20TH INTERNATIONAL CONFERENCE & EXHIBITION ON DEVICE PACKAGING

# Novel Low Loss Polymer for Advanced IC Packaging

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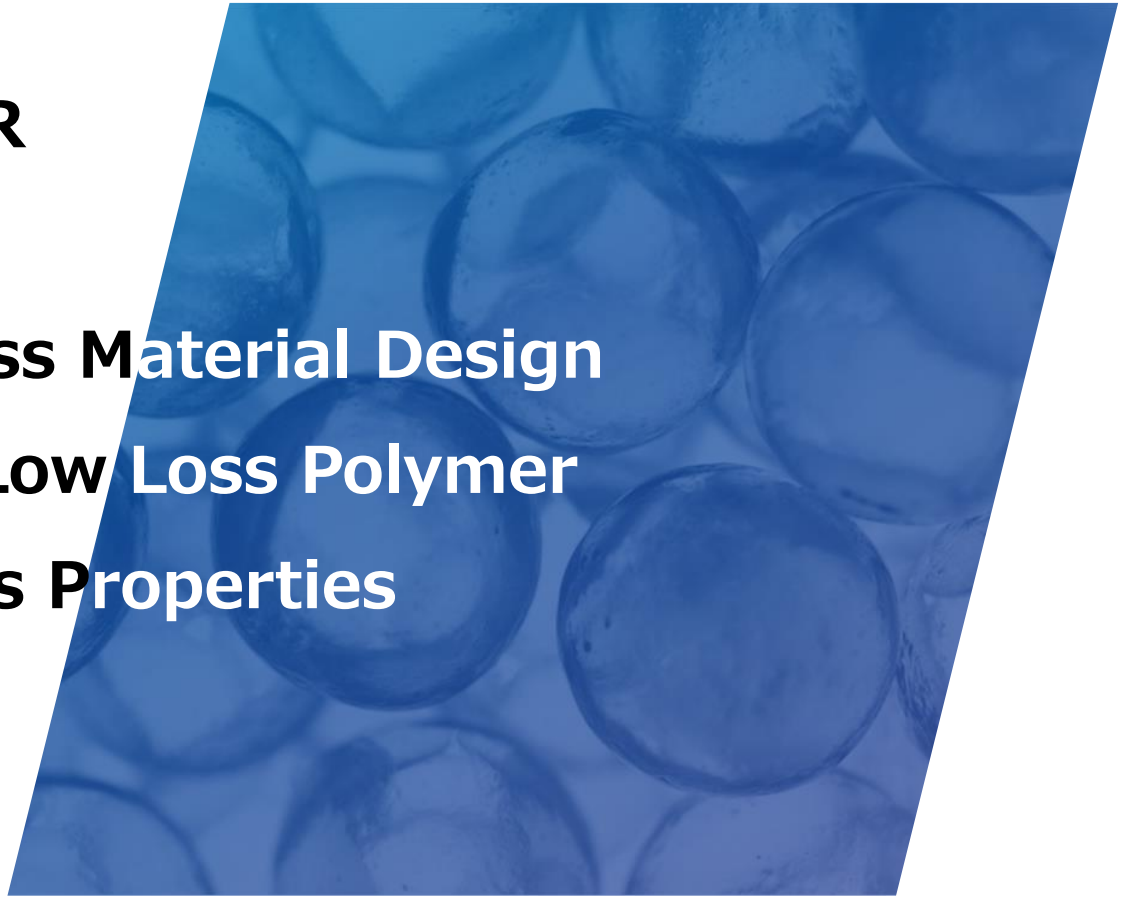
JSR

# Outline



1. Introduction of JSR
2. Background
3. Concept of Low Loss Material Design
4. JSR Approach for Low Loss Polymer
5. Low Loss Polymer's Properties
6. Summary

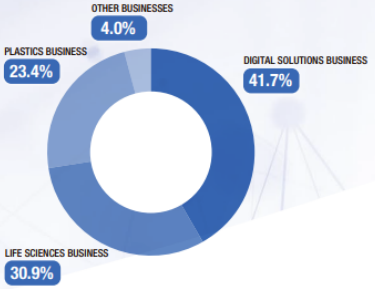
# Introduction of JSR Group

### 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

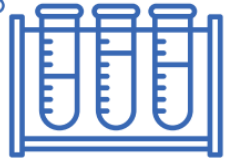
62.2% of these sales are overseas.




### Number of business sites
**47**

* As of April 1, 2023

The JSR Group operates in 19 locations in Japan and 28 locations overseas.



### R&D Expenses
**27** billion yen

* FY2022 results (April 1, 2022 - March 31, 2023)
* Whole JSR Group, including contract research expense of goods purchased.

We are committed to research and development for future technologies.

### 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.


### Percentage of annual paid leave taken
**88.8**%

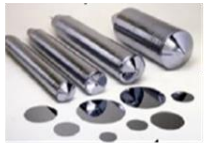
* FY2022 results including employees seconded from JSR. (April 1, 2022 - March 31, 2023)

We encourage a work-life balance.

# JSR Semiconductor Materials

## Front-end

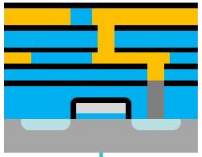
1. Slicing Substrate



2. Resists coating/ Exposure

3. CMP

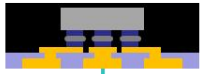
4. Multilayer wiring



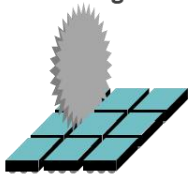
## Back-end

5. Temporary bonding /Wire formation

6. Cleaning



7. Dicing



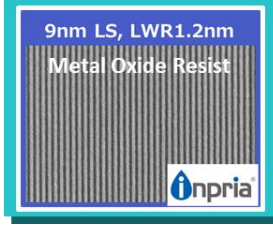
8. Packaging

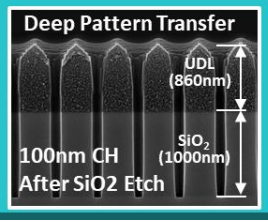
### Lithography Materials

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.

