New Fluorocompounds for Flat Wire Coatings and Insulation

AGC

Fluon+™
Enhanced Material Science

Your Dreams, Our Challenge



Fluorocompound Benefits

- Excellent electrical and insulating properties
- Wide range of temperatures
- Heat and chemical resistance
- Lower εr
- Higher Partial discharge inception voltage (PDIV)

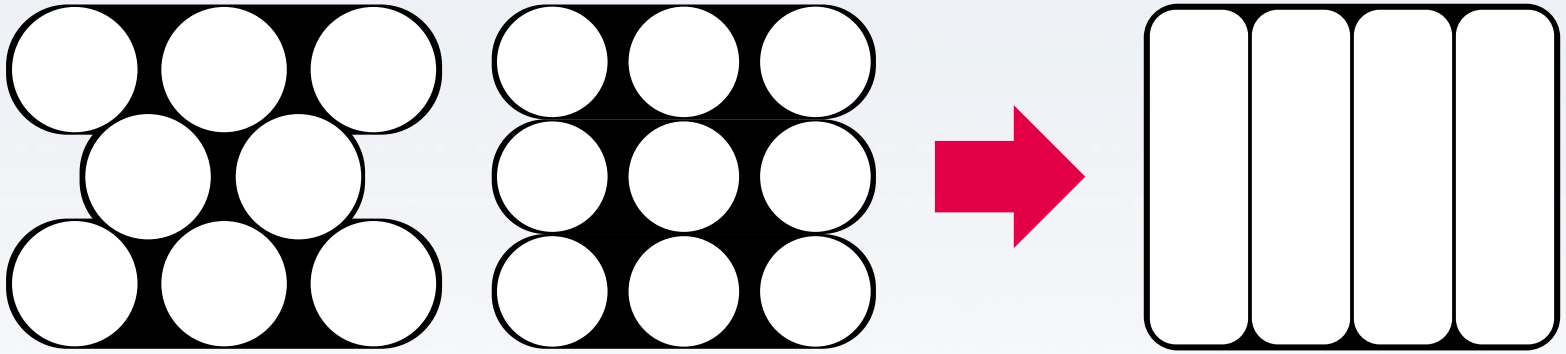
Material	ε_r	ε_r @200°C	Volume resistivity Ω・cm
PFA/PTFE	2.09	2.10	$>10^{18}$
ETFE	2.50	2.40	$>10^{18}$
PEEK	3.30	5.40	$>10^{17}$
PI	3.50	4.20	$>10^{14}$
PAI	3.80	4.80	$>10^{14}$



Background of Flat Wire Cables for EV, HEV, PHEC

Round wire

Flat wire



Occupancy:	78%	88%	96%



Background of Flat Wire Cables for EV, HEV, PHEC

- Fuel/motor efficiency
- Engine performance
- Output density (500~800V)
- Flat wires have more occupancy rate of the stator
- Higher voltage
- Space saving
- Higher output of the motor generator

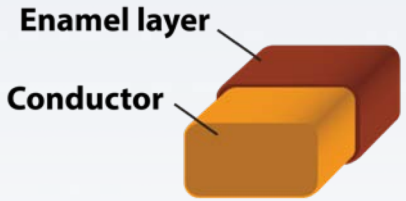
Main motor stator





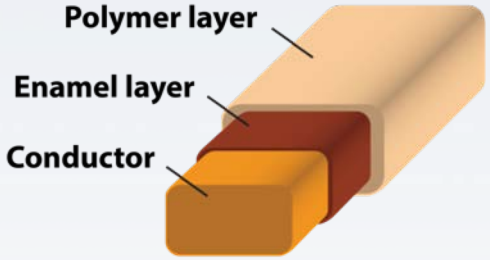
Current Structure of Wires for EV, HEV, PHEV Inverter-Drive Motors





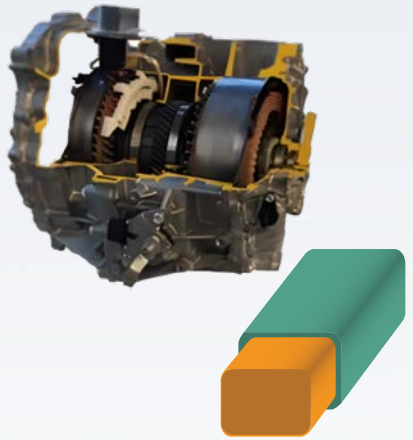
Enamel layer: PI, PAI, etc

200V



Enamel layer: PI, PAI, etc.
Polymer layer: PEEK, PPS, etc

400V



Next generation-800V+



Current Structure of Wires for EV, HEV, PHEV Inverter-Drive Motors

200V

- Maximum 50μm thickness
- Insufficient reliability for high voltage
- Pinhole defect

400V

- Poor adhesion (Primer needs)
- Cracking/wrinkles when bending
- Poor flexibility

800V+

- Heat resistance >> **W**=A×**V**
- **Anti-corona**
- **Flexibility**
- **Lower dielectric constant**
- **Higher PDIV**
- **No surge issue**
- Varnish/Enamel-free **>> Mono-layer structure**

Why is Higher PDIV Required?

