



Novel Low Loss Materials for Advanced IC Packaging

JSR Micro, Inc. Hikaru Mizuno



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Outline



1. Background
2. JSR's Approach for Low Loss and Low CTE
 - ✓ Low Loss Polymer
 - ✓ Low Loss Crosslinker
3. Summary



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Introduction of the JSR Group

Year of Establishment
1957

In 1957, when petrochemical products were indispensable for industrial development, Japan Synthetic Rubber Co., Ltd., now JSR Corporation, was established with the mission of domestically producing synthetic rubber.

Revenue Breakdown by Business Segment (FY2022)
408.9 billion yen

62.2% of these sales are overseas.

Number of business sites
47

* As of April 1, 2023
The JSR Group operates in 19 locations in Japan and 28 locations overseas.

Number of Employees
7,994

* Number of consolidated employees as of March 31, 2023.
Of this number, 4,353 employees work at overseas business sites.

R&D Expenses
27 billion yen

* FY2022 results (April 1, 2022 - March 31, 2023)
** FY2022 JSR Group, including contract research expense of goods purchased.
We are committed to research and development for future technologies.

Percentage of annual paid leave taken
88.8%

* FY2022 results including employees seconded from JSR.
** FY2022 results (April 1, 2022 - March 31, 2023)
We encourage a work-life balance.

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JSR Semiconductor Materials

Front-end

1. Slicing Substrate
2. Resists coating/ Exposure
3. CMP
4. Multilayer wiring

Back-end

5. Temporary bonding /Wire formation
6. Cleaning
7. Dicing
8. Packaging

Lithography Materials

Driving technical viability of semiconductors. Strong position and market share expansion in leading-edge fields.

Photoresists (EUV, ArF, KrF, i/g line) Multilayers (Underlayer, Topcoats, SOG)

Process Materials

Adopted in advanced applications/layers. Aiming to increase adoption opportunities as processes become more complex.

CMP materials Cleans

Advanced Packaging Materials

Strong position in WLP. Aiming to develop new materials including 3D mounting and substrates.

Thick Layer photoresists Low Loss Materials for IC-Substrate/PCB

Cu Pillar(Plating PR)

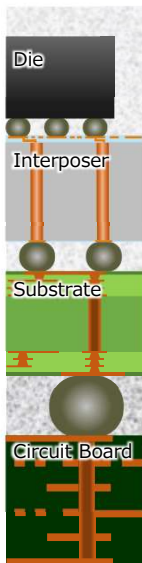
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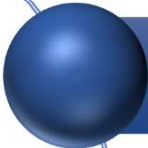
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JSR Packaging Materials


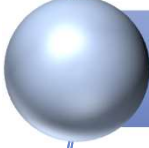


◆ JSR offers high-resolution PR and PID materials as well as low loss materials



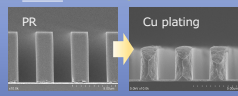
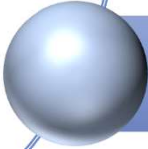
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Low Loss Materials
Low Dk/Df & Low CTE


- 

High-resolution Plating Photoresist

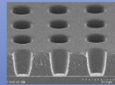
RDL $\leq 2.0 \mu\text{m-L/S}$


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High-resolution/Alkali-developable PID w/ a PFAS-free design

PI Elongation >50%

Thickness: 8 μm
4 $\mu\text{m-SQ}$

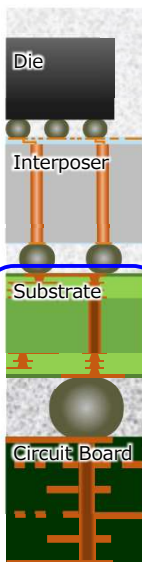




JSR Packaging Materials



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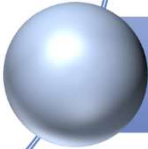
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Low Loss Materials
Low Dk/Df & Low CTE


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High-resolution Plating Photoresist

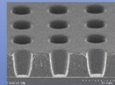
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- ✓ Low Loss Crosslinker

