WIRELESS 5G INFRASTRUCTURE

CHEMISTRY THAT MATTERS™

Classification: General Business Use

CHEMISTRY THAT MATTERS™

SABIC PORTFOLIO OF SPECIALIZED MATERIALS FOR 5G APPLICATIONS



Global 5G success depends on meeting consumer demands for next-generation networking, from speed and reliability to sustainability. To meet these expectations, operators and device makers are implementing new technologies and expanding coverage and capacity. SABIC's specialized materials enable you to evolve with the industry and collaborate on new applications, including 5G devices, and infrastructure and e-mobility components.

As one of the top global suppliers of specialty engineering plastics, SABIC maintains strong relationships with global leaders in the development of 5G telecommunication devices by providing them with a broad portfolio of advanced materials and unique solutions that they need to achieve long-term reliability, weight reduction, improved radio-frequency (RF) performance and innovative design.

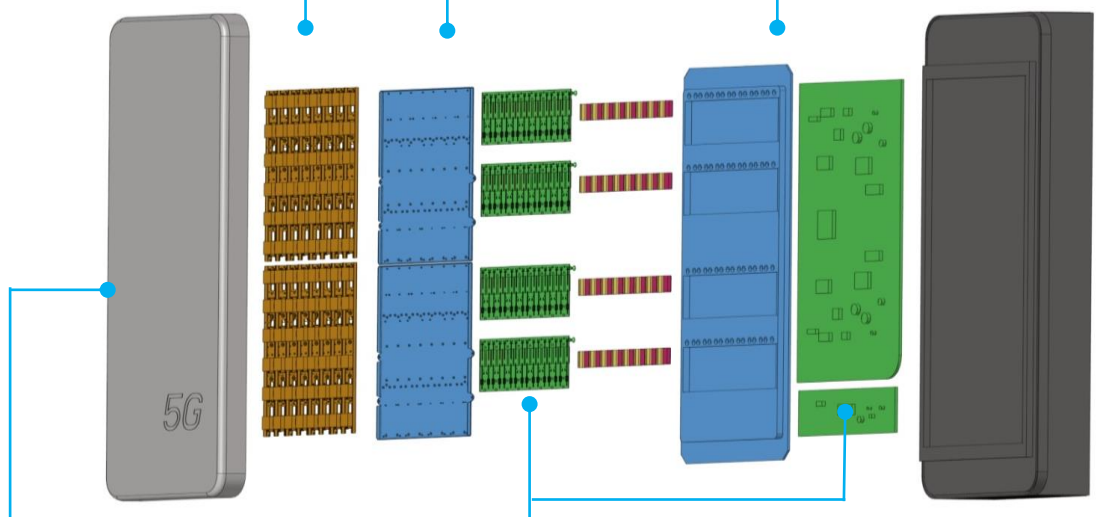
SABIC'S SPECIALTIES OFFERING:

- Superior weatherability and mechanical properties
- PTFE and metal replacement solutions
- Superior low CTE compounds for plastic connectors and cavity RF filters
- EMI shielding and thermally conductive solutions
- Customized Dk/Df solutions
- Ultra Low Dk/Df and moisture-absorbing thermoset oligomer

Dipole & Phase shifter
- LNP™ THERMOCOMP™ compound
- ULTEM™ resin

EMI Shielding Plate
- LNP™ FARADEX™ compound

RF Filter
- ULTEM™ resin



Radome
- LNP™ ELCRES™ copolymer PC

PCB Board, Connector & Optical Transceiver
- NORYL™ SA resin (ultra low dielectric loss)
- ULTEM™ resin
- LNP™ THERMOCOMP™ compound

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SABIC SOLUTIONS FOR 5G APPLICATIONS

