products/pt/felios/felioslcp

LCP vs Polymide







Original statement: LCP was employed due to its smaller signal transmission loss and thick (100μm) product was available

DuPont Pyralux Datasheet

DuPont™ Pyralux® AP

All-Polyimide Double-Sided Copper-Clad Laminate

Flexible Circuit Materials

Product Description

DuPont™ Pyralux® AP is a Double-sided Copper-clad Laminate featuring an adhesive-less, all-polyimide dielectric layer. This material is ideal for multilayer flex and rigid-flex applications that required advanced performance, including low loss properties for excellent signal integrity and thermal resistance for high reliability. Available in a range of conductor and dielectric thicknesses, Pyralux® AP clads provide designers and fabricators outstanding options for fabricating high performance circuits.

Key Features and Benefits

- Low loss all-polyimide dielectric for superior signal integrity
- Excellent bond strength affords high reliability
- High thermal resistance to facilitate processing
- Balanced and unbalanced constructions available
- Certified to IPC-4203/11
- UL 94 V-0, UL File E124294
- RoHS Compliant

Packaging

Pyralux® AP Double-side Clad is supplied in sheet form, with standard dimensions of 24 x 36 in (610 x 914 mm), 24 x 18 in (610 x 457 mm), and 12 x 18 in (305 x 457 mm).

Table 1 - Pyralux® AP Construction Options

Laminate Component			
Copper Foil Thickness, µm (oz/ft²)	6 (0.17) 9 (0.25) 12 (0.33)	18 (0.5) 35 (1.0) 70 (2.0)	105 (3.0) 140 (4.0)
Copper Foil Type	RA, ED, and Double-treated RA		
Dielectric Thickness, µm (mil)	12 (0.5) 25 (1.0)	50 (2.0) 75 (3.0)	125 (5.0) 150 (6.0)

Table 2 - Standard Pyralux® AP Offerings

Product Code*	Copper Thickness µm (oz/ft²)	Dielectric Thickness µm (mil)
AP8515R	18 (0.5)	25 (1.0)
AP9111R	35 (1.0)	25 (1.0)
AP9121R	35 (1.0)	50 (2.0)
AP9131R	35 (1.0)	75 (3.0)
AP9141R	35 (1.0)	100 (4.0)
AP9151R	35 (1.0)	125 (5.0)
AP9161R	35 (1.0)	150 (6.0)

*At the end of the product code, "R" designates rolled-annealed copper (e.g., AP9111R), "E" designates electro-deposited copper (e.g., AP9111E), and "D" designates double-treated rolled-annealed copper (e.g., AP9111D).

DuPont™ Pyralux® AP

All-Polyimide Double-Sided Copper-Clad Laminate

Flexible Circuit Materials

Product Performance

Table 3 - DuPont™ Pyralux® AP Double-sided Copper-clad Laminate Properties

Property	AP9121 Typical Value	Test Method
Dielectric Constant (Dk) 1 MHz 10 GHz	 3.4 3.2	 IPC-TM-650 2.5.5.3 ASTM D2520
Loss Tangent (Df) 1 MHz 10 GHz	 0.002 0.003	 IPC-TM-650 2.5.5.3 ASTM D2520

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Loss Tangent (Df) 1 MHz 10 GHz	 0.002 0.003	 IPC-TM-650 2.5.5.3 ASTM D2520
Peel Strength (Adhesion to Copper) As Received, N/mm (lb/in) After Solder, N/mm (lb/in)	 1.4 (8) 1.4 (8)	IPC-TM-650 2.4.9
Dimensional Stability (MD/TD) After Etching, % After Thermal (200 °C for 30 min), %	 ± 0.04 to ± 0.08 % ± 0.04 to ± 0.07 %	IPC-TM-650 2.2.4
Coefficient of Thermal Expansion XY-Axis, ppm/°C	Below Tg - 25 / Above Tg 30	IPC-TM-650 2.4.41
Solder Float, 288 °C for 10 s	Pass	IPC-TM-650 2.4.13
Moisture Absorption, %	0.8	IPC-TM-650 2.6.2
Moisture & Insulation Resistance, Ω	$> 10^{11}$	IPC-TM-650 2.6.3.2
Dielectric Strength, V/µm	200	ASTM D149
Volume Resistivity, Ω · cm	$> 10^{17}$	IPC-TM-650 2.5.17
Surface Resistance, Ω	$> 10^{16}$	IPC-TM-650 2.5.17
Tensile Modulus, GPa	4.8	IPC-TM-650 2.4.19
Tensile Strength, MPa	345	IPC-TM-650 2.4.19
Elongation, %	50	IPC-TM-650 2.4.19
Flexural Endurance, cycles	6,000	IPC-TM-650 2.4.3
Glass Transition Temperature (Tg), °C	220	DuPont Method, TMA

Data within this table are typical values for the listed product. Performance can vary depending on construction and processing.