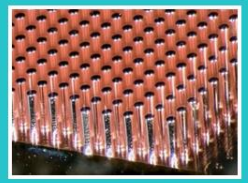
CMP materials

Cleans

### Advanced Packaging Materials

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

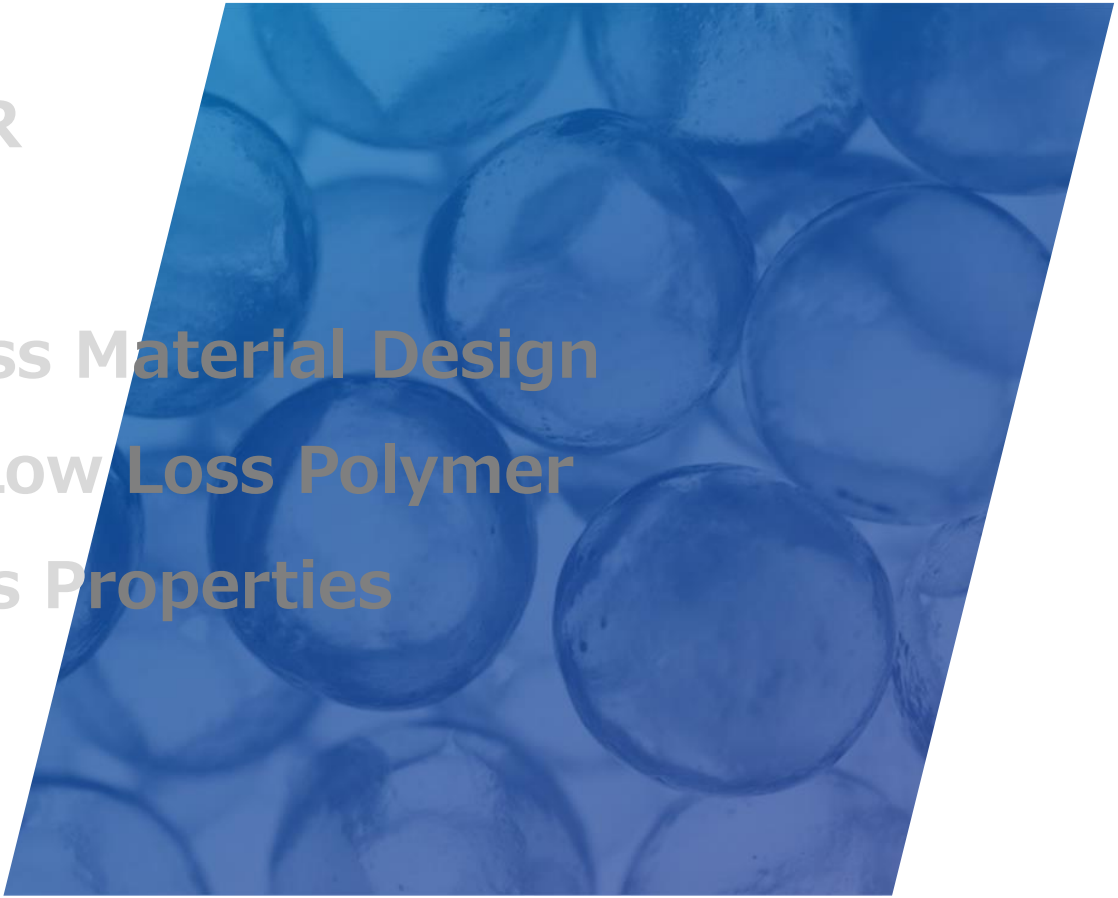
Thick Layer photoresists Cu Pillar(Plating PR)



