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Evaluation Technology of Practical Electric Properties for High Frequency Materials

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Printed Wiring Board Materials Business Sector

Hitachi Chemical Co., Ltd.

Trend of high-Speed & high-frequency applications

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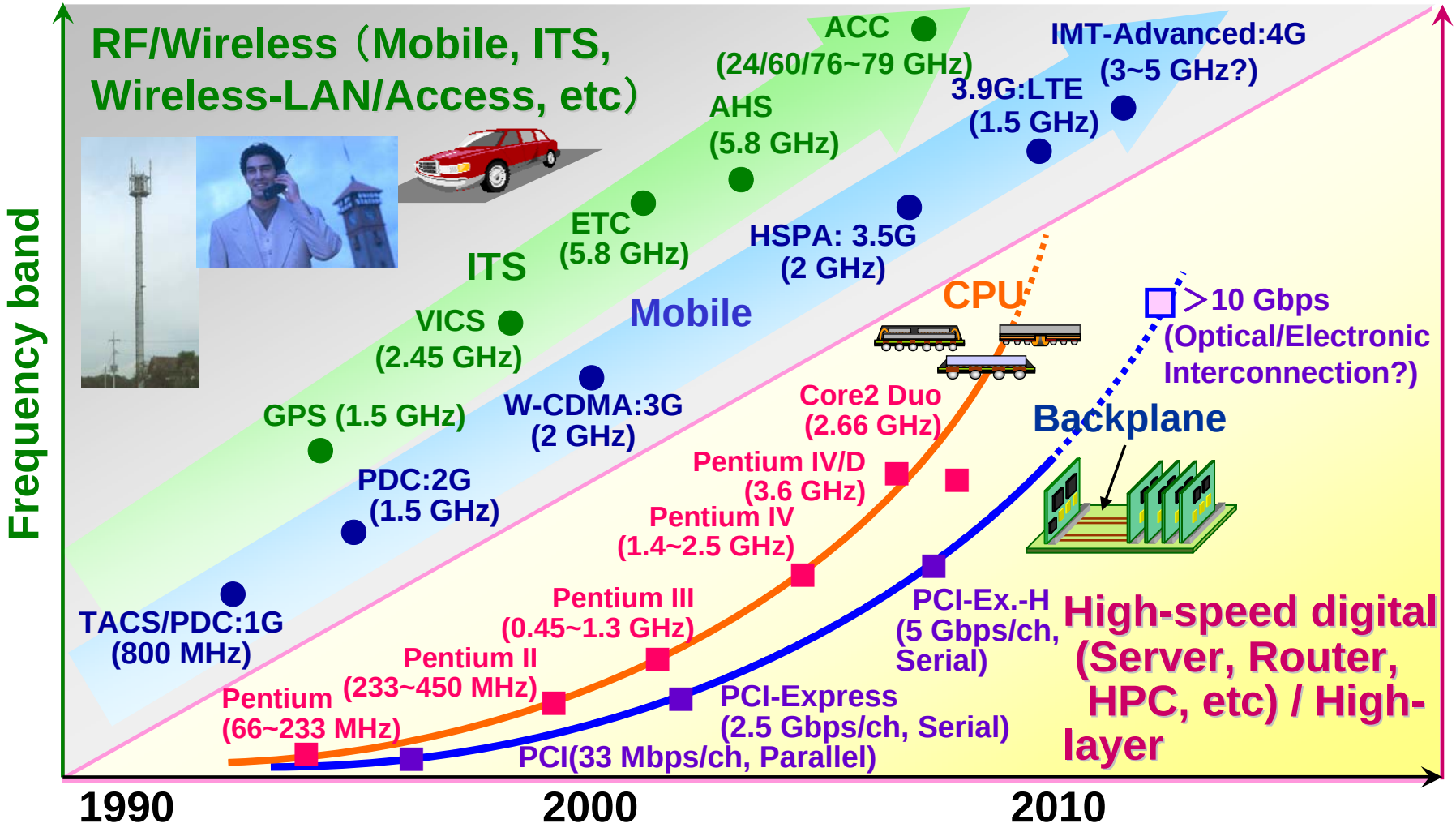

Hitachi Chemical's evaluation technology

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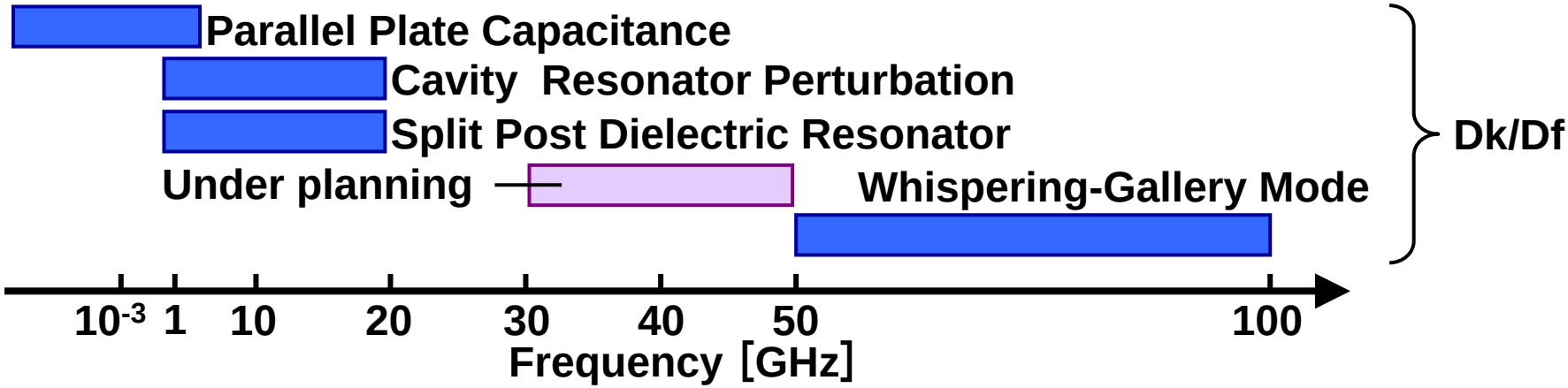
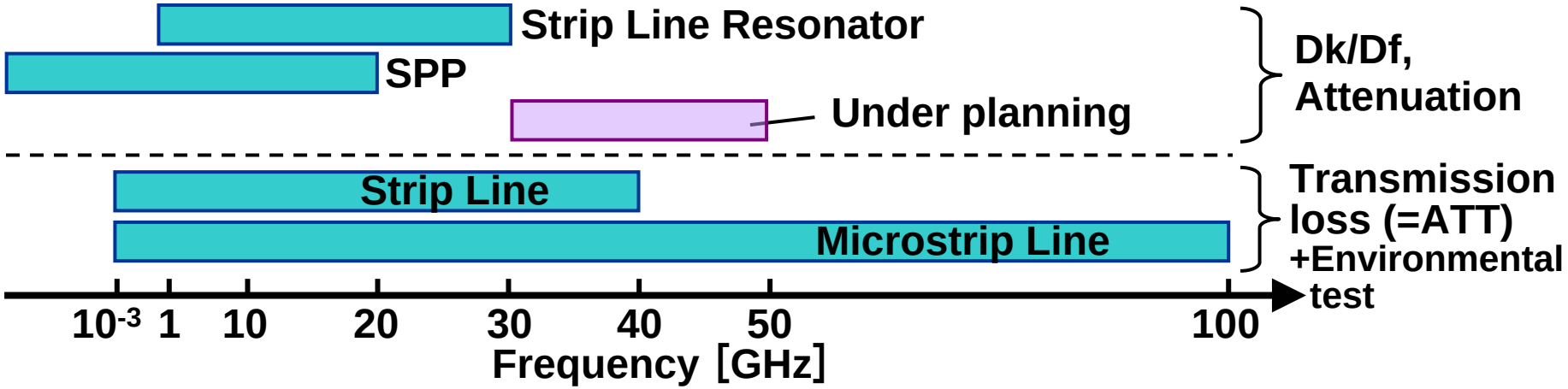
Hitachi Chemical can satisfy various evaluation requirements

Dielectric properties of materials



Practical electrical properties of PCB



Evaluation methods of dielectric properties

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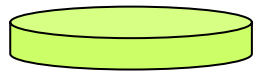
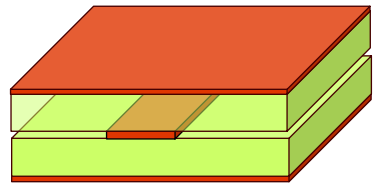
Subject	Material			PCB
Method	Cavity Resonator Perturbation	Split Post Dielectric Resonator	WG mode dielectric resonator	Strip Line Resonator
Freq.	1 ~ 20 GHz	1 ~ 20 GHz	50 ~ 100 GHz	1 ~ 30 GHz
Sample form	 ・w/o conductor ・Stick ・Thickness : ~ 1 mm ・Width: 1~2 mm ・Length: 80 mm	 ・w/o conductor ・Sheet / board ・Thickness : ~ 0.5 mm ・Width : 10 ~ 130 mm	 ・w/o conductor ・Disk ・Thickness : ~ 2 mm ・Diameter : 30 ~ 60 mm	 ・Strip line ・Thickness : ≧1.0mm ・Characteristic impedance:50 Ω
Standard	JIS C-2565	—	Under planning	IPC-TM-650 2.5.5.5.1 JPCA-TM001-2007

・Various methods exist to evaluate dielectric properties of materials and PCBs.
・Usable frequency band and sample form are different.