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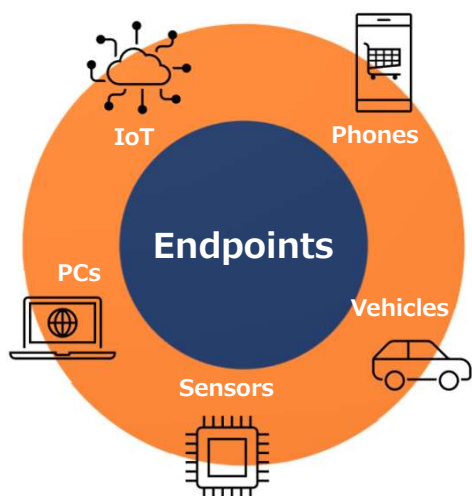
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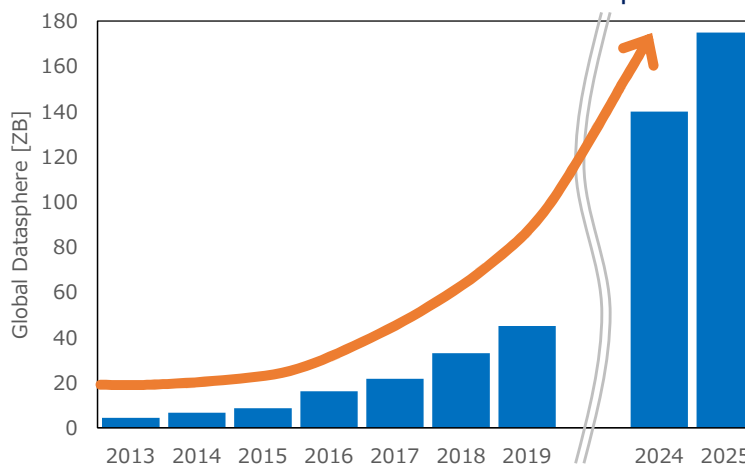
Growth of the Global Datasphere

JSR

- ◆ Global datasphere is significantly increasing with the growth of the information society



Annual Size of the Global Datasphere



Source: IDC Global DataSphere



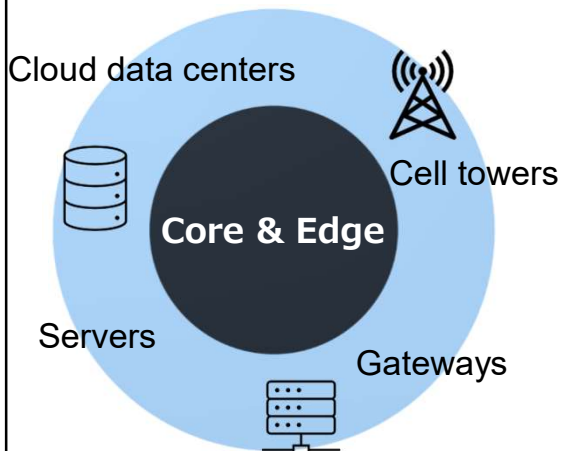
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Growth of the Global Datasphere



- ◆ In order to handle big data with high-speed, an advanced high frequency technology is required
- ◆ Not only at the endpoints, but in the whole data communications systems



Speed trend of wired communications

	2019	2023-2024	2028
Ethernet	400 GbE	800 GbE	1.6 TbE
Speed per lane	56 Gb/s	112 Gb/s	224 Gb/s
Frequency	14 GHz	28 GHz	56 GHz
Required Df	0.0030	0.0012-0.0015	<0.0010