Phase Shifter	ULTEM™ Resin	2300	PEI+30%GF, high dimension stability, high heat, mechanical strength
		2210	PEI+20%GF, high dimension stability, high heat, easy flow
		2200	PEI+20%GF, high dimension stability, high heat
		4001	PEI, high dimensional stability, high heat, wear resistance
		1010	Unfilled PEI, high IR transmittance, high dimension stability
		1000	Pure PEI, high dimension stability and mechanical strength, low Dk/Df
	LNP™ THERMOCOMP™ Compound	Z1COOI	PPO base, Dk 2.55, Df 0.0008, HDT> 160℃
		ZKC04	PPO base, Dk 3.1, Df 0.0011, HDT > 170℃
		ZKC06	PPO base, Dk 3.6, Df 0.0011, HDT> 170℃
		ZKC08	PPO base, Dk 3.9, Df 0.0012, HDT> 170℃
		ZX08309	PPO base, Dk 4.5, Df 0.003, HDT> 130℃
		ZX06323	PPO base, Dk 6.3, Df 0.004, HDT> 120℃
		DX09309	PC Base, Dk 8.0, Df 0.01, HDT> 90℃
Radome	LNP™ ELCRES™ Copolymers	CX7240	PC/ABS, V0 1.5mm, 5VA 3mm, thin walls
		EXL5689	Si-PC, 9% GF, robust mechanical strength under 0°C, V0 1.5mm
		EXL9134	Si-PC, robust mechanical strength under -35℃, UV resistance and long term hydro stability
		EXL9334	Si-PC, robust mechanical strength under -40℃, UV resistance and long term hydro stability
		EXL9334E	Si-PC, robust mechanical strength under -40℃, UV resistance, extrudable
		EXL9330	Si-PC, robust mechanical strength under -60℃, UV resistance and long term hydro stability
RF Filter	ULTEM™ Resin	3452	PEI+45%GF/mineral, low CTE, high dimension stability, easy plating
Antenna array	LNP™ THERMOCOMP™ Compound	OFC08V	PPS+30%GF LDS, high mechanical strength, low df, low density, very good LDS performance
		OFC08	PPS+40%GF, high mechanical strength, stable dk/df, easy plating
		OFC08XXP	PPS, low warpage, high modulus/strength, pass high temp SMT, easy plating
BTB Connector	ULTEM™ Resin	1010	Unfilled PEI, high IR transmittance, high dimension stability, low Dk/Df
FOC + Lenses	ULTEM™ Resin	1010	Unfilled PEI, high IR transmittance, high dimension stability
	EXTEM™ Resin	XH1015	Polyimide, IR transparency, dimensional stability, SMT capable
CCL	NORYL™ Resin	SA9000	Super low dk, low df, additive for CCL
		SA90	Super low dk, low df, additive for CCL
FCCL	NORYL™ Resin	SD1100P	High purity building block in polyimides, low Dk/Df, low water adsorption, soluble in organic solvent
		BISDA-1000	Comonomer in polyimides or curing agent in epoxy, high-heat resistance, dimension stability and adhesion.
EMI shielding plate	LNP™ FARADEX™ Compound	NX07344	FR V0, PC/ABS, EMI shielding >65 db
		DS0036I	FR V0, PC, EMI shielding >55 db, high impact

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SABIC'S SOLUTIONS FOR PHASE SHIFTERS



A phase shifter is a device that can focus the radiation signal in a particular direction. It is well known that in-phase waves add up "constructively," while out-of-phase waves diminish "destructively." This same concept applies to RF signals. Phase shifters are placed between the radio and the radiating elements of an antenna. By tuning these shifters, the pattern shape and direction of the signal can be altered.

Why should the direction of the signal change? If capacity requirements increase or there's a need to avoid interference between cell sites for example, the antenna's vertical pattern can be tilted downward towards the ground.