Anisotropy of PCB materials

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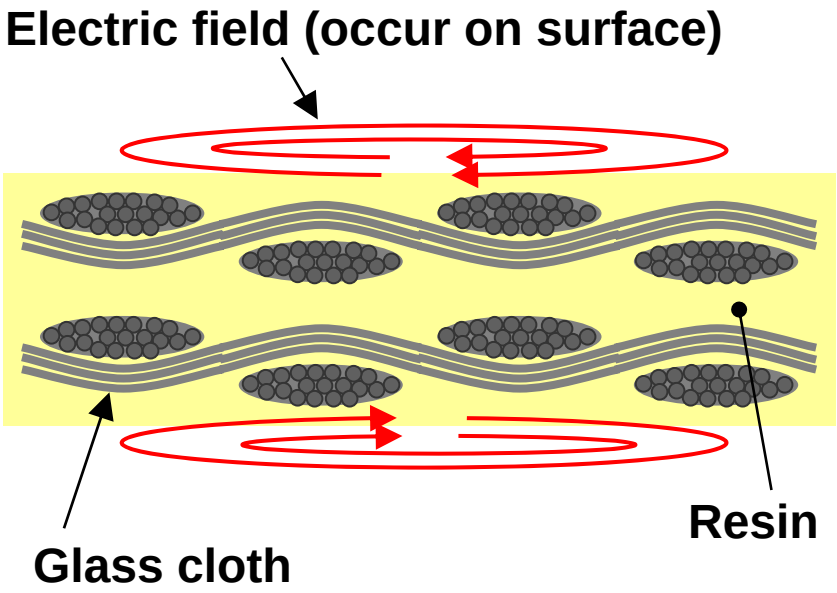
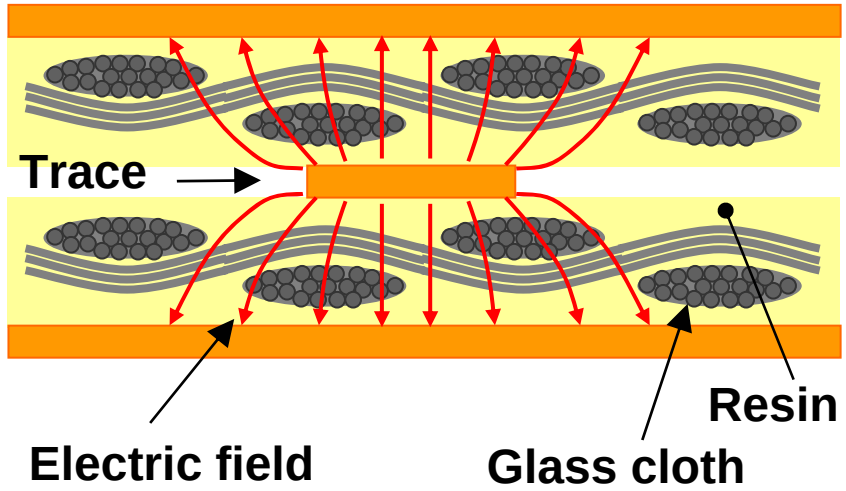
Split Post Dielectric Resonator

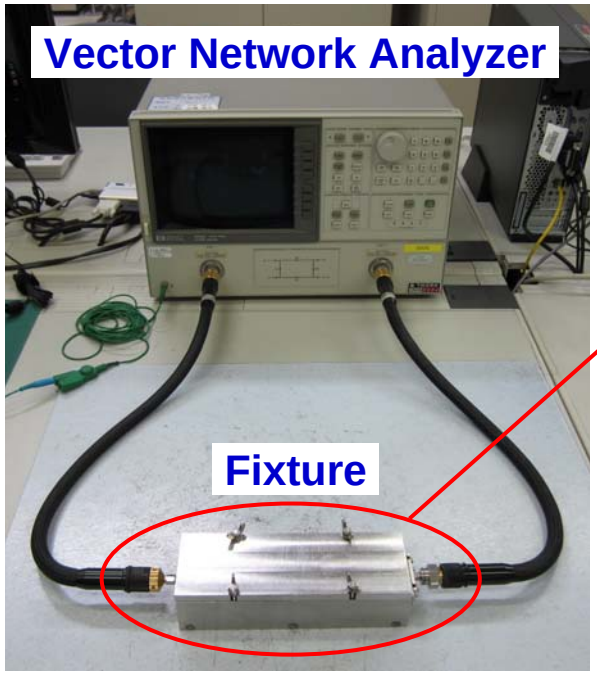


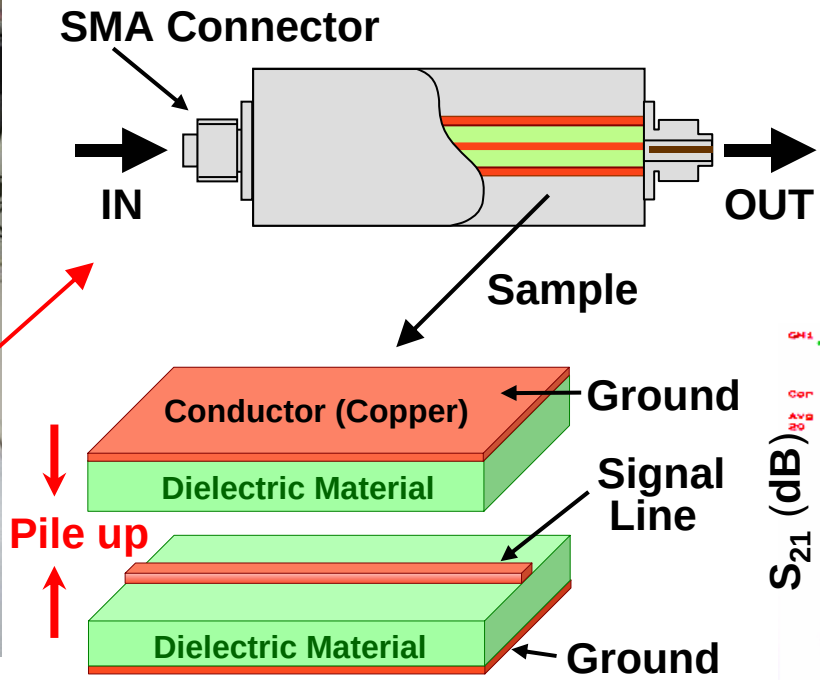
Strip Line Resonator

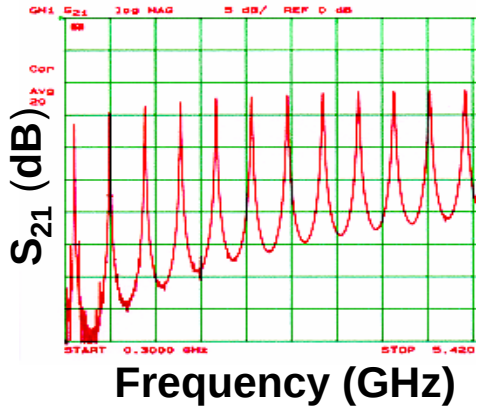


- PCB materials have anisotropy because of difference of Dk between resin and glass cloth.
- Suitable methods are utilized to evaluate anisotropic dielectric properties and practical electric properties of materials depending on frequency band and application of materials.

Strip Line Resonator







Periodic resonance frequencies => Calculation => Dk

Transmission curve, S_{21} => Calculation => Attenuation, Df

(Original conversion method)

- Frequency domain method
- Capable of measuring properties of thermal drift and moisture absorption drift

Dielectric properties (vs. frequency)

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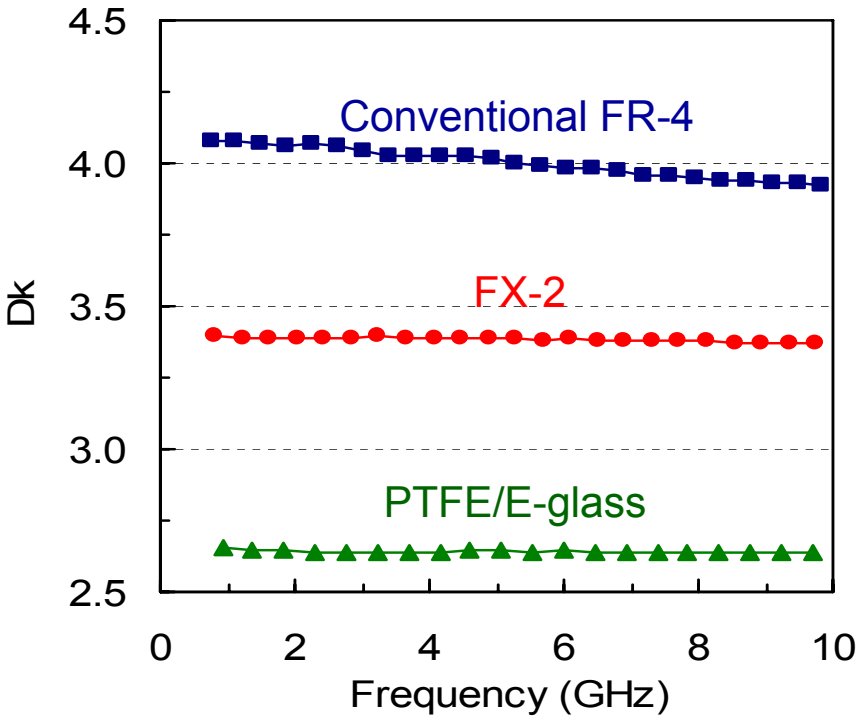
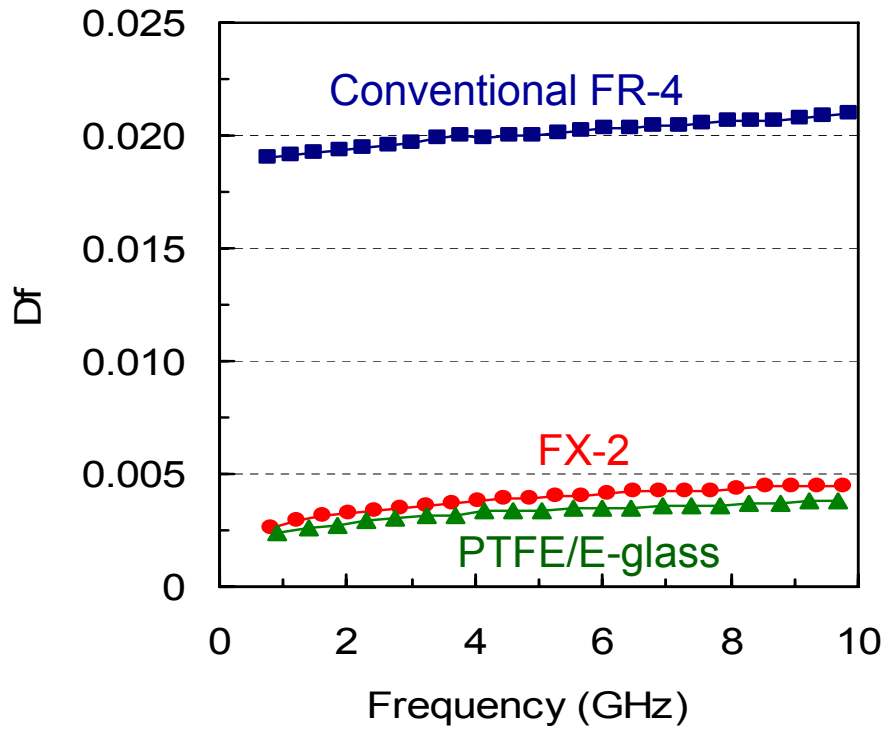
< Measurement conditions >