Raw materials for IC-Substrate/PCB
(NEW) HC-G series

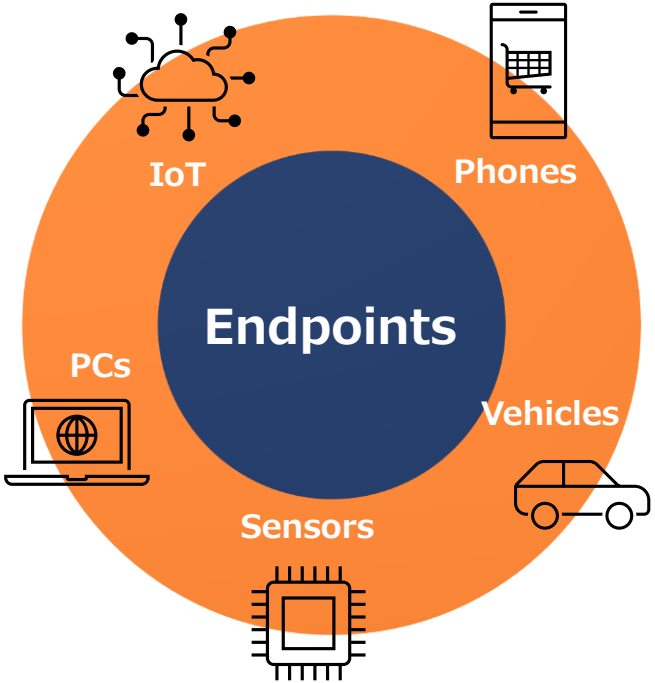
# Outline

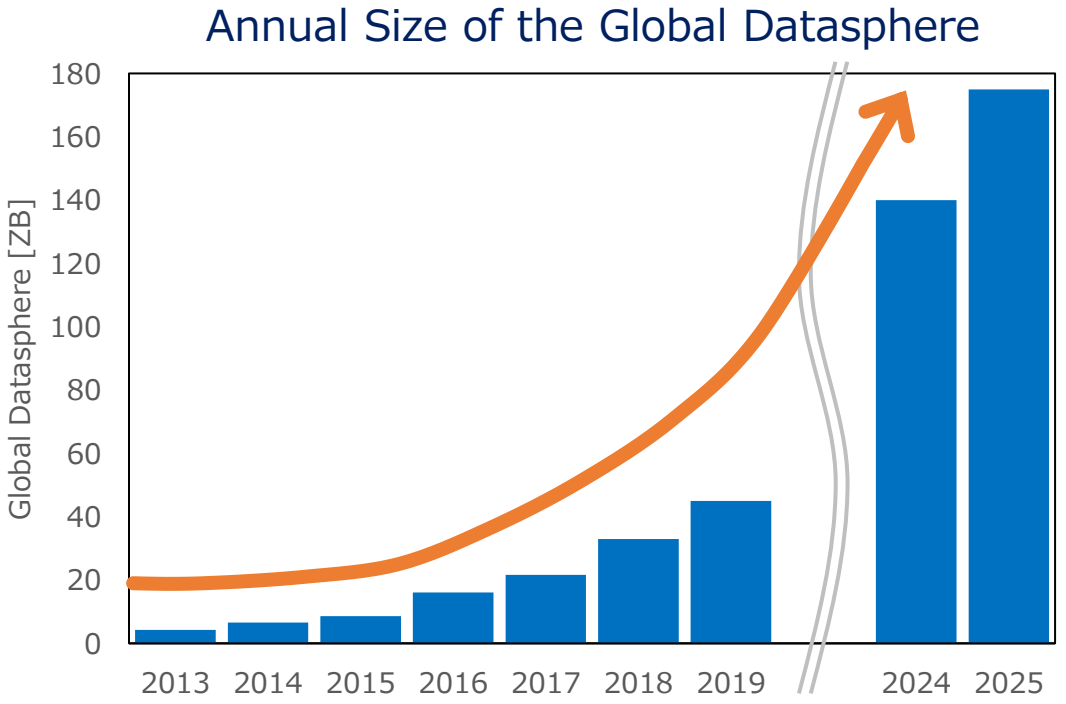




# Growth of the Global Datasphere

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

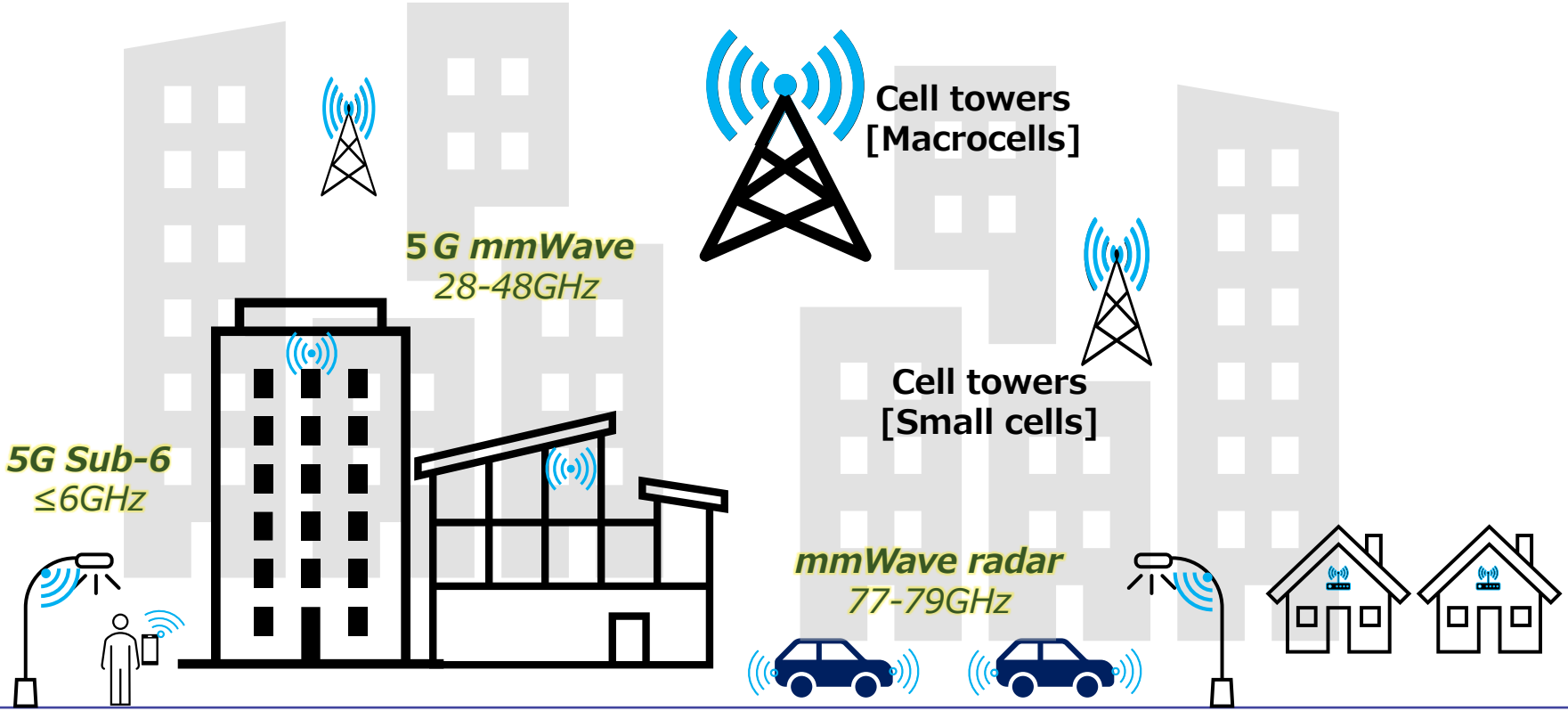



*Source: IDC Global DataSphere*

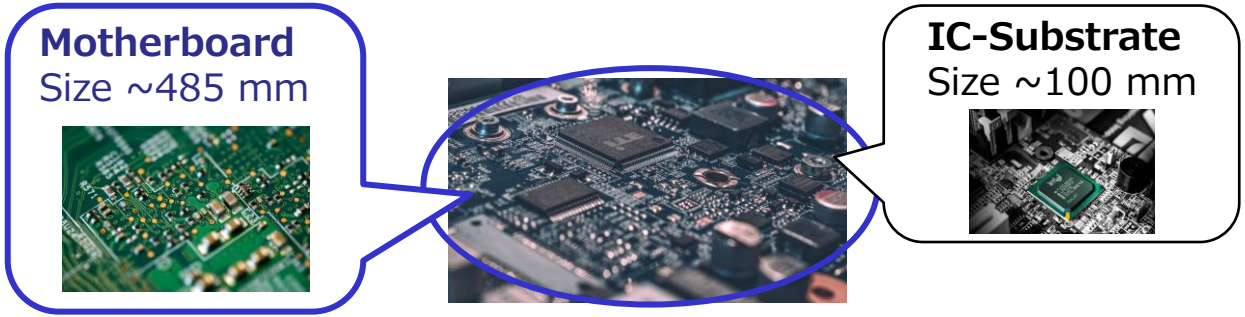
# Solution for High-speed Telecommunications

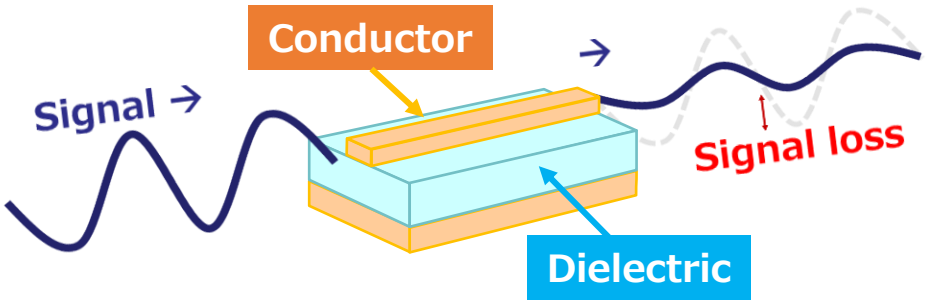
- High frequency signals enable high-speed telecommunications