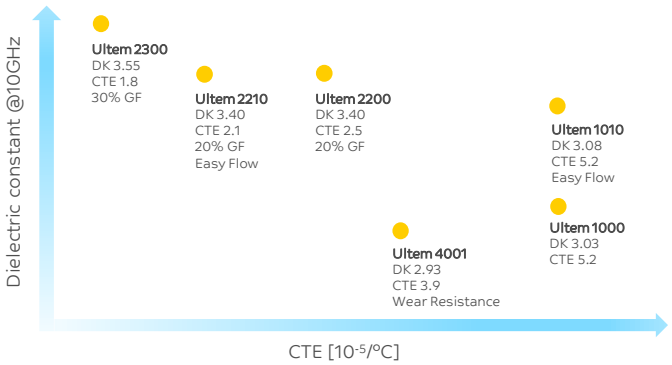
There are different phase shifter types that can be grouped together in two categories:

MOVING CIRCUIT PHASE SHIFTER

In a moving circuit phase shifter, there is a moveable device that can change the geometric length of the line (l) and then the phase. SABIC's materials for moving circuit phase shifters offer:

- Dimensional stability
- FR UL V0 rated
- High heat resistance
- Stable Dk/Df
- High Modulus

SABIC'S SPECIALTIES OFFERING

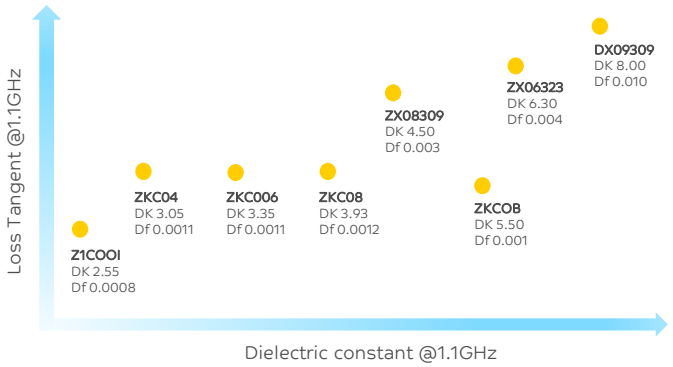


MOVING DIELECTRIC PHASE SHIFTER

A moving dielectric phase shifter contains a movable dielectric plate. The position of this plate inside the phase shifter affects the velocity and the wavelength of the electromagnetic wave. Consequently, the phase shifts. SABIC's materials for moving dielectric phase shifters offer:

- Customized and stable DK
- Stable Df
- Dimensional stability
- Impact resistance

SABIC'S SPECIALTIES OFFERING



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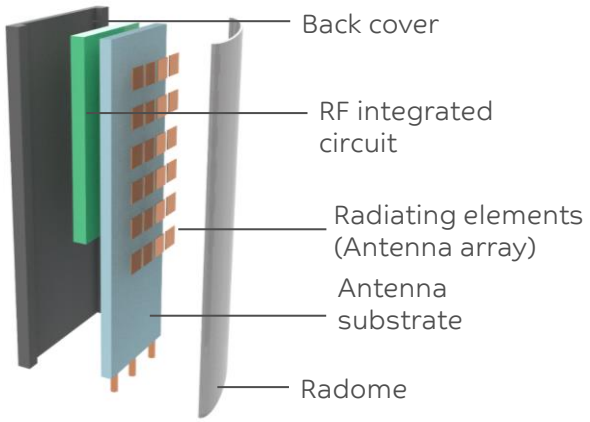
SABIC'S SOLUTIONS FOR RADOMES

A radome is an enclosure that protects the antenna from the impact of multiple elements such as wind and snow. On the other hand, it represents an obstacle that the signal has to go through. That is why the radome needs to be RF transparent to minimize the degradation of the electrical performance of the enclosed antenna.

Depending on the frequency range there are different requirements that the radome has to meet.