/ Method: Strip Line Resonator by Vector Network Analyzer/JPCA TM001/IPC-TM-650_2.5.5.5.1
/ Temperature & humidity: 25 °C/ 60 %RH
/ Laminate thickness: 0.8 mm (signal-ground distance: 0.8 mm), copper foil:18 μm
/ Line width: 1 mm





Good stability of dielectric properties in wide frequency bands

Dielectric properties (vs. moisture absorption)

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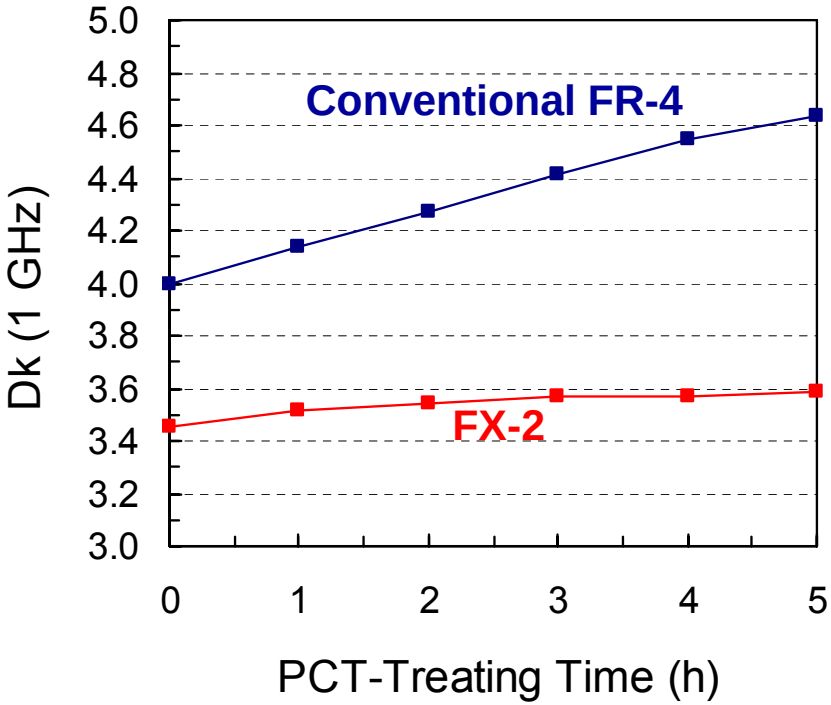
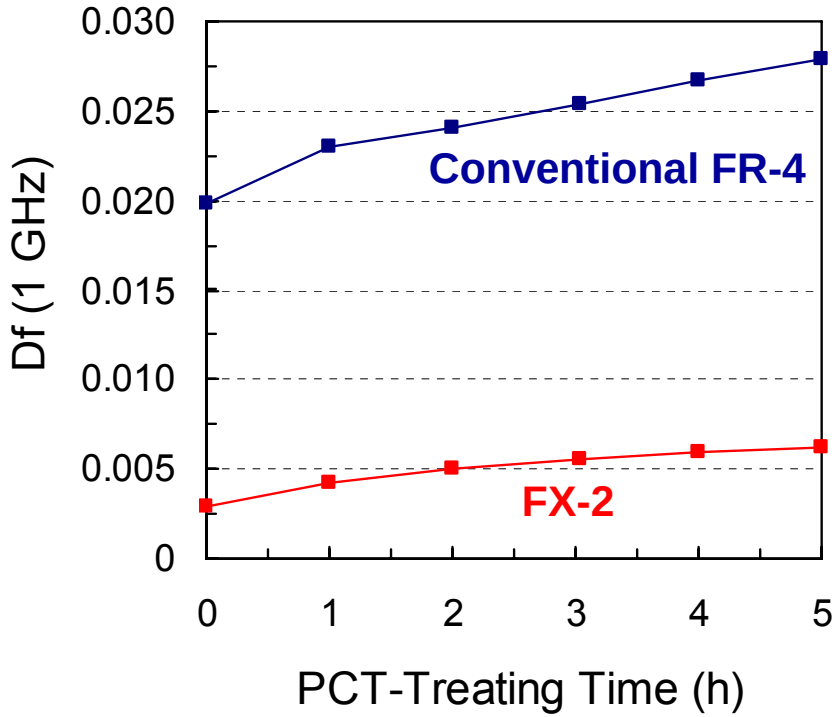
< Measurement conditions >

/ Method: Strip Line Resonator by Vector Network Analyzer/JPCA TM001/IPC-TM-650 2.5.5.5.1
/ Moisture treatment condition: PCT(121°C/0.22 MPa)-1~5 h
/ Temperature : 25 °C
/ Laminate thickness: 1.6 mm (signal-ground distance: 0.8 mm), copper foil:18 μm
/ Line width: 1 mm





Stable Dk & Df against PCT treatment compared with FR-4

Dielectric properties (vs. temperature)

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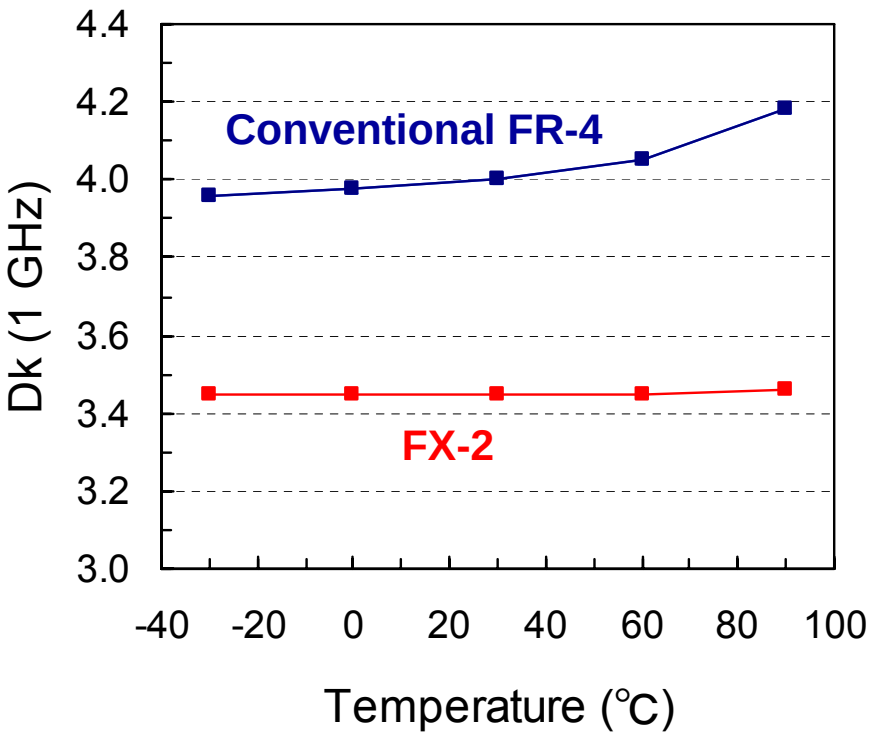
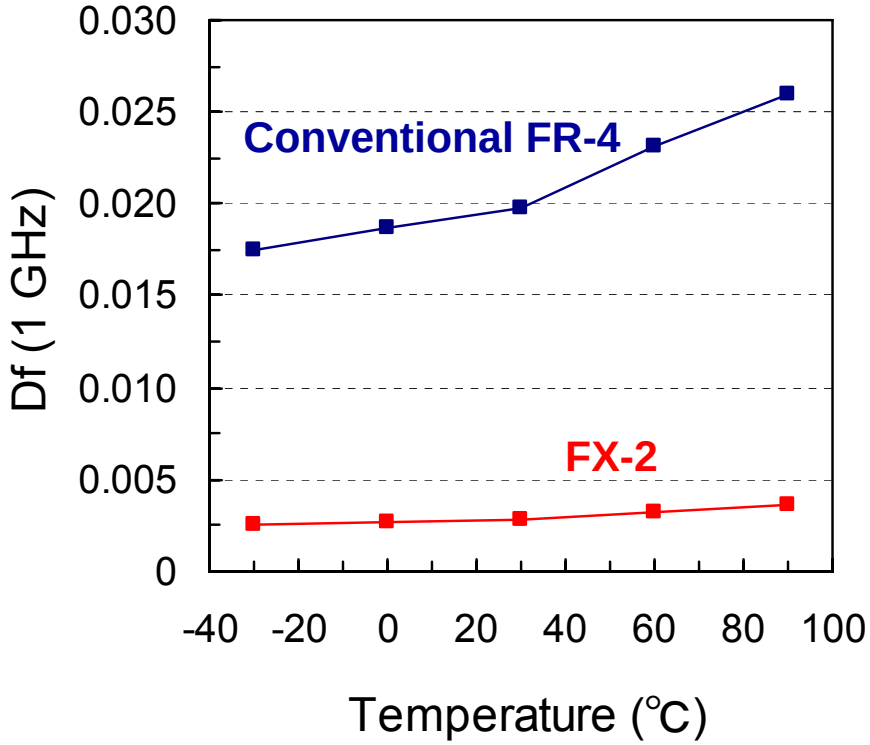
< Measurement conditions >