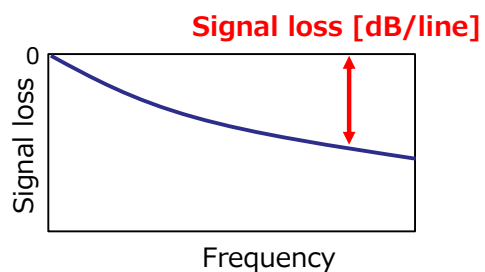
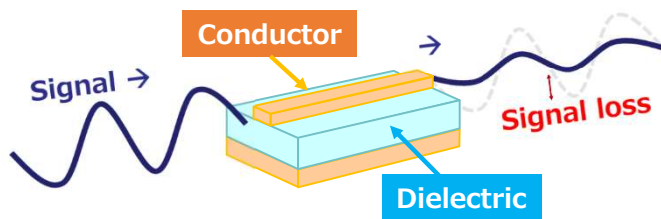
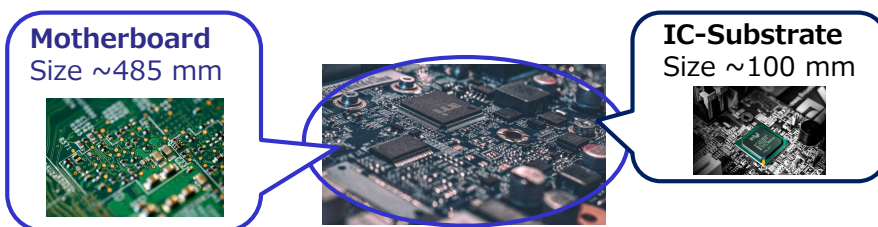
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Challenges at High Frequency



- ◆ IC-Substrate and PCB require low loss materials due to long signal transmission paths



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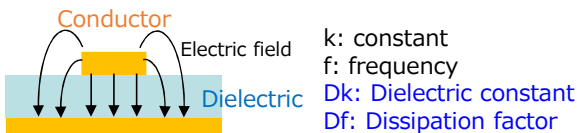
Requirements of Low Loss Materials



- ◆ Transmission loss = "Dielectric loss" + "Conductor loss"
- ◆ The low transmission loss requires a dielectric with low Dk/Df and good adhesion

Dielectric loss → Dk, Df

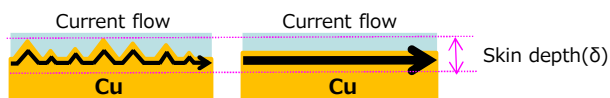
$$\text{Dielectric loss} = k \times f \times \sqrt{Dk} \times Df$$



• Dielectric loss is proportional to frequency, \sqrt{Dk} and Df.

Key: Low Dk, Df

Conductor loss → Skin effect



$$\text{Skin depth } \delta = \frac{1}{\sqrt{\pi f \mu_0 \sigma}}$$

f: frequency
 μ : permeability
 σ : conductivity

• Surface roughness is significant at high frequencies due to the skin effect.

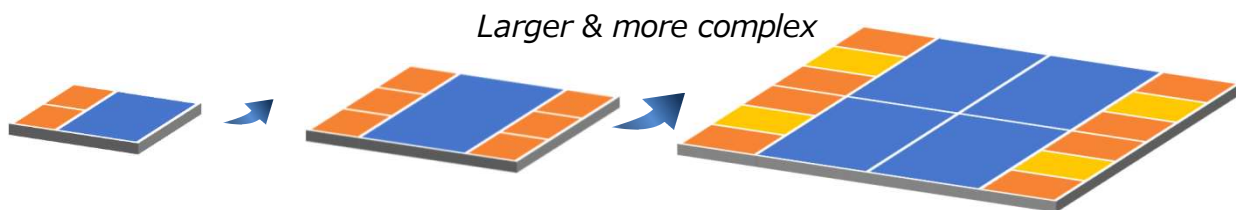
Key: Adhesion to smooth Cu



Requirements of Low CTE Materials



Packaging design trend



Technology trend

	2022-2023	2024-2025
Substrate Size (mm ²)	5k-12k	9k-17k
CTE_core (ppm/°C)	~7	~5
Electrical Property (Df)	0.0020	0.0015