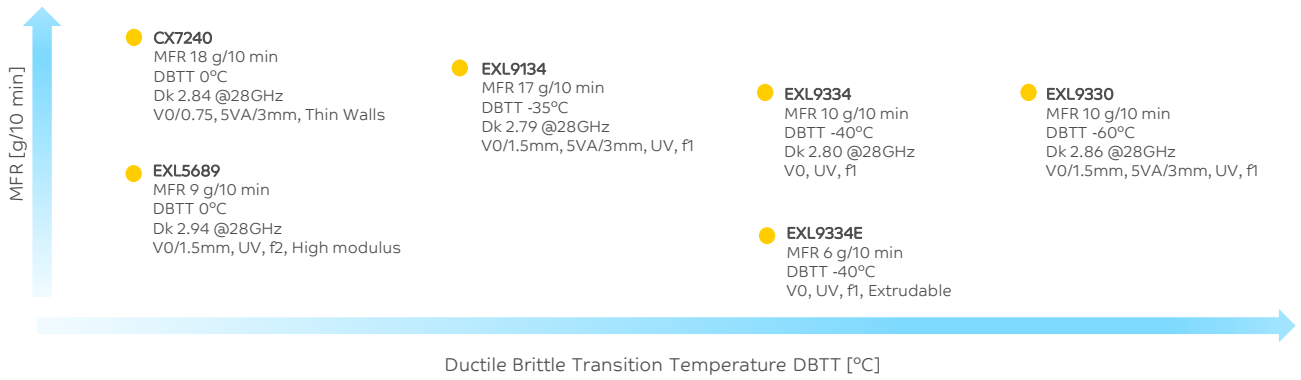
FREQUENCY RANGE BELOW 6GHz

- At these wavelength/frequencies, the signal can still propagate a fair distance.
- The radome normally is composed by a monolithic structure that can be extruded or injection molded.
- The Dk determines the reflection of the wave while the Df determines the attenuation of the signal when it travels through the radome sheet.
- Key materials requirements include impact resistance, UL V0 rating, weatherability, low moisture absorption.

FREQUENCY RANGE ABOVE 24GHz

- New network infrastructure needed. At these wavelengths the signal can't propagate far and it doesn't pass through obstacles. A lot of antennas are needed to avoid signal loss.
- The radome typically is composed of a sandwich with three layers made of two high density skins and a low-density core (foam).
- A material's dielectric properties are very important: ultra low Df and low Dk are needed.
- Key material requirements include impact resistance, UL V0 rating, weatherability, low moisture absorption.

SABIC'S SPECIALTIES OFFERING



Bio-based materials or solutions with post consumer recycled (PCR) content are available upon request.

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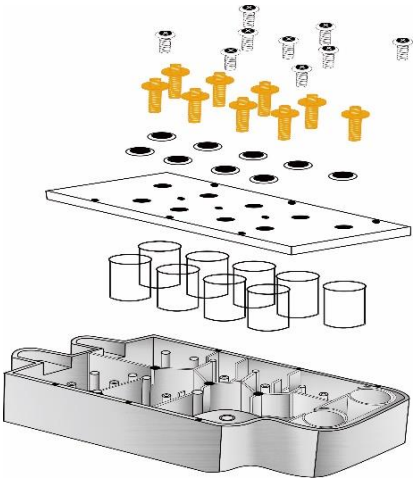
SABIC'S SOLUTIONS FOR CAVITY FILTERS

Radio frequency filters are one of the most critical components for RF and microwave systems. They are used to prevent unwanted signals from entering or leaving a system without attenuating the wavelengths that needs to pass through.
The more antennas and frequency bands a system needs to handle, the more filters it will require to function properly. As an example, Massive multiple-input multiple-output (MIMO) systems, that leverage beamforming techniques to communicate with multiple users, use large antenna arrays (typically using 16, 32 or 64 array elements). Each element is connected to a filter.