/ Method: Strip Line Resonator by Vector Network Analyzer/JPCA TM001/IPC-TM-650 2.5.5.5.1
/ Temperature: -30~90°C
/ Laminate thickness: 1.6 mm (signal-ground distance: 0.8 mm), copper foil:18 μm
/ Line width: 1 mm





Good stability of dielectric properties against temperature

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Test vehicle / SMASPP2z

Category	Frequency	FX-2		HE-679G	
		Resin rich, PF	Resin poor, LP	Resin rich, RTF	Resin poor, LP
Dk	1 GHz	3.12	3.48	3.67	3.95
	3 GHz	3.11	3.47	3.63	3.92
	10 GHz	3.09	3.45	3.59	3.88
	20 GHz	3.09	3.44	3.56	3.86
Df	1 GHz	0.0050	0.0054	0.0148	0.0115
	3 GHz	0.0053	0.0058	0.0161	0.0124
	10 GHz	0.0053	0.0062	0.0165	0.0125
	20 GHz	0.0064	0.0074	0.0169	0.0134

- Hitachi Chemical is certificated as an evaluator of SPP
- SPP assessment is useful to accelerate R&D of materials because we can know performance of materials including influence of copper foils

Whispering- Gallery Mode Dielectric Resonator

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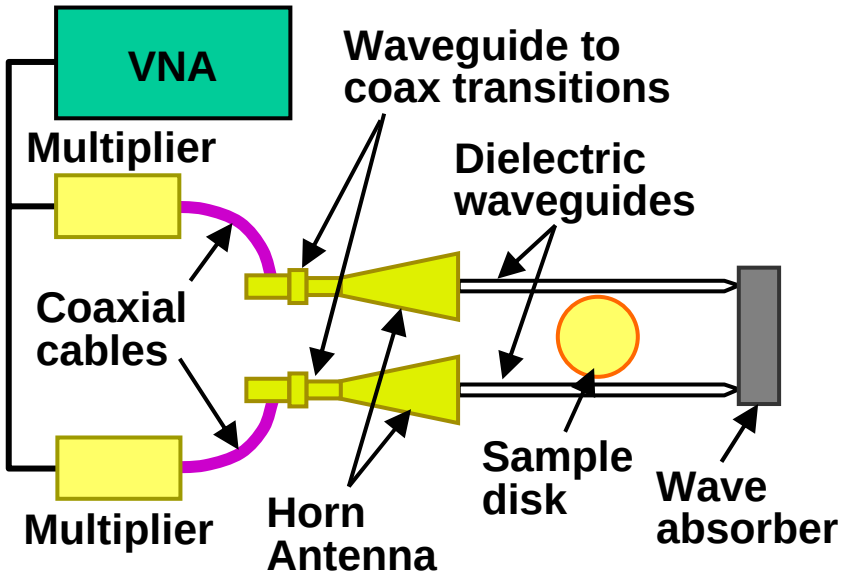
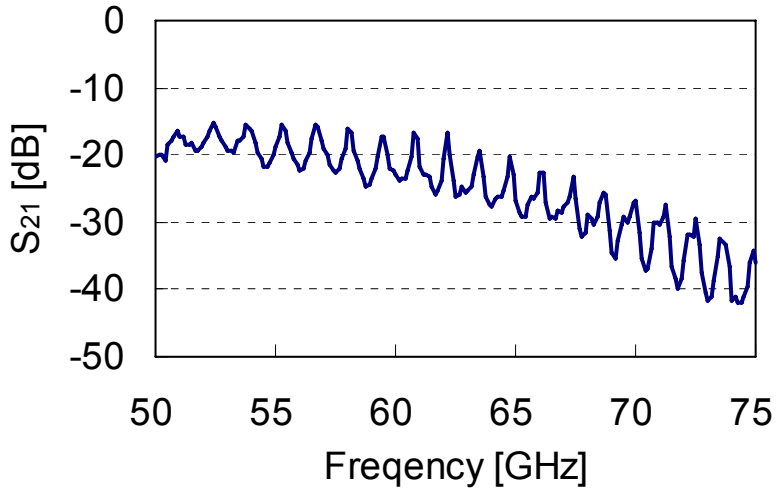
Measurement system



Resonance wave form



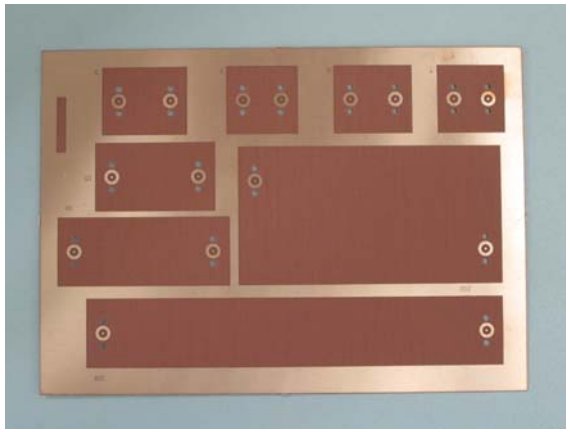
Dielectric properties (@60 GHz)

Material	Dk	Df
HE- 679G	4.16	0.0096
LZ- 71G	3.68	0.0069
FX- 2	3.52	0.0039
E- 700G(R)	4.61	0.0101
E- 800G(L)	3.91	0.0078

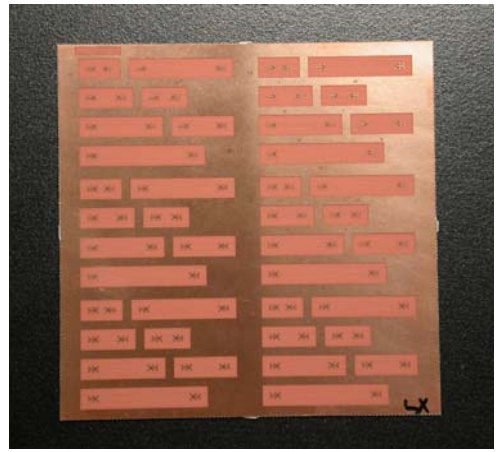
Dielectric properties can be measured in millimeter wave band

Evaluation of PCB (SL)

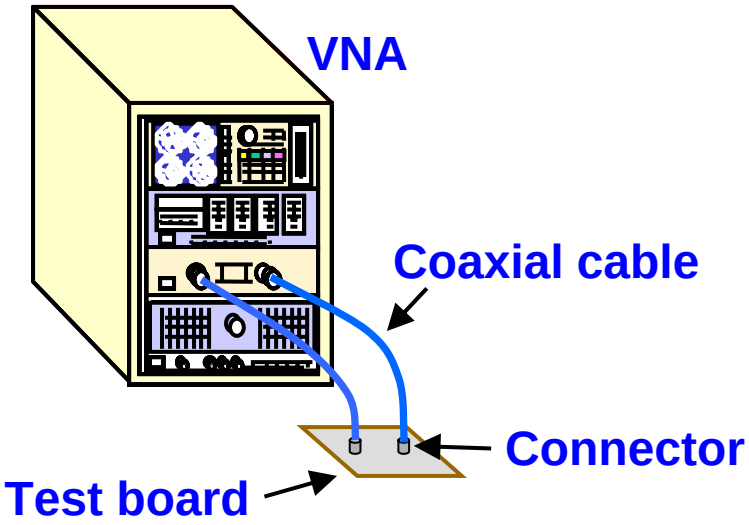
Measurement of Strip line

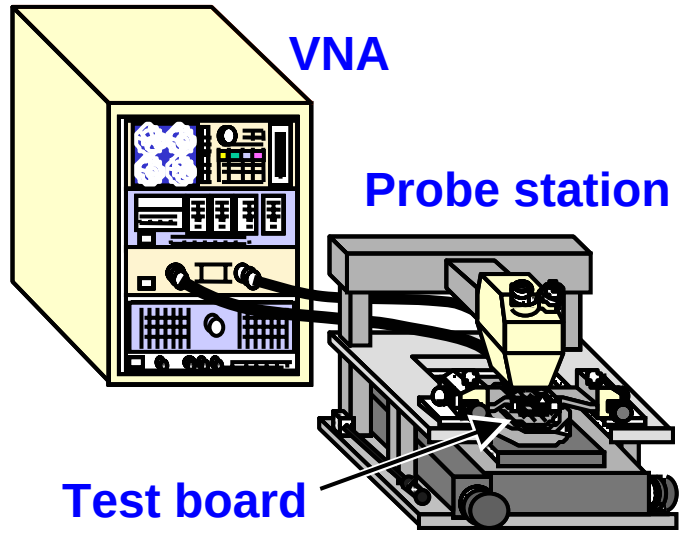


Test board (up to 20 GHz)



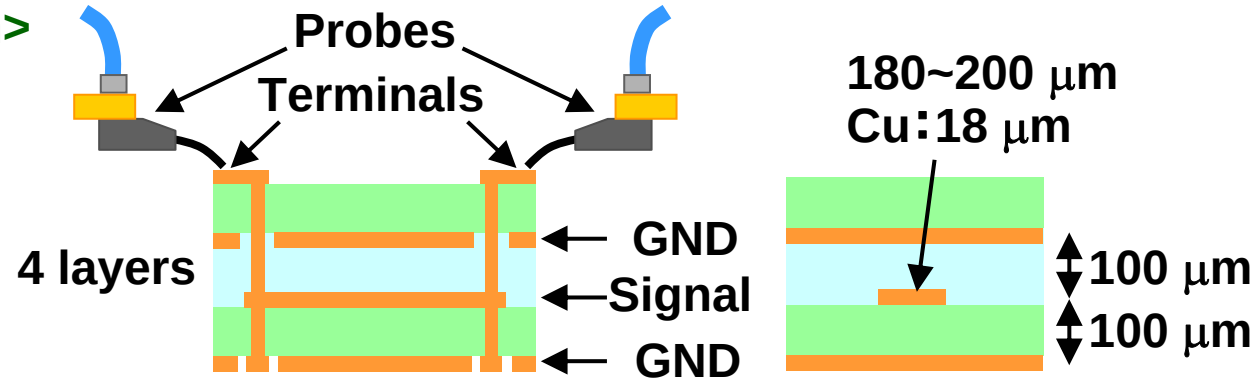
Test board (up to 40 GHz)