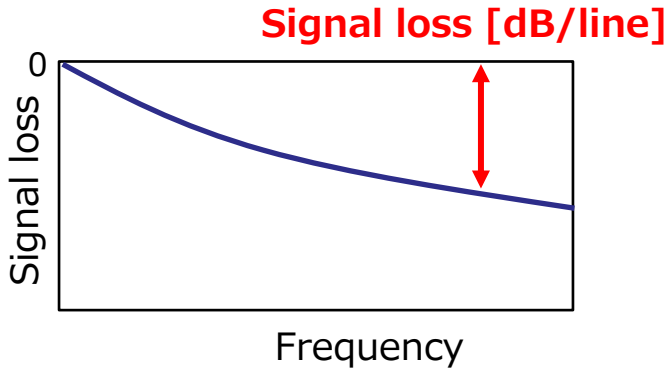


# Challenges at High Frequency

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



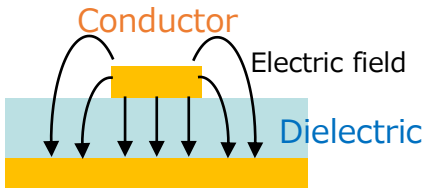



# Requirements of Low Loss Materials

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

## Dielectric loss → Dk, Df

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

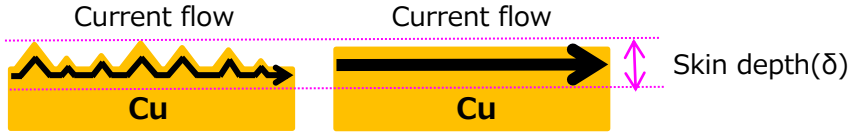



k: constant
f: frequency
Dk: Dielectric constant
Df: Dissipation factor

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

**Key: Low Dk, Df**

## Conductor loss → Skin effect




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

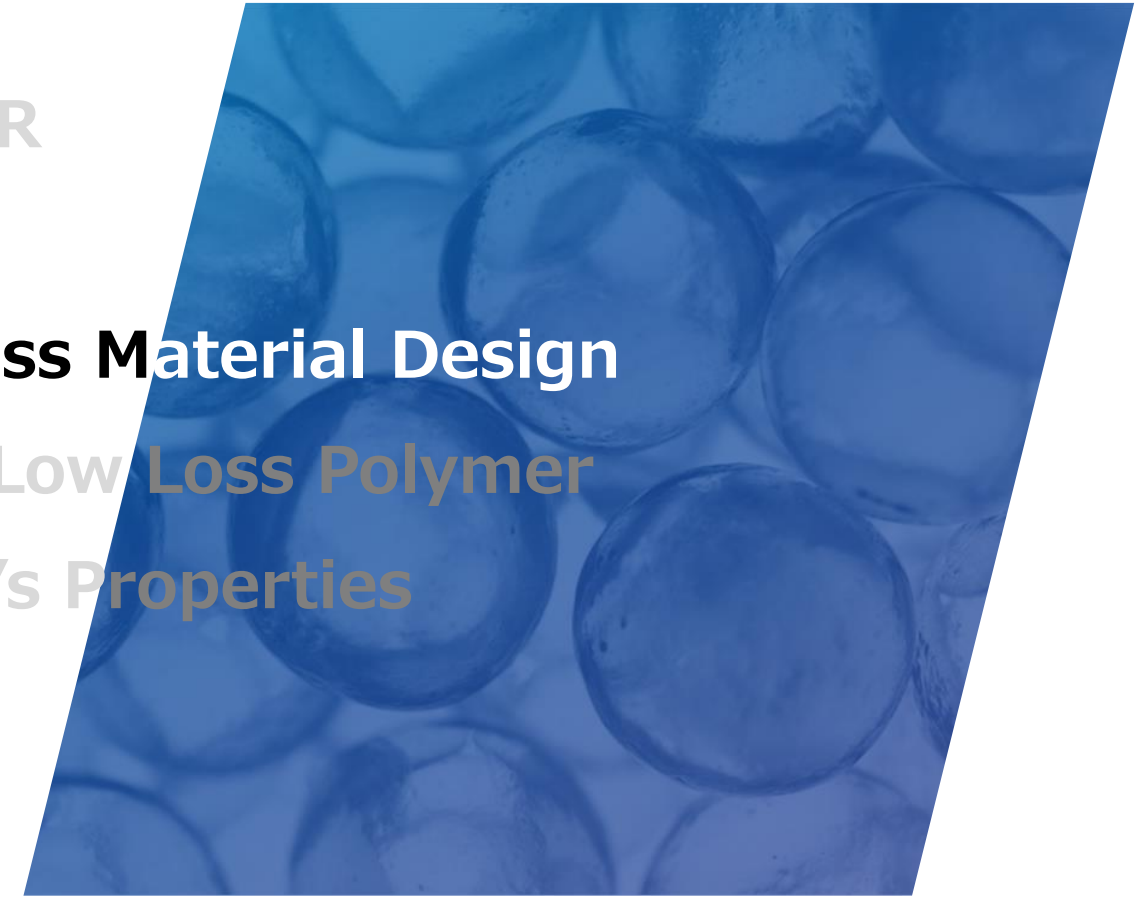
f: frequency
μ: permeability
σ: conductivity

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

**Key: Adhesion to smooth Cu**

# Outline





# Design of Low Loss Material

## ◆ Dielectric constant (Dk)

Clausius–Mossotti equation

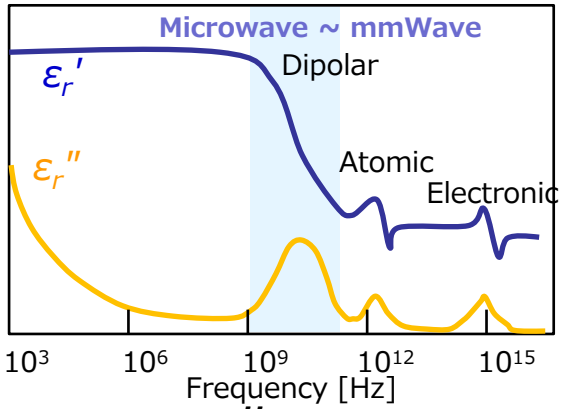
$$\mathrm{Dk} = (1 + 2\frac{\mathrm{P_m}}{\mathrm{V_m}})/(1 - \frac{\mathrm{P_m}}{\mathrm{V_m}})$$

$P_m$: Molar polarizability, $V_m$: Molar volume

To achieve low Dk

- ✓ Smaller Pm
  = Low polarity design of a molecule
- ✓ Larger Vm
  = Design of large molecular volume

## ◆ Dissipation factor (Df)




$$\mathrm{Df}\ (= \tan\delta) = \frac{\varepsilon_r''}{\varepsilon_r'}$$

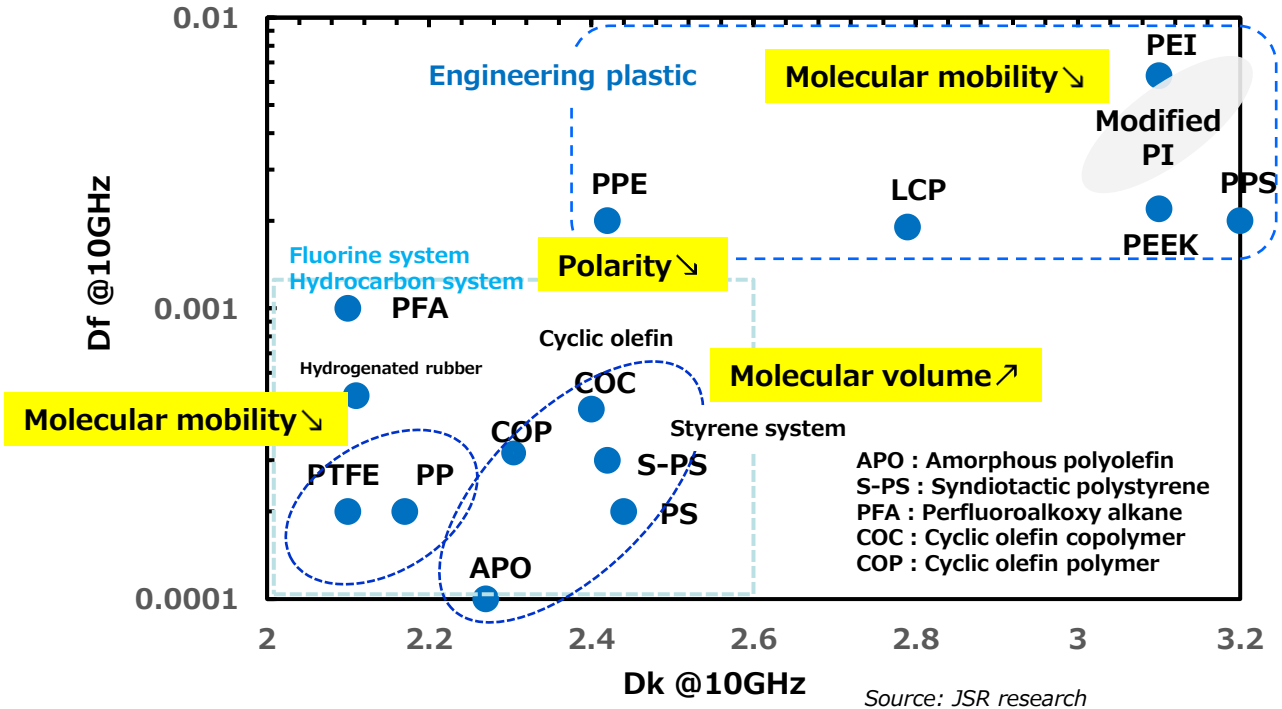
($\varepsilon_r'$: The real part of permittivity, $\varepsilon_r''$: The imaginary part of permittivity)