	PDIV/V
PI enamel	800~900
PI enamel+PEEK layer	1400
New criteria	**> 1500**



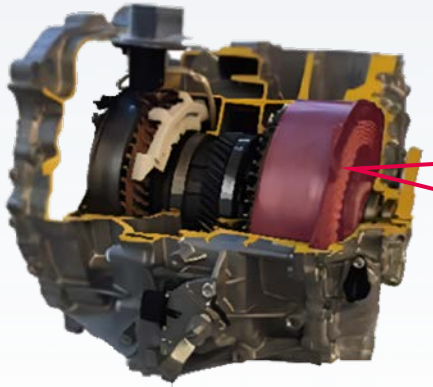
Next generation-800V

- Instantaneous voltage during sudden braking and sudden acceleration is 2 to 3 times the normal voltage
- **For 400V motor**, instantaneous voltage can be within PDIV ⇒ Partial discharge does not occur
- **For 800V+ motor**, instantaneous voltage exceeds PDIV ⇒ Partial discharge occurs

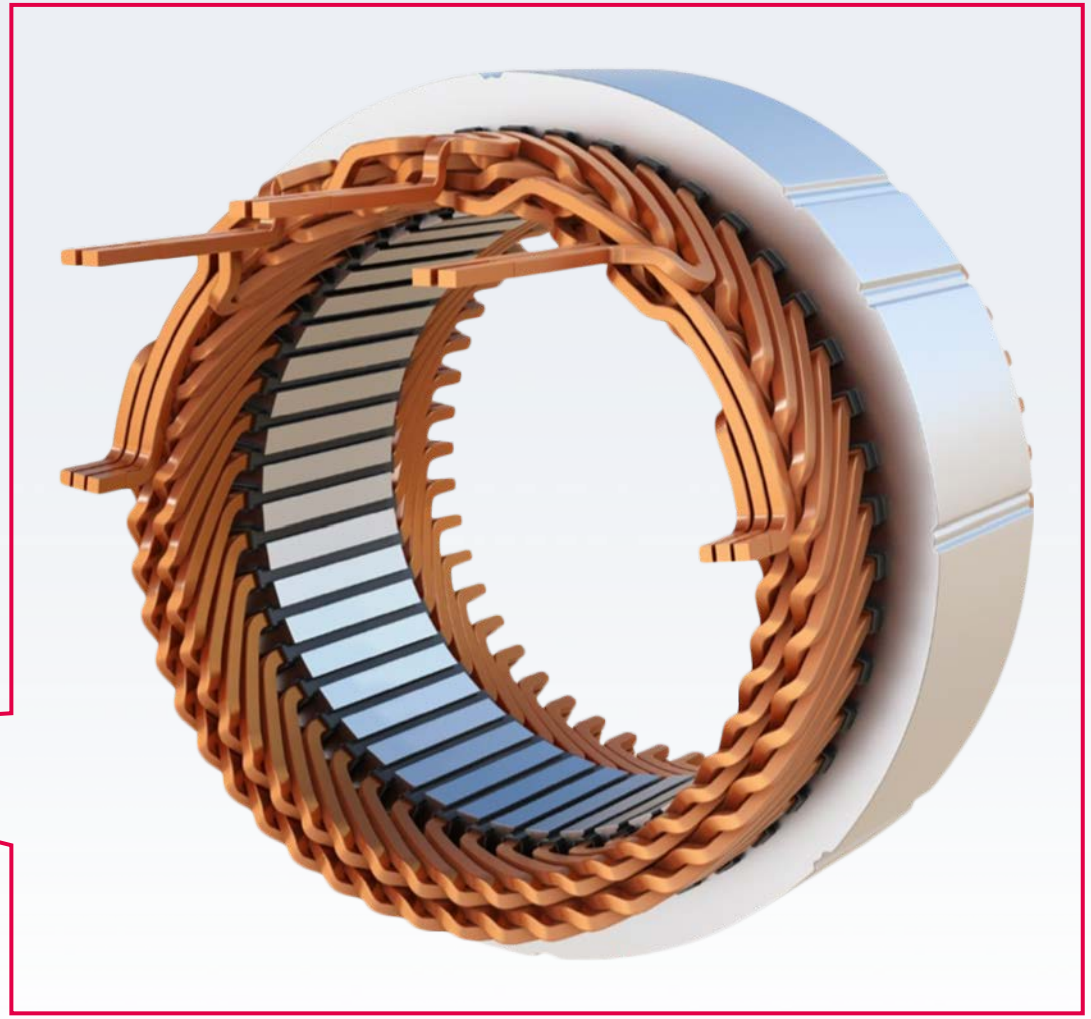
>> Higher PDIV

Why Flexibility Requirement?

Wires in motor stator are winded and bended for more occupancy rate of the stator

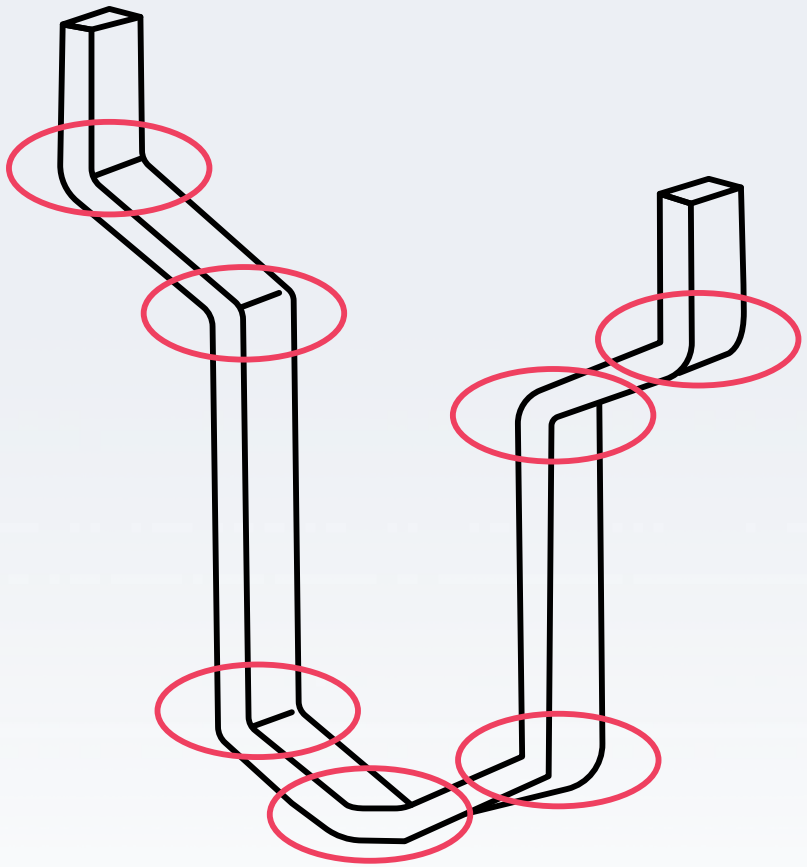


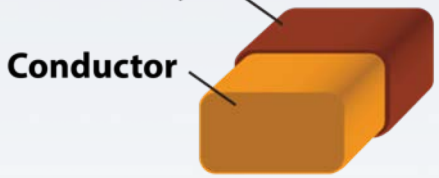
Main motor



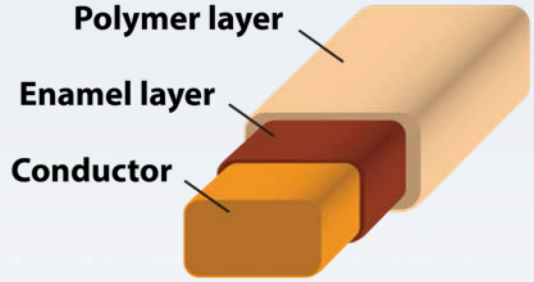
Wires in motor stator

Why is Flexibility Required?