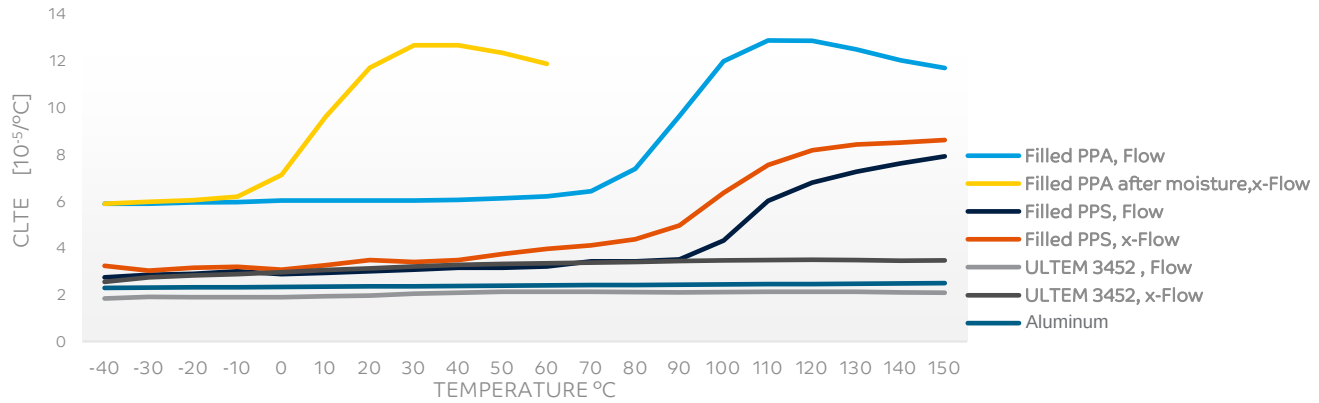
SABIC'S SPECIALTIES OFFERING

SABIC ULTEM™ polyetherimide resin is a high-performance amorphous thermoplastic with a glass transition temperature (Tg) of up to 217°C, excellent dimensional stability, excellent mechanical strength and modulus, stable dielectric performance and good electroplating performance. It has long-term recognition by customers in the communications industry, and is widely used in tuning screws, fixed screws, cross coupler base and other internal and external components.

ULTEM resin offers a metal replacement solution for 5G cavity filters with unique advantages:

- Low density, weigh reduction
- Easy processing, suitable for large-scale mass production and quality control, cost-competitive
- Design flexibility, integration
- Low CTE, good dimensional stability within wide temp range (-40°C ~ 150°C)
- Reliable metallization
- High strength and modulus

High-performance thermoplastic dimensional stability comparison



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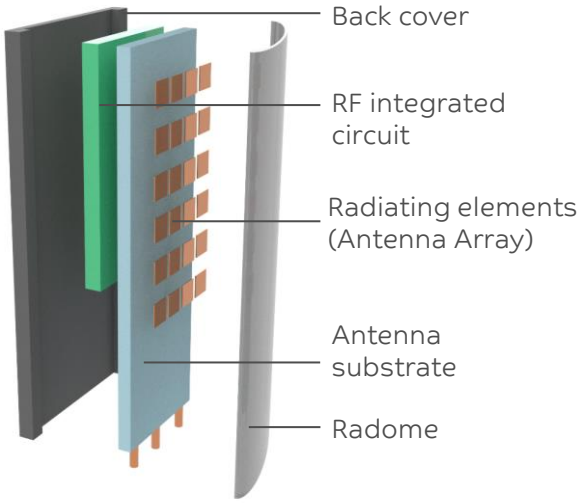
SABIC SOLUTIONS FOR ANTENNA ARRAYS

As RF antenna designs evolves to address higher demands in 5G, single band pole mounted passive antennas are being replaced with more complex multi-band and wider band antennas. These antennas required different materials and solutions to achieve a higher gain at microwave frequencies. An **antenna array** is a set of multiple connected antennas which work together as a single antenna inside the active antenna unit (AAU), to transmit or receive radio waves. It enables high gain beams and makes it possible to steer those beams over a range of angles. This component can be manufacturer with a combination of injection plastic and electroplating technology.



In general, there are two major technologies for the electroplating process, including selective plating and laser direct structuring (LDS) technology. Both have proven successful in typical dipole array designs.

SELECTIVE PLATING TECHNOLOGY

- Selective plating includes depositing the metal onto specific surfaces of the plastic part or component.
- The selective plating is a widely used but yet fastidious process. It contains six major steps after injection molding: 1) physical coarsening, 2) ultrasonic cleaning, 3) chemical coarsening, 4) nickel electroless plating, 5) copper electroplating and 6) tin electroplating.