To achieve low Df

- ✓ Low overall permittivity
  = To suppress dipole orientation of a molecule

# Existing Low Loss Material

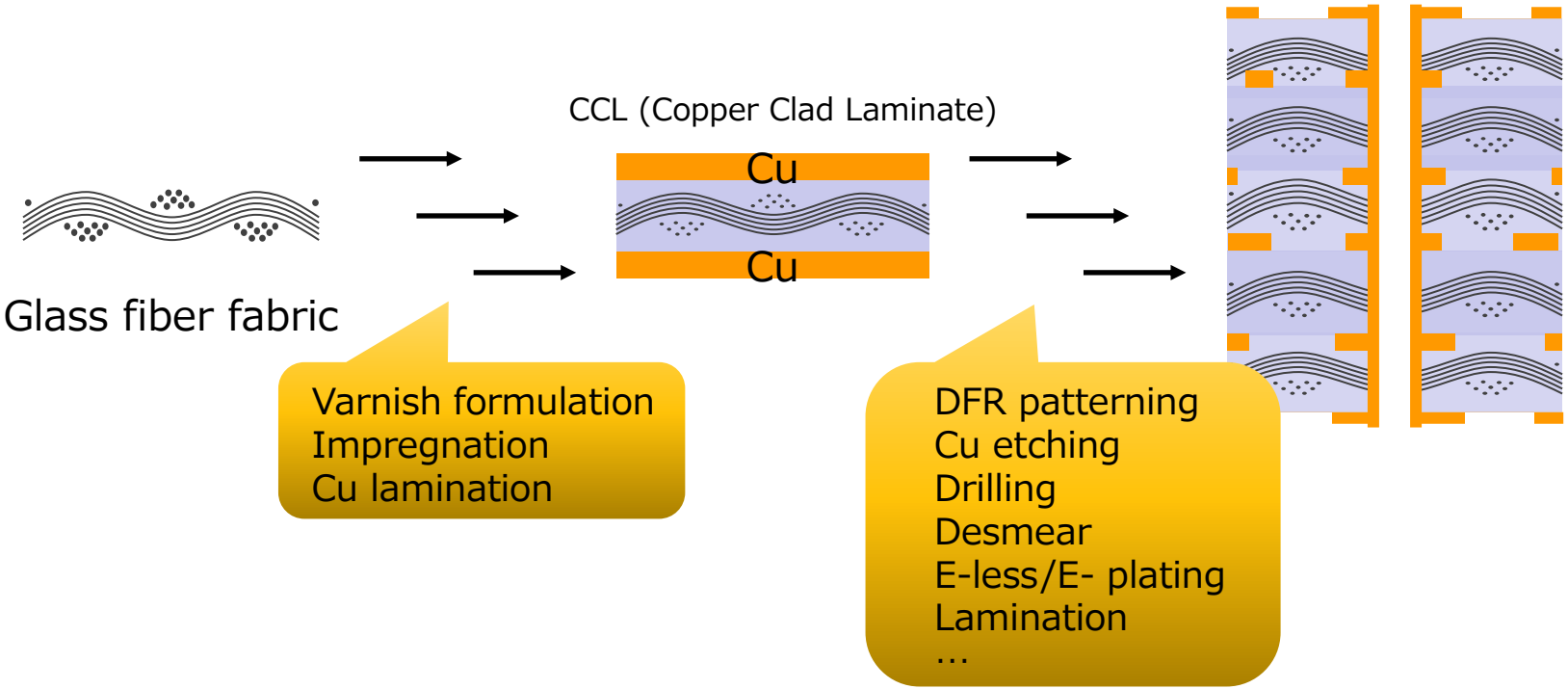
- A low Dk/Df polymer can be designed using the following strategies: ①low polarity structure, ②inhibition of molecular mobility and ③large molecular volume




*Source: JSR research*
*Development of Substrate Materials for Electronics Package CMC P115*

# Requirement of Multilayer Lamination

- For manufacturing a CCL and a multilayer lamination, numerous steps are required

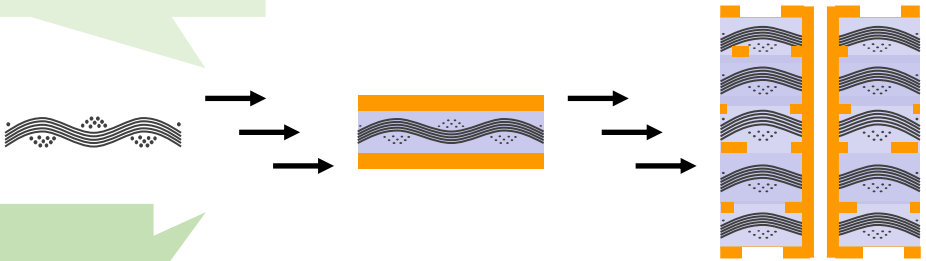


# Requirement of Multilayer Lamination

- A material for multilayer lamination requires low loss properties as well as process compatibility