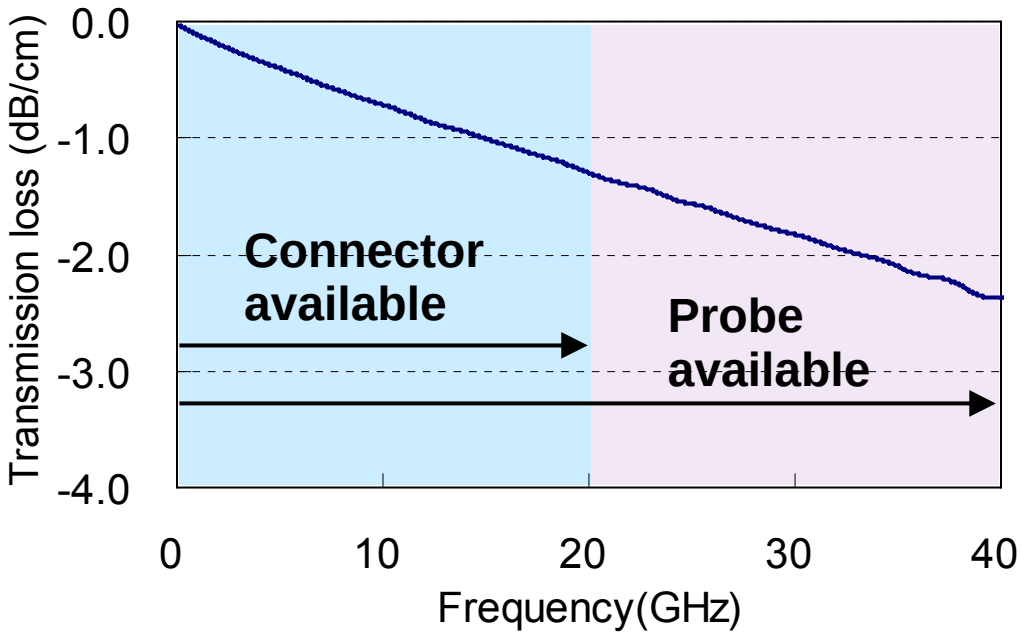




Transmission loss of Strip line

<Measurement condition>
/ Structure: strip line
/ Equipment: VNA
/ Calibration：TRL





Capable of evaluating strip line up to approximately 40 GHz

Evaluation of PCB (MSL)

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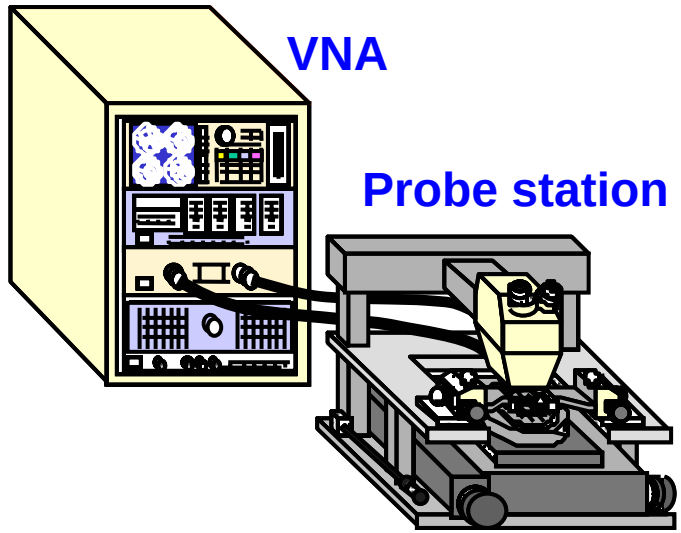
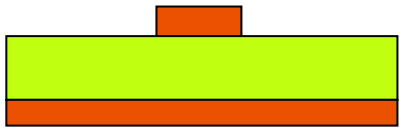
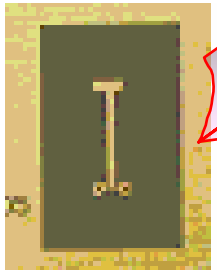
Evaluation system for semi-microwave ~ milliwave properties



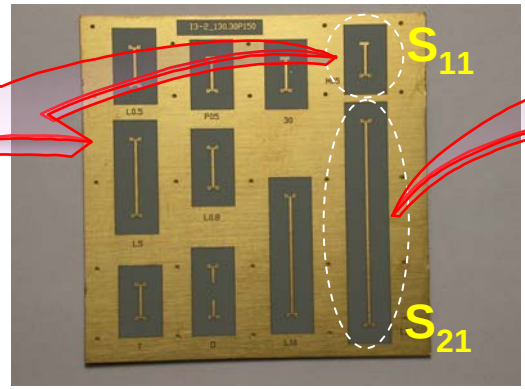
TEG PWB for evaluation (microstrip line structure)

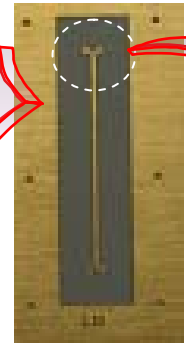


Cross section of TEG

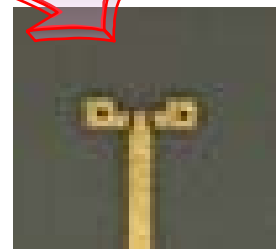


Pattern for S11





Pattern for S21



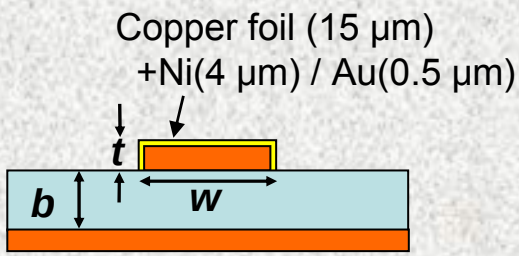
Measurement terminal

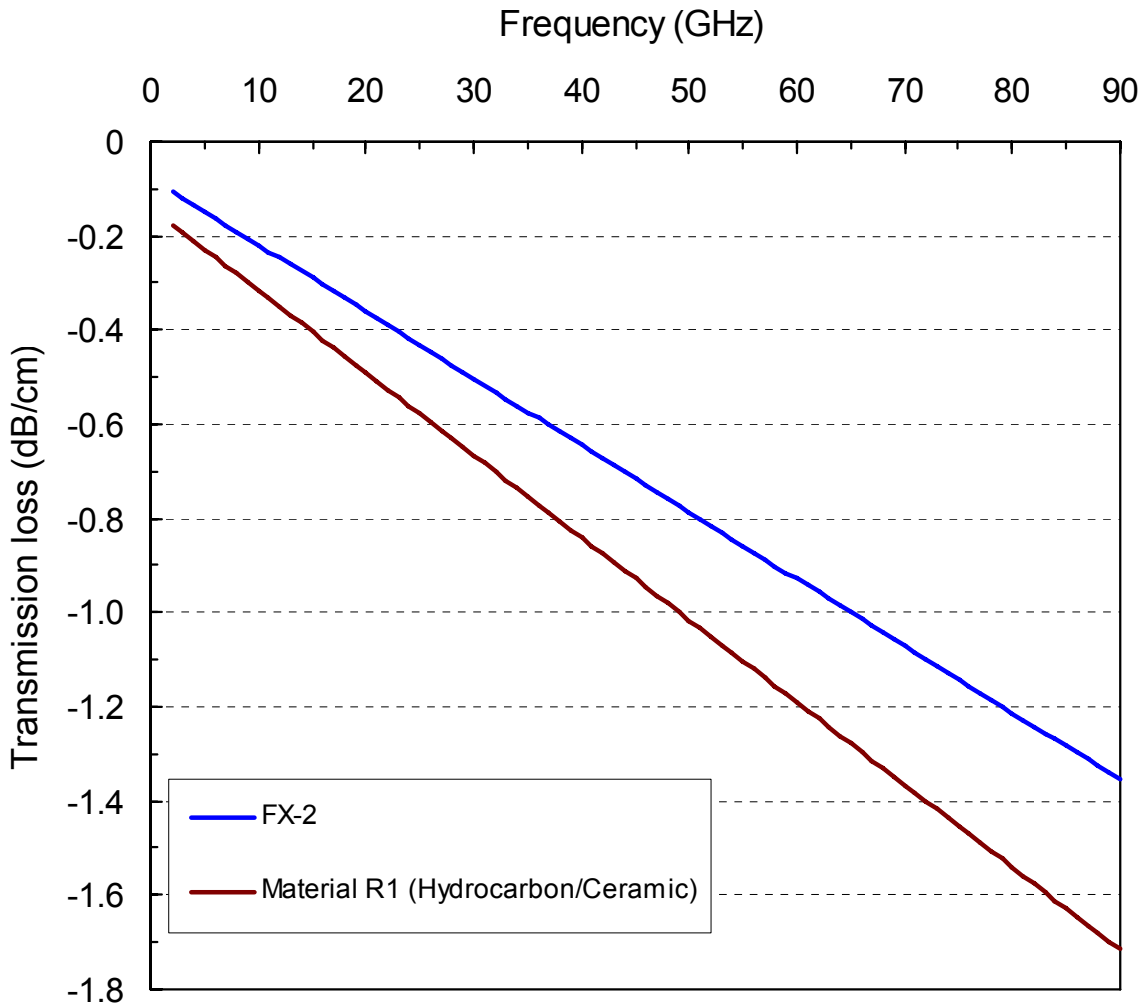
Transmission properties

Transmission loss (1 ~ 90GHz, S_{21}@MSL)