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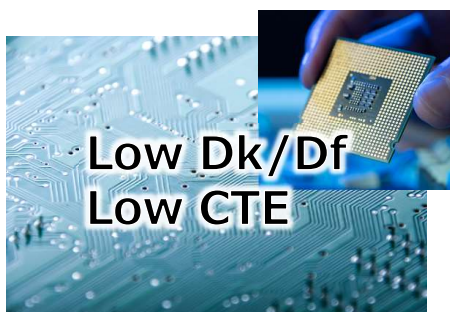
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JSR's Approach for Low Loss & Low CTE

JSR

- ◆ JSR focuses on material development to realize low loss and low CTE



Low Loss Polymer
for BUF, RCC, PP, CCL

Low Loss Crosslinker
for BUF, Core, RCC, PP, CCL

BUF: Buildup film, RCC: Resin coated copper, PP: Prepreg, CCL: Copper clad laminate



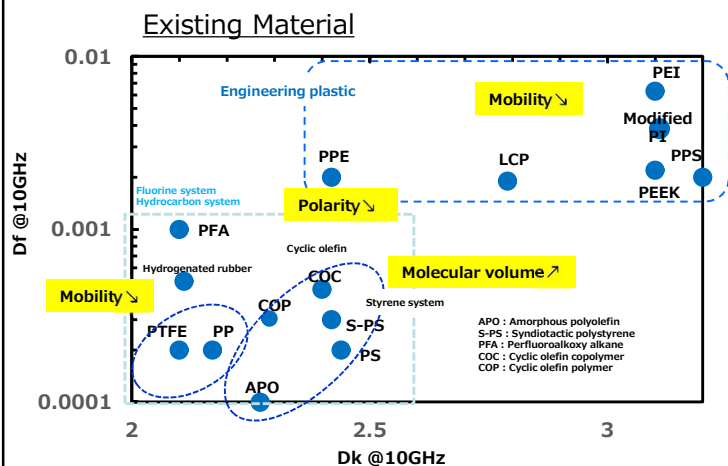
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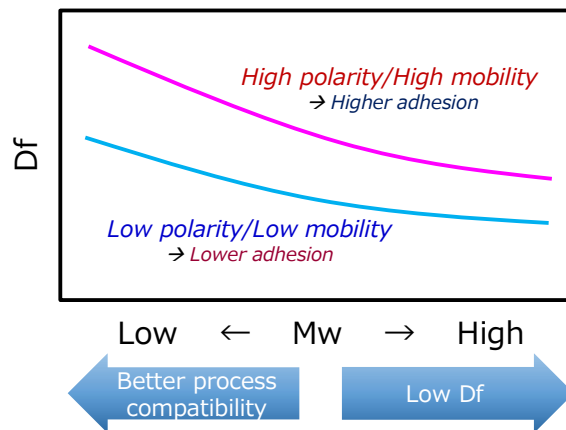
Designing a Low Loss Polymer



- ◆ A low Dk/Df polymer is designed using the following strategies: ①low polarity, ②low mobility and ③large molecular volume
- ◆ Molecule design is required to balance low loss, adhesion and process compatibility



Polymer structure vs. Df



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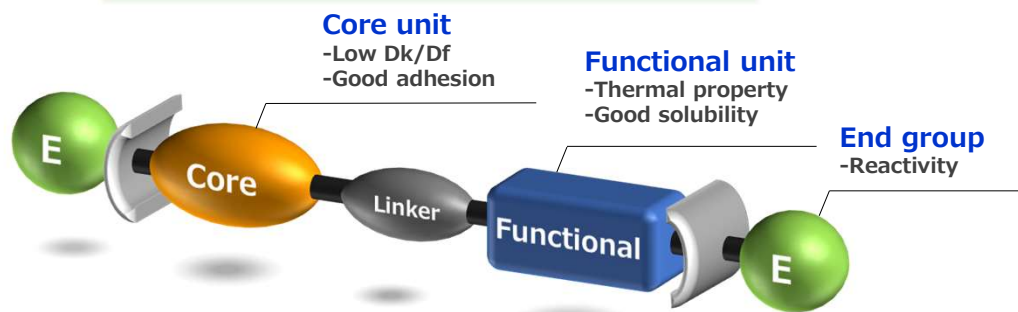
JSR's Approach for Low Loss Polymer