Varnish
- Compatibilities
- Impregnation property

- Solder heat resistance
- Electrical insulation reliability



Film
- Adhesion to Cu
- Resin flow property

- Adhesion to plating
- Drilling compatibility

- Thermal stability
- Chemical resistance

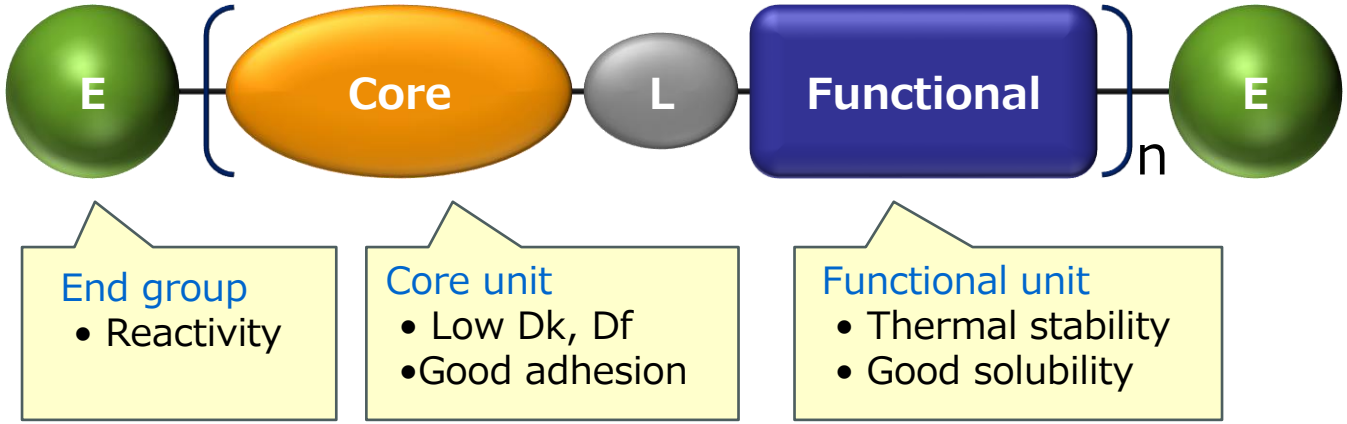
# Outline



# 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

## JSR ELPAC™ HC-G series

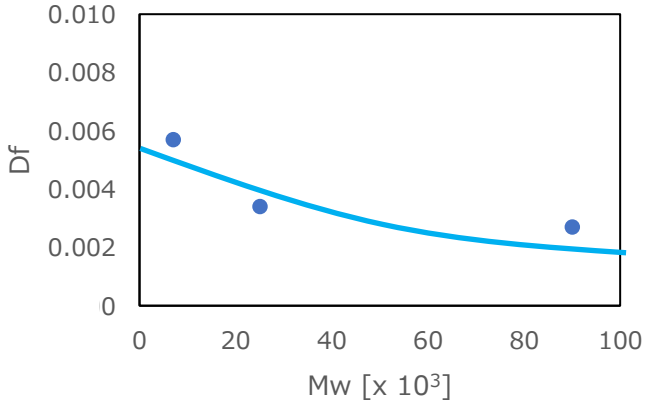


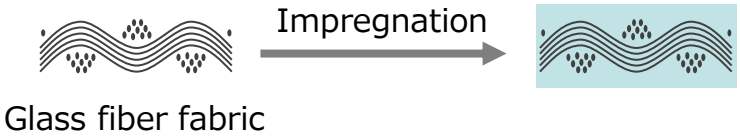

L: Linker, E: End group

# Impact of Mw on Prepreg Properties

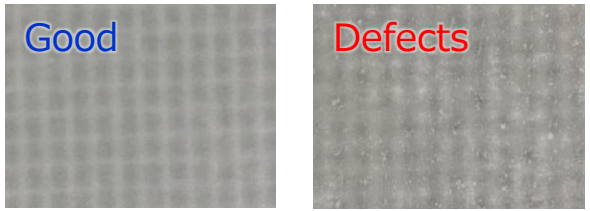
- A higher Mw polymer provides a lower Df. However, higher Mw polymer creates impregnation property concerns

| Item | Polymer | | |
|---|---|---|---|
| | ***#1*** | ***#2*** | ***#3*** |
| Molecular Weight | **90k** | **25k** | **7k** |
| Polymer Structure | Type-1 | Type-1 | Type-1 |
| Dk (10GHz) | 2.6 | 2.6 | 2.6 |
| Df (10GHz) | 0.0027 | 0.0034 | 0.0057 |




Appearance of prepreg

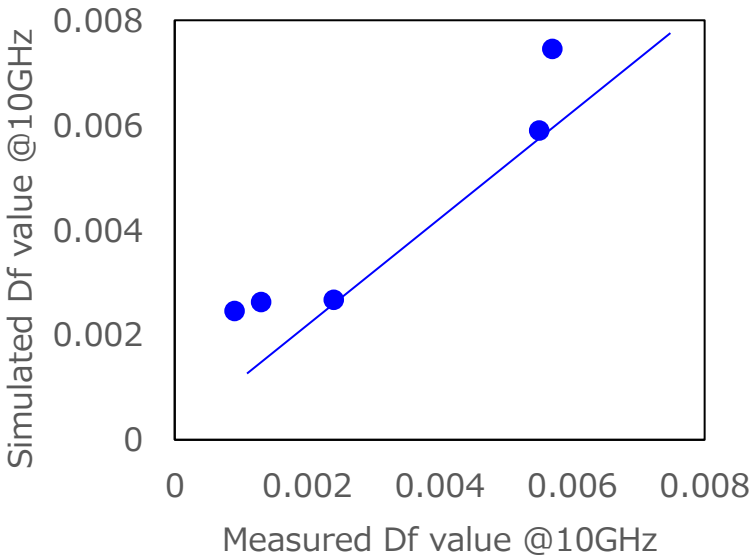


# Impact of Polymer Structure to Properties

- An appropriate polymer structure (#6) was found through simulation and experimentation

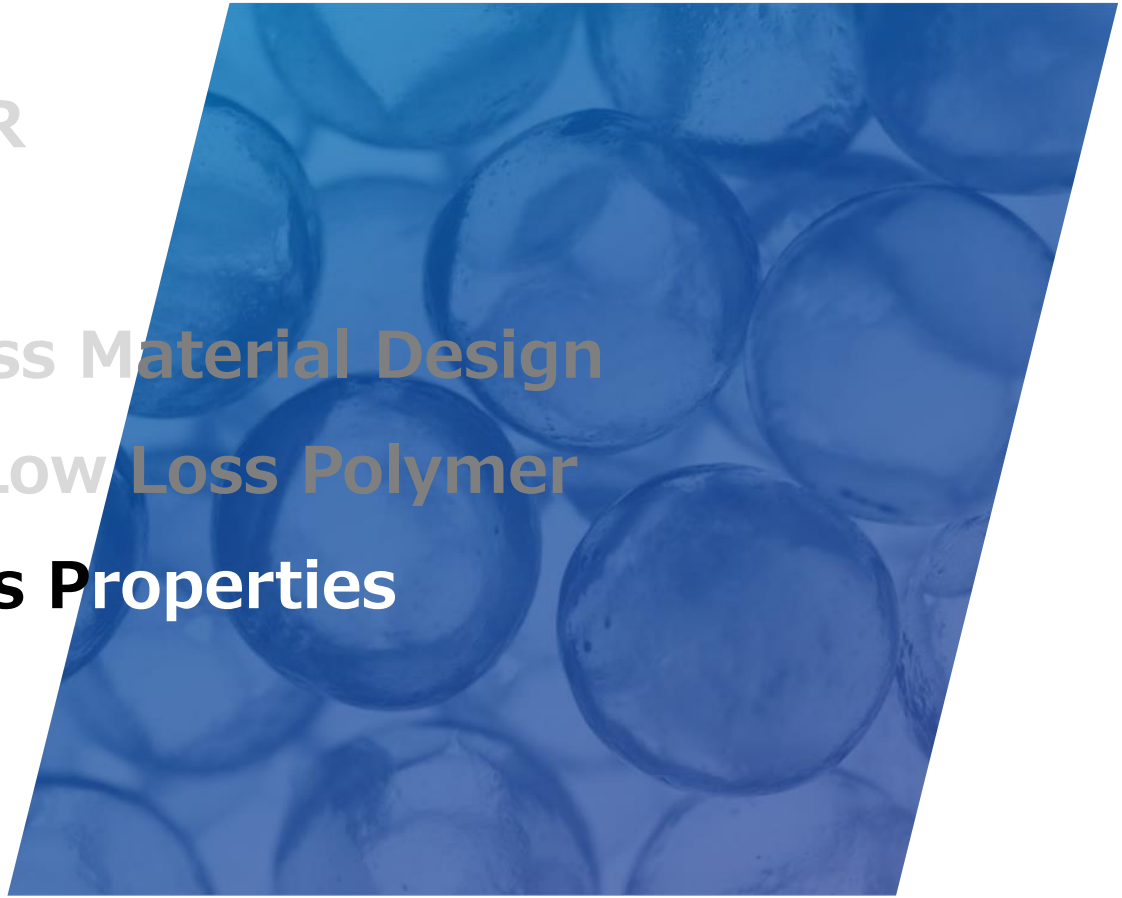
| Item | Polymer | | |
|---|---|---|---|
| | ***#4*** | ***#5*** | ***#6*** |
| Molecular Weight | 4k | 4k | 4k |
| Polymer Structure | **Type-2** | **Type-3** | **Type-4** |
| Dk (10GHz) | 2.6 | 2.6 | 2.6 |
| Df (10GHz) | 0.0020 | 0.0013 | 0.0011 |