< Measurement conditions >

/ Structure: microstrip line
/ Temperature & humidity: 25℃/40%RH
/ Characteristic impedance: 50 Ω
/ Calibration: TRL
/ Dimension parameters
- Line width(***w***): 0.2 ~ 0.22 mm
- Dielectric thickness(***b***): 0.1～0.13 mm
- Copper thickness(***t***): 18 μm
- Line length: 10 mm & 20 mm
- Surface treatment of copper: Ni(4 μm)/Au(0.5 μm) plating





Transmission loss (vs. temperature)

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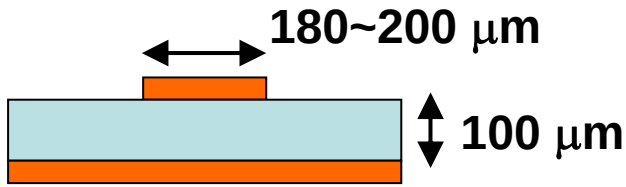
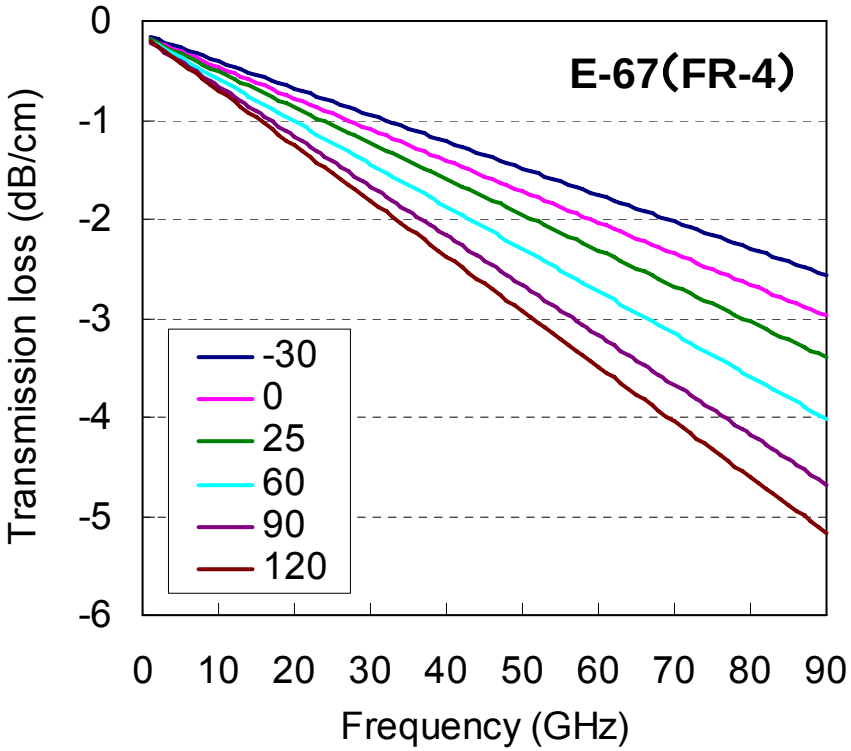
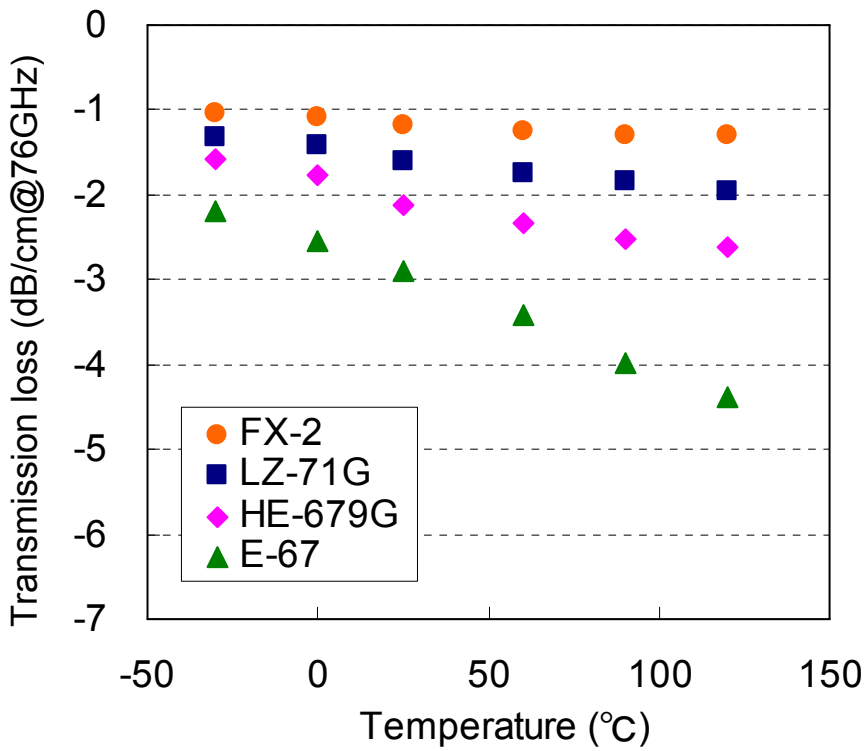
<Measurement condition>
/ Structure: microstrip line
/ Equipment: VNA
/ Calibration : SOLT





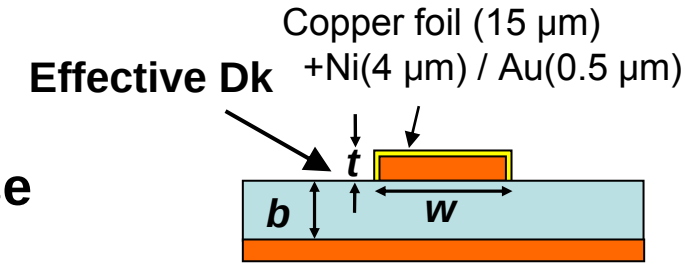


High frequency materials have good stability of transmission loss against temperature

Drift property of effective Dk (MSL)

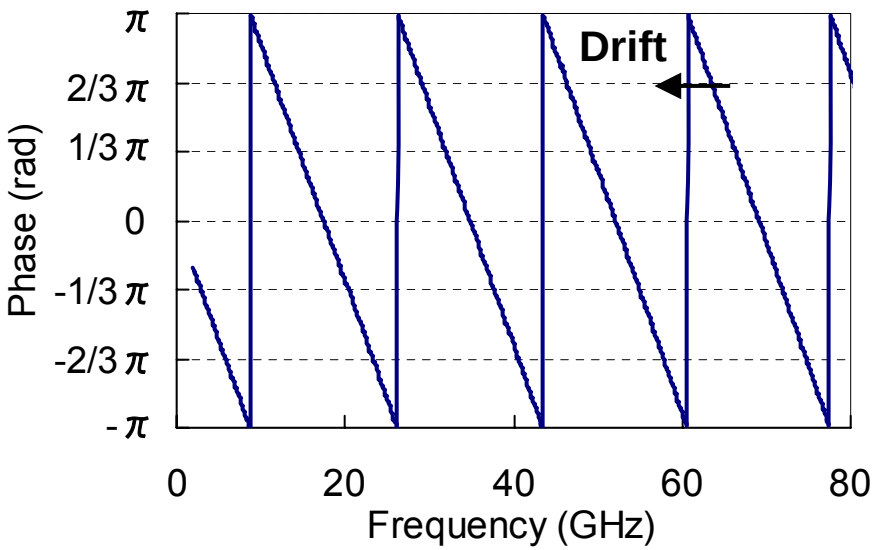
Influence of heat-processing

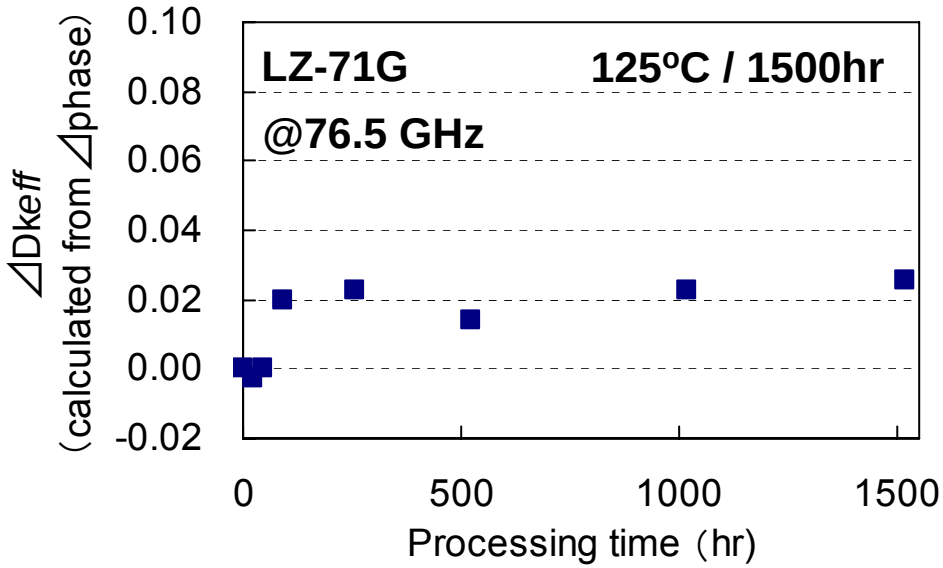
Effective Dk can be calculated from phase



- Line width(***w***): 0.2 ~ 0.22 mm
- Dielectric thickness(***b***): 0.1～0.13 mm
- Copper thickness(***t***): 18 μm
- Line length: 10 mm & 20 mm
- Surface treatment of copper: Ni(4 μm)/Au(0.5 μm) plating

Phase (vs. frequency)





Drift of Effective Dk can be evaluated in millimeter wave band

Drift property of transmission loss and Dk (MSL)