- ◆ JSR designed an original polymer, HC-G series, which includes four parts: end group, core unit, linker and functional unit
- ◆ It achieves a good balance between low loss properties and adhesion to copper

Low Loss Polymer
for BUF, RCC, PP, CCL

JSR ELPAC™ HC-G series



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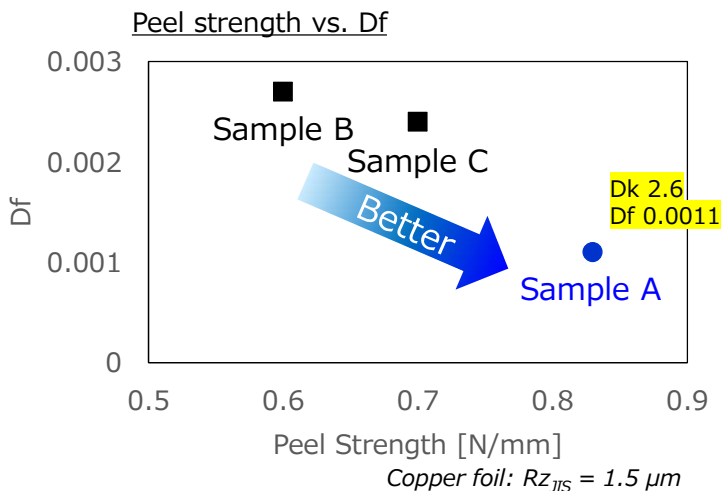
Polymer's Properties



- ◆ Sample A, which contained HC-G series, shows a good balance between Df and adhesion

Sample information

Sample#	Polymer	Initiator
Sample A	HC-G series	w/
Sample B	PPE based polymer-1	w/
Sample C	PPE based polymer-2	w/

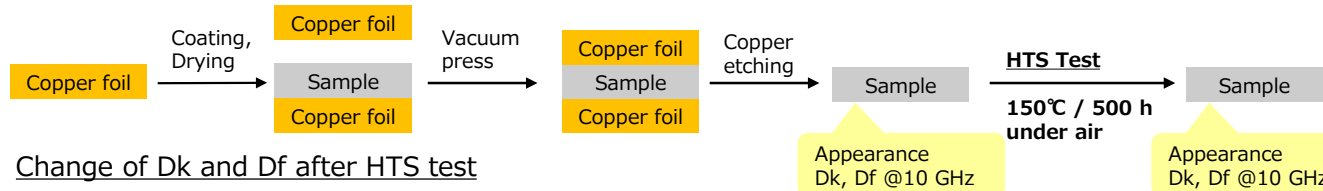


Polymer's Thermal Stability

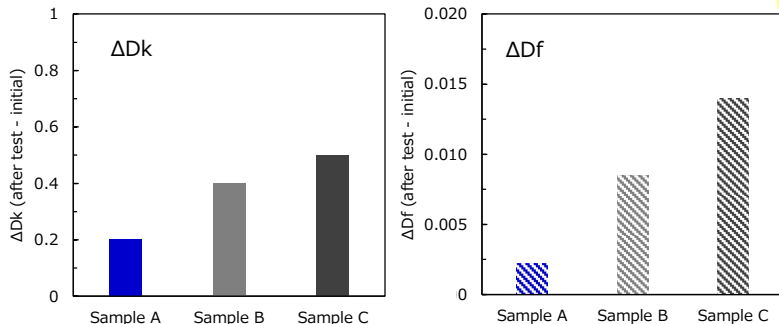


- ◆ Sample A, HC-G series, shows better thermal stability after HTS test compared to other polymer systems

Thermal stability characterization procedure



Change of Dk and Df after HTS test



Film appearance after HTS test

Appearance	Sample A	Sample B	Sample C
Initial (Before HTS test)			
After HTS test			