LASER DIRECT STRUCTURING (LDS)

- Laser direct structuring technology is a simpler process vs. selective plating. It consists of the following two steps after injection molding: 1) laser structuring and 2) chemical plating.
- SABIC offers a broad range of LDS materials based on different resins, combined with unique coloring, fiber reinforcement, flame retardants, and laser activated additive technologies to meet the most challenging requirements.

SABIC'S SPECIALTIES OFFERING

Second Process	Grade	Base Resin	Features	Dk/Df (1.1GHz)
LDS	OFC08V	PPO	High modulus/strength, light weight, low DF, pass high temp SMT, high efficiency	Dk 4.0 Df 0.004
Selective Plating	OFC08	PPS	High modulus/strength, pass high temp SMT, easy plating and good long-term reliability	Dk 4.0 Df 0.004
	OFC08XXP	PPS	Low warpage, high modulus/strength, pass high temp SMT, easy plating and good long-term reliability	Dk 4.0 Df 0.004

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SABIC'S SOLUTIONS FOR 5G BOARD-TO-BOARD CONNECTOR APPLICATIONS



In the 5G era, in order to achieve high speed and hyperconnectivity, 5G base station antennas use large-scale MIMO technology to achieve high spectral efficiency of antenna arrays. The demand for antenna vibrators, filters, and board-to-board connectors that transmit RF signals is increasing exponentially. With the increase of the 5G infrastructure, the manufacturers of the related components and production processes are required to pursue lower costs and economies of scale, while combining stability and reliability performance.



For insulation in the 4G era polytetrafluoroethylene (PTFE) is used, and the CNC processing methods for PTFE provide slow cycle times and high costs in the 5G era. ULTEM™ resin, as an excellent insulation material, with excellent processing performance and installation convenience, can greatly shorten the cycle of large-scale mass production and reduce system costs. In addition, ULTEM resins provide good dielectric properties, technical strength and dimensional stability, making them the material of choice for board-to-board connector insulators.

The performance advantages of ULTEM resins in board-to-board connector applications include:

- Stable Dk, low Df at different frequencies
- Dimensional stability within a wide temperature range (-40°C to 150°C)
- High-heat resistance, RTI 170°C-180°C
- High mechanical strength and modulus up to 3200MPa
- No flame retardant, non-halogenated, polyfluoroalkyl-substance (PFAS) free
- Excellent processing performance, shorten production cycles, mass production capability



Board-to-board connector plug

SABIC'S SPECIALTIES OFFERING

	Freq./GHz	1.1	1.9	5	10
ULTEM 1010 resin	Dk	3.05	3.07	3.06	3.08
	Df	0.0022	0.0026	0.003	0.0042

* Test Method: ASTM D-2520, Method B - Resonant cavity method

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SABIC'S SOLUTIONS FOR FIBER OPTIC CONNECTORS AND OPTICAL LENSES

Fiber optic communication permits the transfer of data via infrared (IR) light pulse traveling through optical fibers. Lenses and connectors are both needed for assembly and installation of optical transceivers/sensors. These components require certain optical characteristics (high IR transmission with no defects, and high refractive Index) and very high dimensional stability during temperature and humidity variations. Further improvement of these properties are needed to accommodate the higher frequencies and data rates afforded by 5G technologies.



POTENTIAL APPLICATIONS AND REQUIREMENTS

SENSOR LENS

- SMT capable (reflow at 260°C)
- High IR transmission
- Low CTE at 25°C-250°C
- High flow for complex tooling



FIBER OPTICAL CONNECTOR

- High IR transmission
- High refractive Index
- Low CTE at 25°C-200°C
- Ability to mold housing and lens in one injection molding step