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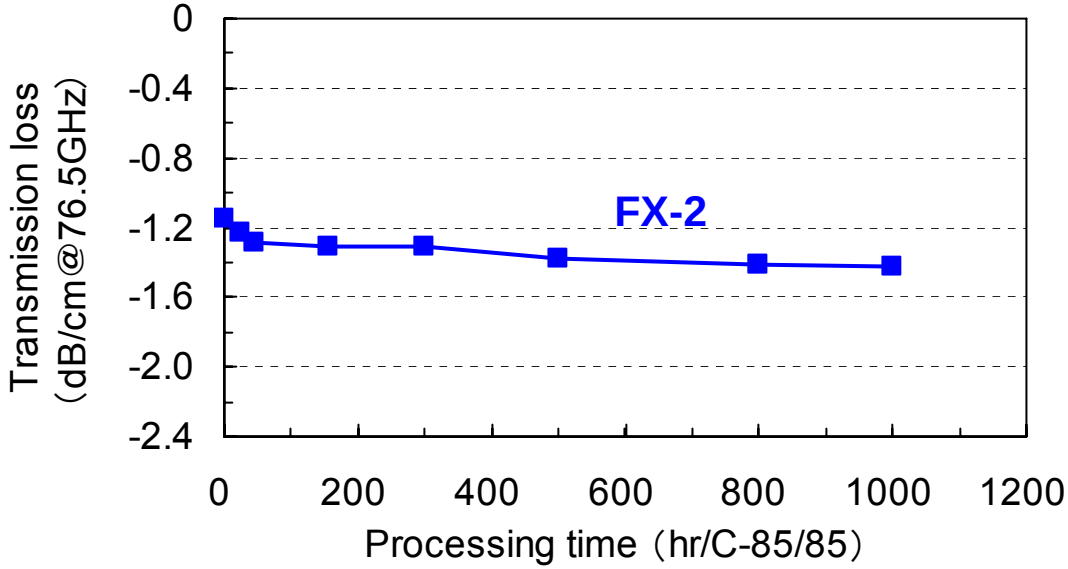
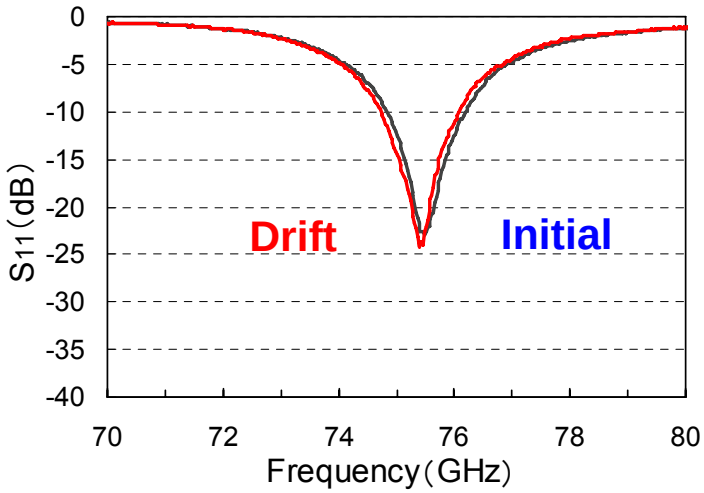
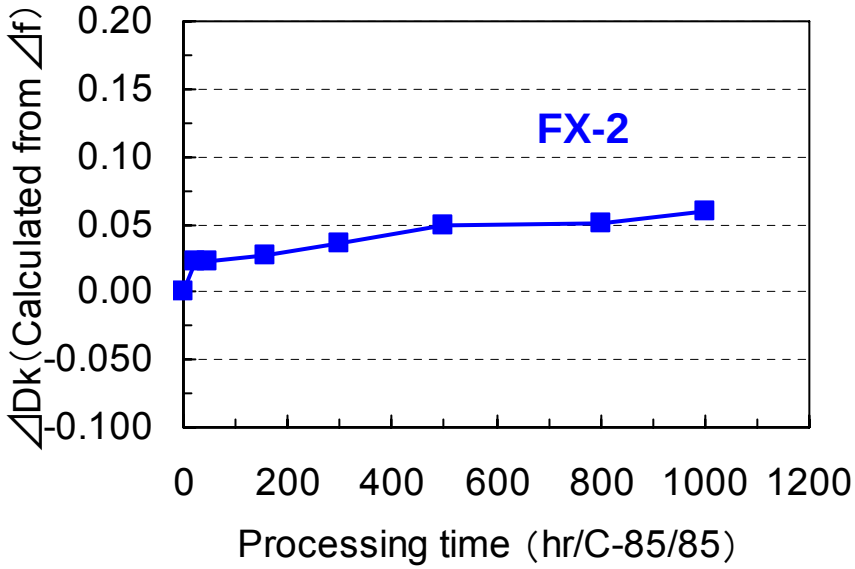
Influence of humidity absorption



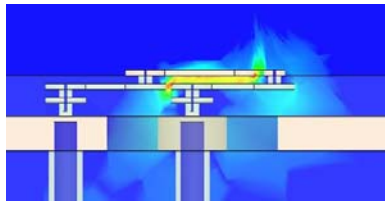


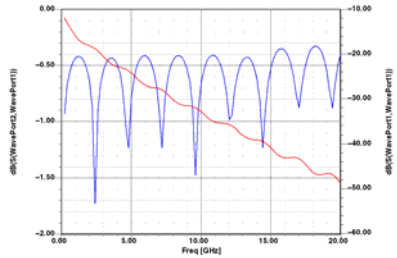


Simulation technology

- 3D EM field solver (Ansys HFSS)
- Circuit simulator (Agilent ADS)

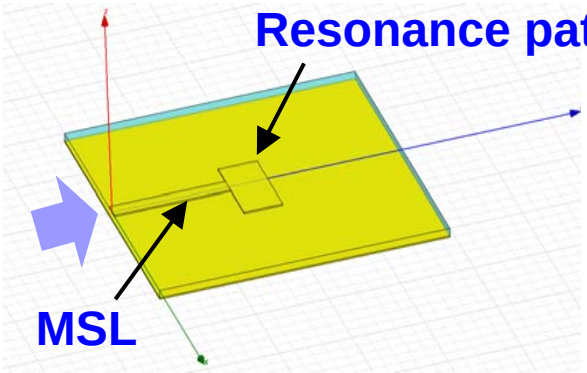
/ Guessing of electrical performance, combination of structures, and the most suitable materials

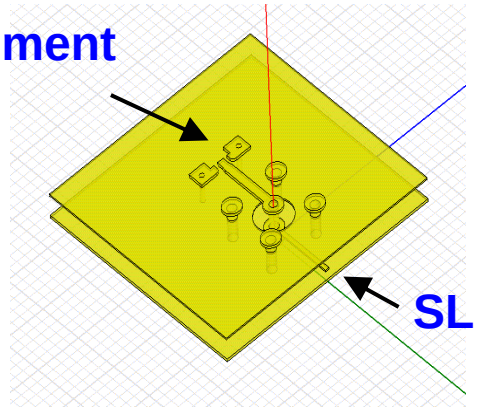




/ Designing of measurement terminals for evaluation of transmission properties to W-band, 100 GHz

/ Guessing of dielectric drift properties, ⊿Dk, by fitting calculated resonance properties, S_{11}, to measured S_{11}





Reliability of FX-2 (update)

IST result after Pb-free

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Layer count : 24 layers
PCB thickness : 3.1 mm
Test temp.: 150°C +/- 3°C in 3 minutes
Criteria of failure: more than 10% change of resistance

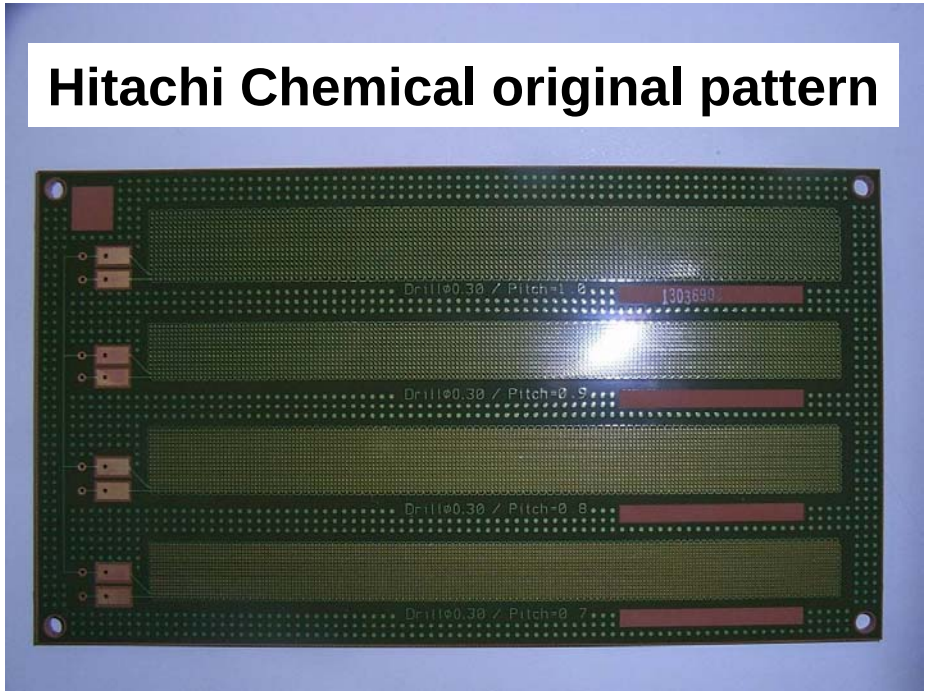
Drill hole size	Pre-conditioning	Cycles
0.010”	AS IS	> 1,000
	4X (260°C)	> 1,000
	6X (260°C)	> 1,000
0.0135”	AS IS	> 1,000
	4X (260°C)	> 1,000
	6X (260°C)	> 1,000