Example of Df simulation



# Outline

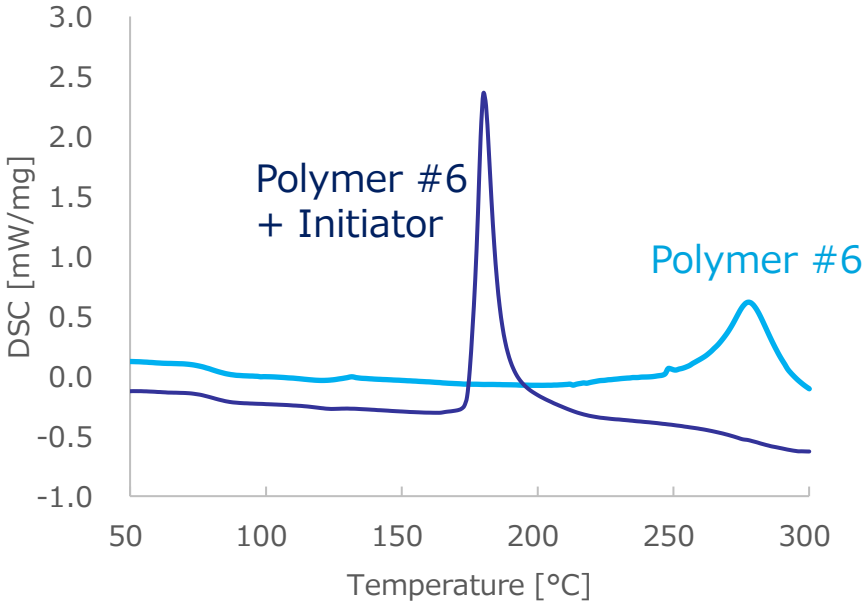




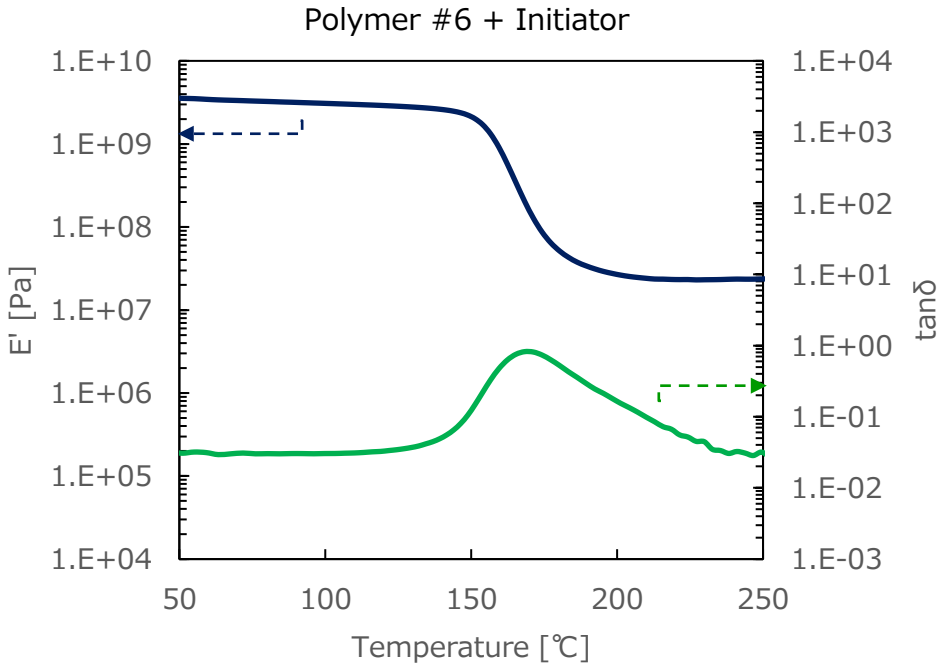
# Polymer's Thermal Properties

- The HC-G polymer is curable by itself at over 250℃. The starting temperature of curing is controlled by adding an initiator. The polymer's Tg is over 170℃