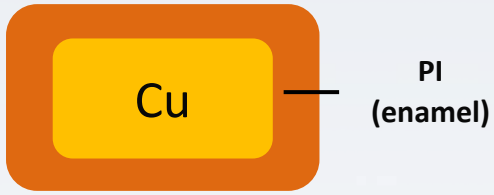
Enamel layer: PI, PAI, etc



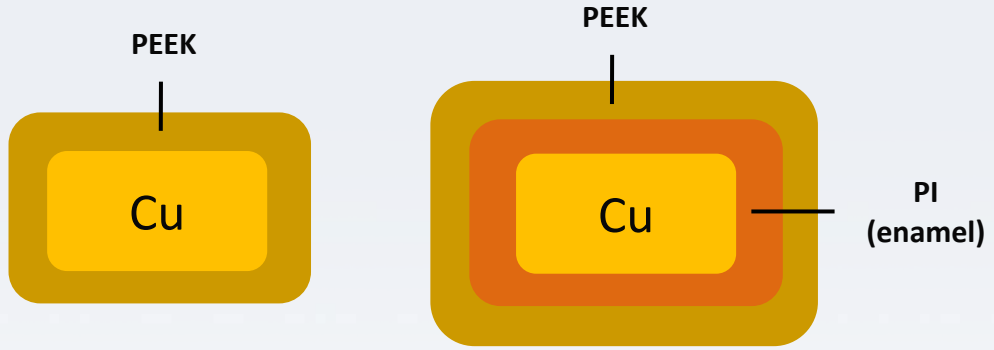
Enamel layer: PI, PAI, etc.
Polymer layer: PEEK, PPS, etc

- Avoids cracking and wrinkles when bending
- Partial discharges are easier to occur at corners