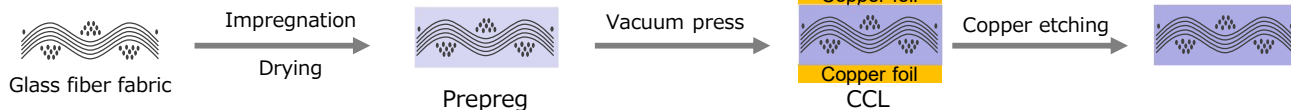


CCL Properties



- ◆ HC-G series balances Electrical, Thermal and Mechanical properties for optimum performance

Procedure and properties



Item		Unit	Test Condition	Laminate with HC-G series
Electrical Properties	Dk	-	Split cylinder resonator @10GHz	3.2
	Df	-		0.0013
Thermal Properties	Tg	°C	DMA	182
	Solder resistance	sec.	Solder dip testing @300°C	>300
Mechanical Properties	CTE	ppm/K	x-y axis, α1	23
	Peel strength	N/mm	with H-VLP3 Copper foil	0.9



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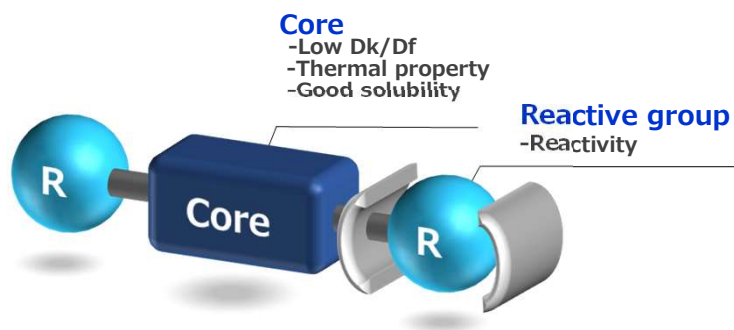
JSR's Approach for Low Loss Crosslinker



- ◆ JSR has designed a new crosslinker, PJ series, which achieves low CTE and high Tg with low Df
- ◆ The core's unique design ensures excellent compatibility within the resin matrix

Low Loss Crosslinker
for BUF, Core, RCC, PP, CCL

JSR ELPACT™ PJ series



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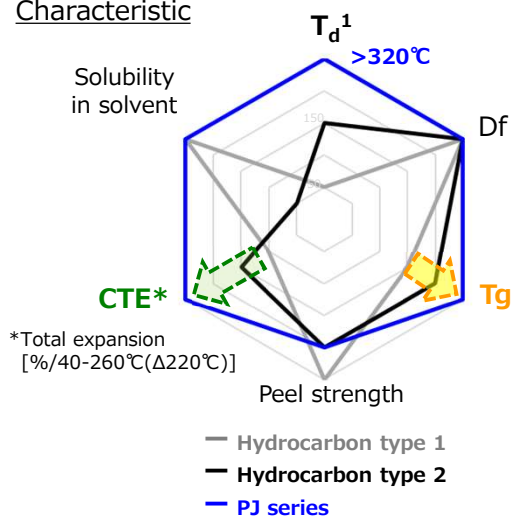
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Properties of New Crosslinker



◆ PJ series achieves low CTE and high Tg with low Df

Characteristic



Sample information & Film properties

		Sample D (w/o crosslinker)	Sample E (w/ crosslinker)
Formulation	Polymer (Thermoset)	HC-G series	HC-G series
	Crosslinker	w/o	PJ series (30wt%)
	Initiator	w/	w/
Properties	Dk @10GHz	2.6	2.6
	Df @10GHz	0.0011	0.0012
	Tg @DMA	Ref.	20°C up
	Total Expansion (40-260°C)	Ref.	35% down



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Summary



- ◆ As digital communication technology advances, IC-Substrate and PCB designs require low loss and low CTE dielectric materials that achieve high signal speed with high reliability
- ◆ JSR has developed the “**HC-G series**” of thermoset polymer with low Dk/Df, good adhesion and excellent thermal stability
- ◆ Newly developed crosslinker “**PJ series**” achieves low Dk/Df as well as low CTE
- ◆ JSR supports advanced IC-Substrate/PCB applications and continues to develop **new low loss material products**

Thank you!



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