DSC chart




DMA chart



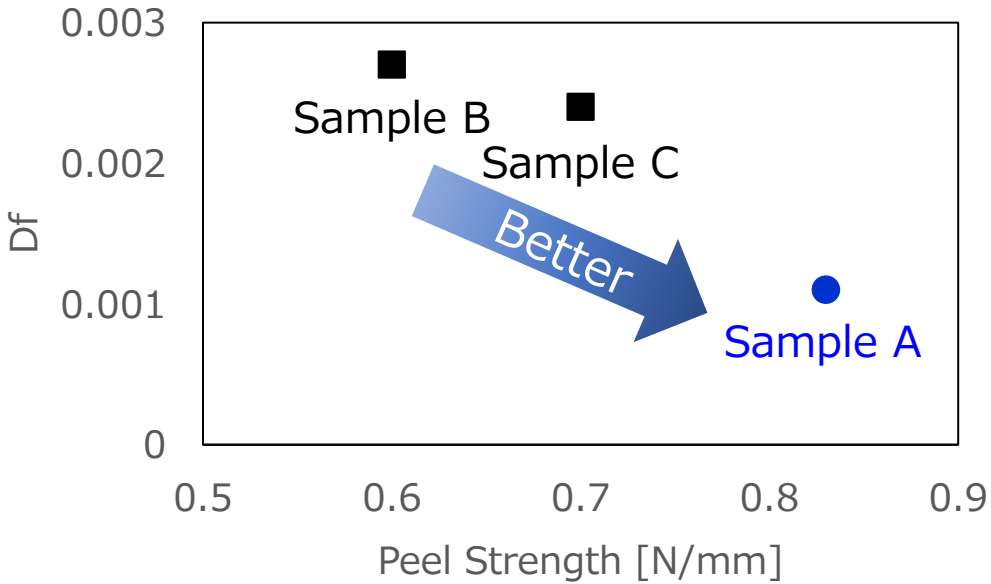
# Polymer's Adhesion Property

- 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/ |

Peel Strength vs. Df

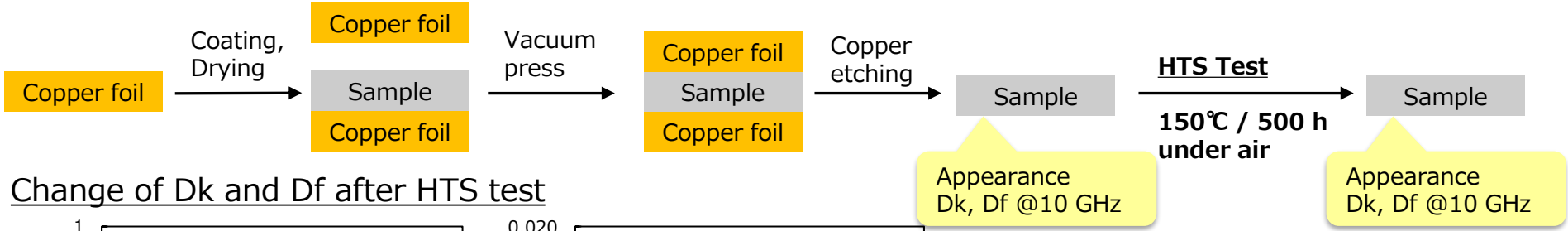



*Copper foil: $Rz_{JIS}$ = 1.5 µm*

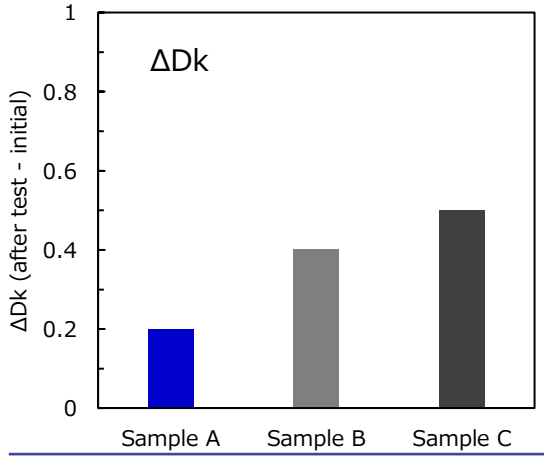
# Polymer's Thermal Stability

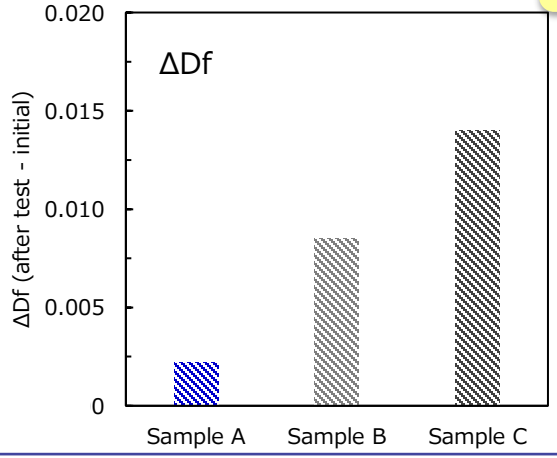
- Sample A, HC-G series, shows better thermal stability after HTS test compared to other polymer systems

## Procedure to Check Thermal Stability

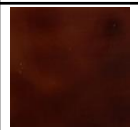
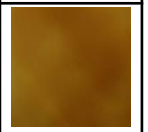



## Change of Dk and Df after HTS test



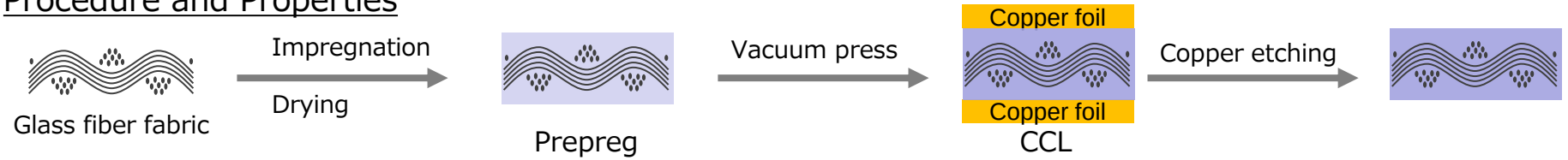

## Film Appearance after HTS Test

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

# CCL Properties

◆ HC-G series achieves a great balance of properties in CCL applications

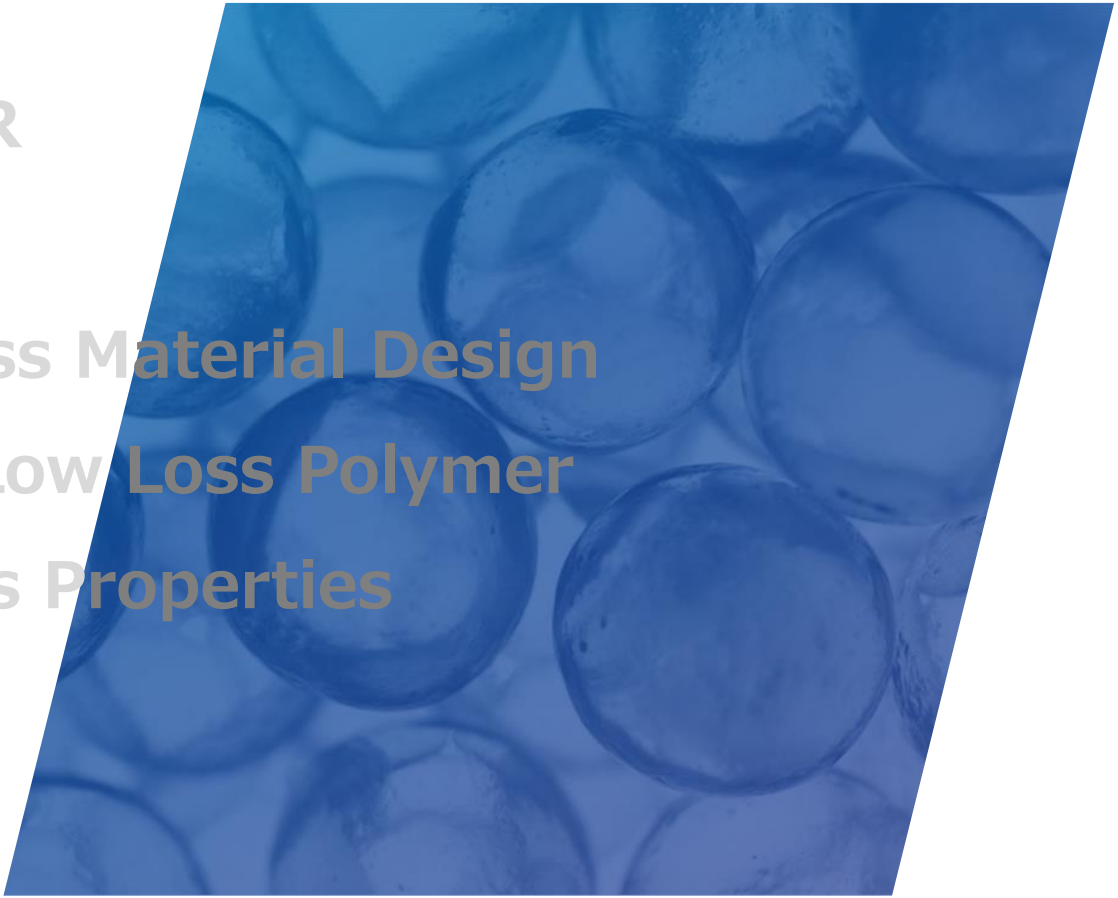
Procedure and Properties




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

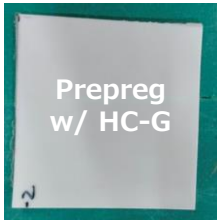
# Outline

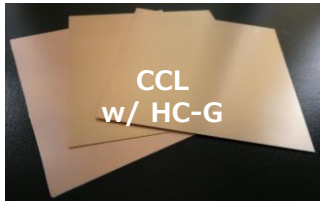




# Summary

- As 5G/6G wireless technology expands, IC-Substrate and PCB designs require low loss dielectric materials that decrease loss at high frequency, and achieve high signal speed
- JSR has developed the HC-G series of thermoset polymer with low Dk and Df
- HC-G series yielded Dk of 2.6 and Df of 0.0011 at 10 GHz, as well as peel strength 0.8 N/mm.
- HC-G series showed 70% lower Df than other polymer systems after the HTS test at 150℃ for 500 hours
- CCL with HC-G series provides the low loss properties required for high-speed / high frequency applications



# Thank you!

***Hikaru Mizuno (hmizuno@jsrmicro.com)***