SABIC'S SPECIALTIES OFFERING

Property	Flexural Modulus	HDT, 0.45 Mpa	Density	CTE	Light Transmission at 850nm / 1mm	Light Transmission at 1310nm / 1mm	Refractive index at 850 and 1310nm
Standard	ISO 178	ISO 75	ISO 1183	ISO 11359	ASTM D1002	ASTM D1002	ISO 489
Unit	MPa	°C	g/cm³	10^{-5}/°C	%	%	-
ULTEM 1010	3300	207	1.27	5.5	>87	>88	1.639 1.626
EXTEM XH1015	2870	250	1.31	5	>83	>86	1.634 1.622

- IR transparency, 850nm-1550nm
- SMT-capable (EXTEM resin)
- Good dimensional stability within wide temperature range (-40°C-150°C)
- Long-term adaptability in harsh environments such as high temperature, high humidity and salt mist

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SABIC'S SOLUTIONS FOR RIGID CCL FORMULATIONS

SABIC's portfolio of additives support formulators of rigid copper clad laminates (CCLs) in developing products that support 5G infrastructure technology requirements. When used in traditional CCL manufacturing, SABIC's NORYL™ oligomers help formulators achieve high speed, low loss products that enable multi-layer printed circuit board designs with ultra-low insertion loss. Potential applications for these high speed, low loss CCLs include high speed servers, routers and switches as well as components in base stations and active antenna units.



SABIC's portfolio of additives helps thermoset formulators develop products that support 5G infrastructure systems.

Improving dielectric performance in CCLs with NORYL oligomers

NORYL oligomers are based on polyphenylene ether and modified for improved solubility in conventional solvents and tailored functionality that can be used in various resin and curing systems. When incorporated into certain formulations, NORYL oligomers may provide:

- Solubility in methyl ethyl ketone (MEK) and toluene
- Improved dimensional stability
- Lower dielectric constant and dissipation factor
- Lower FR loadings
- Increased system Tg
- Single phase system in formulation

SABIC'S SPECIALTIES OFFERING

Grade	Base resin	Features
SA9000	PPE	Bi-functional, methacrylate capped PPE for use in UV cured and free-radically cured solvent-based systems
SA90	PPE	Bi-functional, hydroxyl capped PPE for use in solvent-based epoxy and cyanate ester catalytically cured systems

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CHEMISTRY THAT MATTERS™

SABIC'S SOLUTIONS FOR FCCL FORMULATIONS

SABIC's portfolio of additives support formulators of rigid and flexible copper clad laminates (FCCL) in developing products that support 5G infrastructure technology requirements. SABIC's specialty dianhydrides used in polyimide film, adhesive or coverlay formulations can achieve a unique performance profile for the flexible copper clad laminate producer and flexible printed circuit board designer.



SABIC's portfolio of additives helps thermoset formulators develop products that support 5G infrastructure systems.

Achieving a unique balance of properties in polyimide chemistry

SD1100P powder is a high purity 4,4'-BPADA powder. When used in polyimide applications, SD1100P powder may offer performance improvements such as the solubility of polyimides in organic solvents, lower water absorption, and a lower dielectric constant and dissipation factor.

- Lower water absorption
- Improved metal adhesion
- Lower dielectric constant and dissipation factor
- Improved solubility in organic solvents

SABIC'S SPECIALTIES OFFERING

Grade	Base Chemistry	Features
SD1100P	Dianhydride	High purity: >99% 4,4' BPADA content
BISDA-1000	Dianhydride	Standard purity: >97.5% BPADA content

Effect of SD1100P in polyimide formulations

Typical Properties	SD1100P-ODA	ODPA-ODA	PMDA-ODA
Glass transition (DSC, 20 °C / min)	**220-224 °C**	260 – 265 °C	390 – 410 °C
T_d 5% (TGA, under N_2, 10 °C / min)	**520 °C**	550 °C	580 °C
Dielectric constant, 10 Ghz	**3.1**	3.3	3.4
Loss tangent, 10 Ghz	**0.005**	0.009	0.019
Water uptake, % by weight	**0.7 – 1 %**	1.9 %	2.6 %
T-Peel adhesion strength to copper foil	**1.45 N/mm**	1.34 N/mm	1.29 N/mm