n = 6pnl

Good through-hole connection reliability

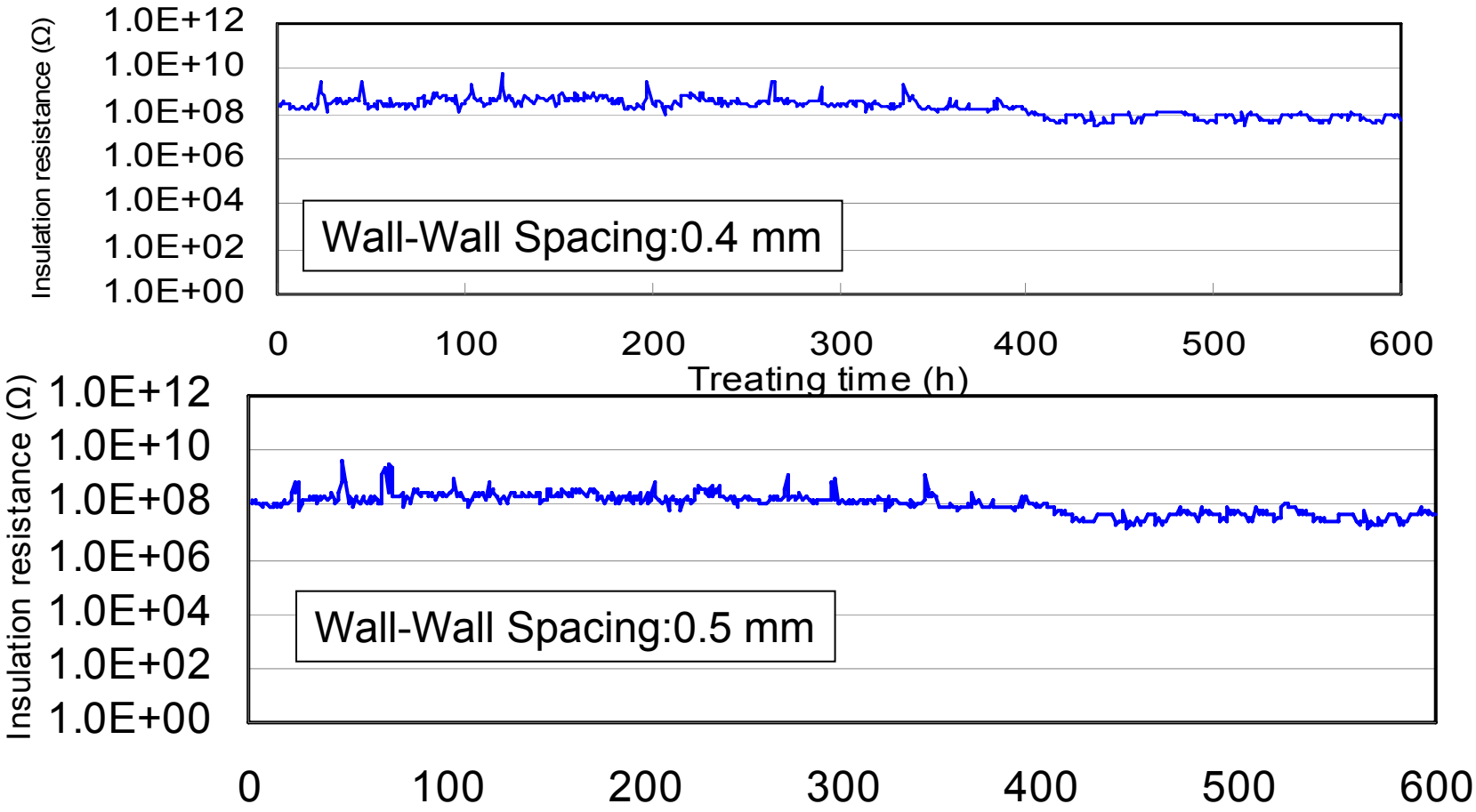
CAF evaluation of high layer count board

/ Total thickness: 4.1 mm (28 layer board)
/ Wall-Wall Spacing: 0.40 mm,0.50 mm, about 2,000holes
/ Precondition: 85°C/85%RH/120 h + Reflow 260°C X 10 times
/ Measurement condition: 85°C/85%RH DC100 V
/ The measurement of insulation resistance in chamber



Results of CAF evaluation

Measurement condition: 85°C/85%RH DC100V,
The measurement of insulation resistance in chamber

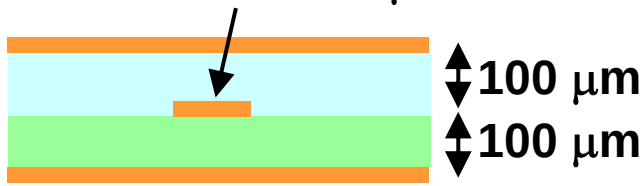


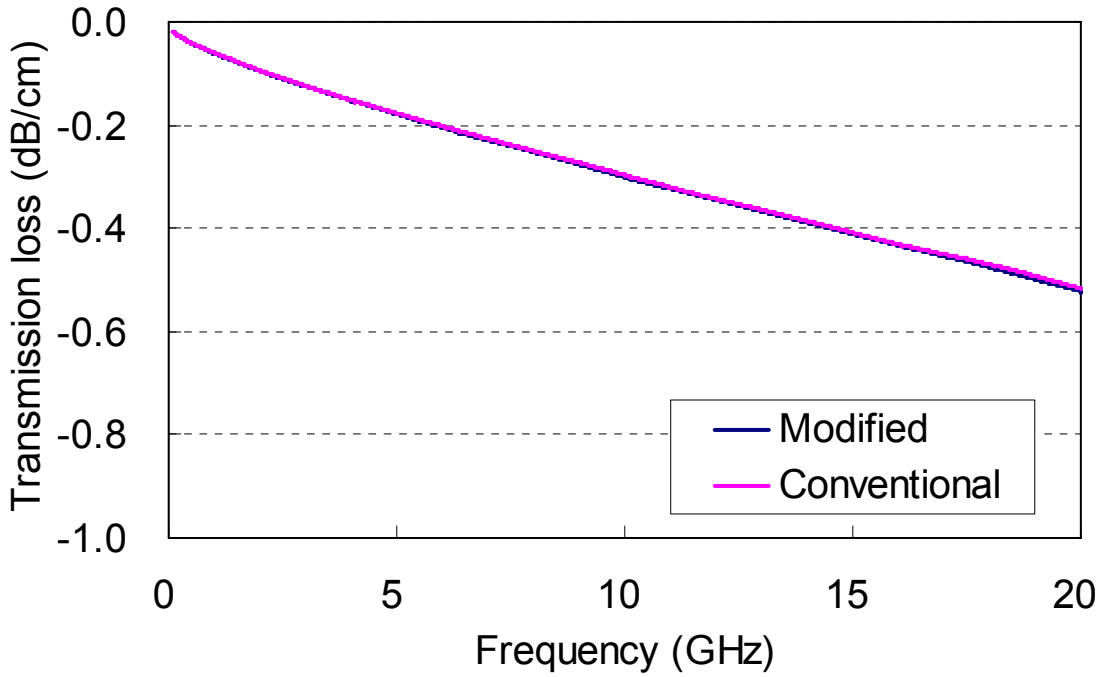
Good CAF restraining property

Transmission loss of modified FX-2

<Measurement condition>
/ Structure: Strip line
/ Equipment: VNA
/ Calibration：TRL

Line width:180~200 μm
Cu thickness：18 μm





Equal to conventional FX-2

Road map of Hitachi high frequency PWB materials

Hitachi Chemical
Working On Wonders

Applications		~2000	2002	2004	2006	2008	2010	2012	2014
Transmission rate/Link (Backplane)		300 Mbps~1 Gbps		1.25~2.5 Gbps		3.2~6.4 Gbps		~10 Gbps	>10 Gbps
(Mobile)		<2.4 kbps	9.6~144 kbps		2 Mbps	3.8 Mbps	5.7 Mbps	7.2 Mbps	>10 Mbps
High-end digital (High-speed & High-layer)	High-end Router High-end Server Transport Super computer IC tester Measuring equipment BTS (Sgnl.-Pros.)	Dk<3.8/Df<0.005					Dk<3.7 Df<0.003		Dk<3.5 Df<0.002
			LX-67/LX-67Y Dk:3.5/Df:0.005		LZ-71G Dk:3.6/Df:0.006			FX-2/FX-3 Dk:3.2-3.5/ Df:0.0025-0.0028	New Material or Opt ?
Middle ~Low digital (High-speed & High-layer)	Mobile devices Low~Middle Router/Server BTS (Sgnl.-Pros.)	Dk<4.5/Df<0.025			Dk<4.5/Df<0.018			Dk<4.0/Df<0.01	Dk<3.8 Df<0.007
		E-67/E-679 Dk:>4.0/Df:>0.02		BE-67G(H) Dk:4.5/Df:0.01		E-679FJ Dk:4.3/Df:0.018		HE-679G Dk:4.0/Df:0.009	HE-679G(K) Dk:3.7/Df:0.007
RF/Wireless (Analog high-Freq.)	Antenna Sensor RF-Module Base station Mobile devices Satellite	Df<0.01			Df<0.005		Dk<3.5 Df<0.003		Dk<3.2 Df<0.002
		HD-67 Dk:10.2/Df:0.009		LX-67F Dk:3.7/Df:0.003			FX-2/FX-3 Dk:3.2-3.5/ Df:0.0025-0.0028	FX-4 Dk:3.2/ Df:0.0025	
High-Freq. -PKG	Mobile devices RF-Module MMIC-PKG OEIC-PKG	Df<0.015					Df<0.01		Df<0.005
				E-679FG Dk:4.5/Df:0.014		LZ-71G Dk:3.6/Df:0.006		E-800G,Falcon Dk:4.0/Df:0.005	AS-Z5(BU) Dk:3.1 /Df:0.004

Dk&Df:@1GHz

Summary

1. Hitachi Chemical has various evaluation technology of dielectric properties and practical electrical properties.

2. Hitachi Chemical intend to accelerate R&D of materials for next generation through these technology and newly constructed technology.

3. We also would like to propose the combination of the most suitable materials depending on PCB structure and applications by using evaluation technology and simulation.

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