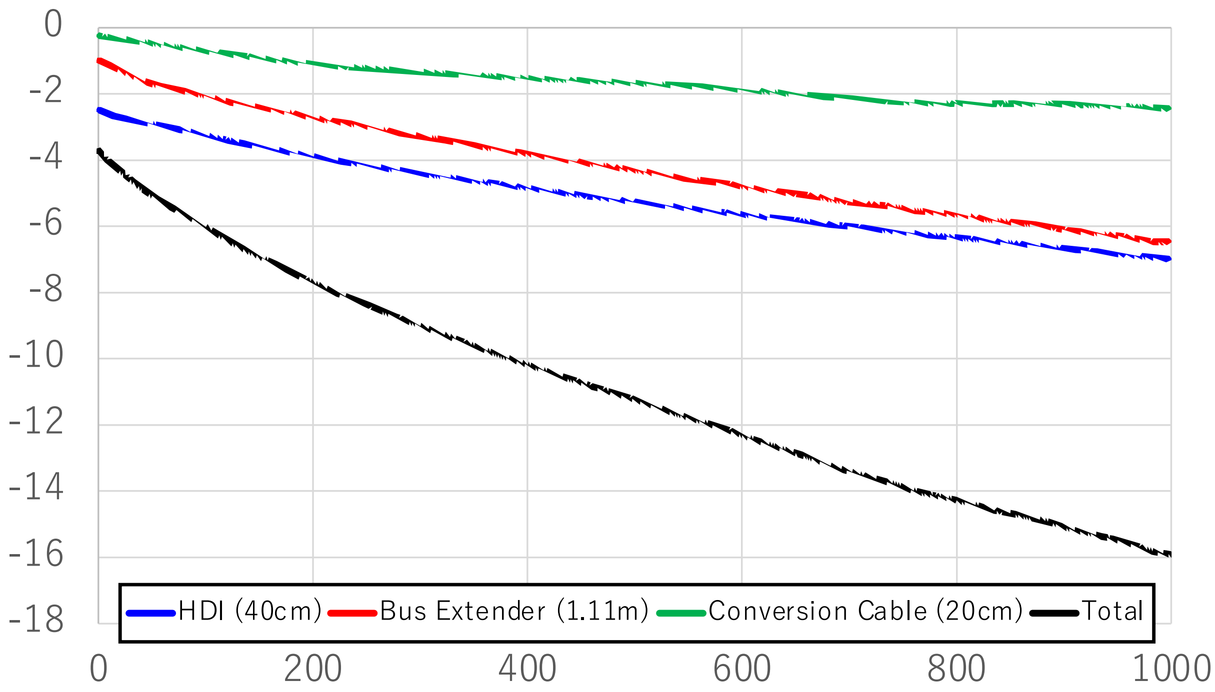
https://www.dupont.com/resource-center.html?BU=eni&shared-asset=Doc-EI-10124-Pyralux-AP-Data-Sheet.pdf

Advantage of LCP

	Panasonic FELIOS R-F705S LCP	Dupont Polyimide AP9141R	Panasonic Polyimide R-F775
Thickness [um]	100	100	25
Dielectric Constant	3.3 @ 10 GHz	3.4 @ 1MHz 3.2 @ 10GHz	3.2 @ 1GHz
Dissipation Factor	0.002 @ 10 GHz	0.002 @ 1MHz 0.003 @ 10GHz	0.002 @ 1GHz
Water absorption	0.04 % (24 hours/23°C immersion)		0.9% (24 hours/23°C immersion)

Changed strategy to stress the moderate water absorption as the advantage of LCP

Signal Transmission Performance



Added measured results of insertion loss for each cables up on suggestions to evaluate the signal transmission performance of each cables from the reviewer-A.

Also estimated safety factor 5 or more at 500 MHz based on the knee frequency of 800 ps signal rise time.