Existing Materials for Extrusion Coating

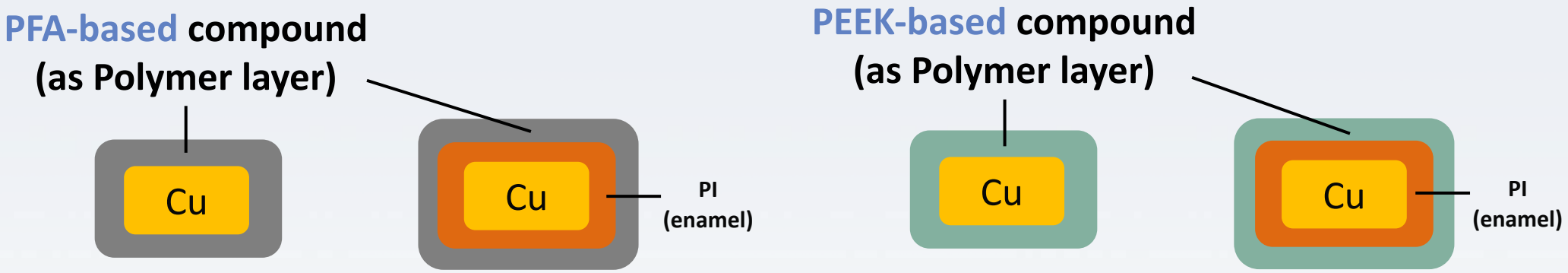


- Insufficient reliability for high voltage
- Pinhole defect



- Poor adhesion (primer needs)
- Cracking when bending
- Poor flexibility

AGC's Solution for Extrusion Coating

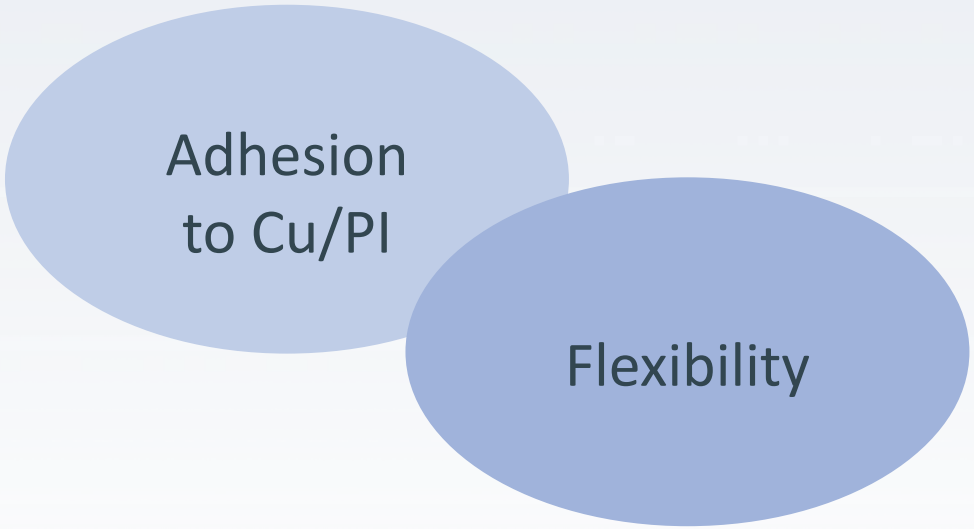


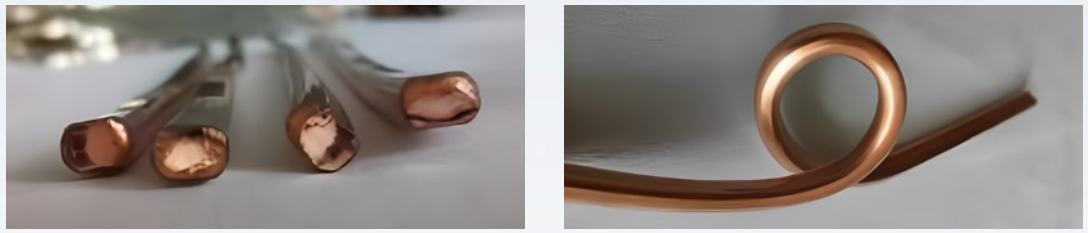
Benefits

- Strong adhesion to Cu/PI
- No cracking (good flexibility)
- Better electrical insulation

PFA-Based Compound

- Better flexibility and adhesion to polyimide and copper without losing outstanding insulation and thermal properties of PFA.





Flat wise + edge wise bending testing



No damage, no cracking, no wrinkles

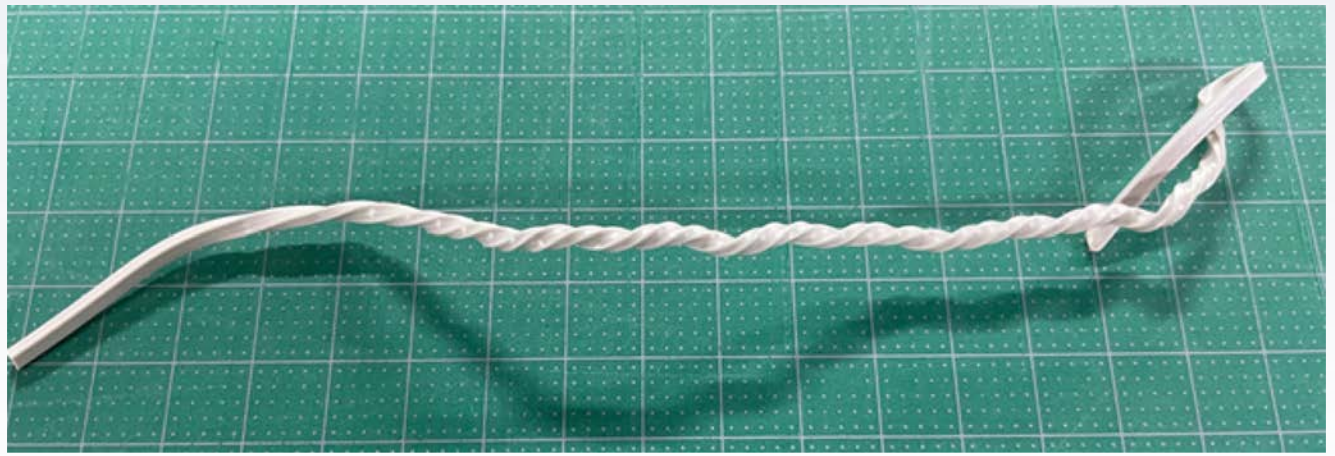
PFA-Based Compound

Test		Unit	PFA	PFA-based compound
Physical	Melting point	C	300	300
	Specific gravity	–	2.1	2.1
	Melt flow rate (MFR) 327C/5kg	g/10 min	11	11
Mechanical	Tensile strength	MPa	39	35
	Tensile elongation	%	440	400
	Flex modulus	MPa	560	**380**
Electrical	Volume resistivity	Ω • cm	$> 10^{18}$	$> 10^{18}$
	Dielectric constant – εr	–	2.09	< 2.10
	Tanδ 1kH/z/1MHz	tanδ	< 0.0003	< 0.0003
	Corona resistance	Hour	> 200	> 200
	PDIV	V	1,600	1,700
	Withstand voltage	V	> 10,000	> 10,000
Adhesion	to Polyimide	N/cm	Delamination	**28.0**
	to Copper		2.1	**29.1**
Thermal	TGA-5wt%	C	505	508
	TGA-10wt%		520	525

PEEK-Based Compound : mPEEK

- Better flexibility and impact strength than PEEK
- Flexible
- Impact resistant
- Tests under evaluation: mPEEK High flow-2





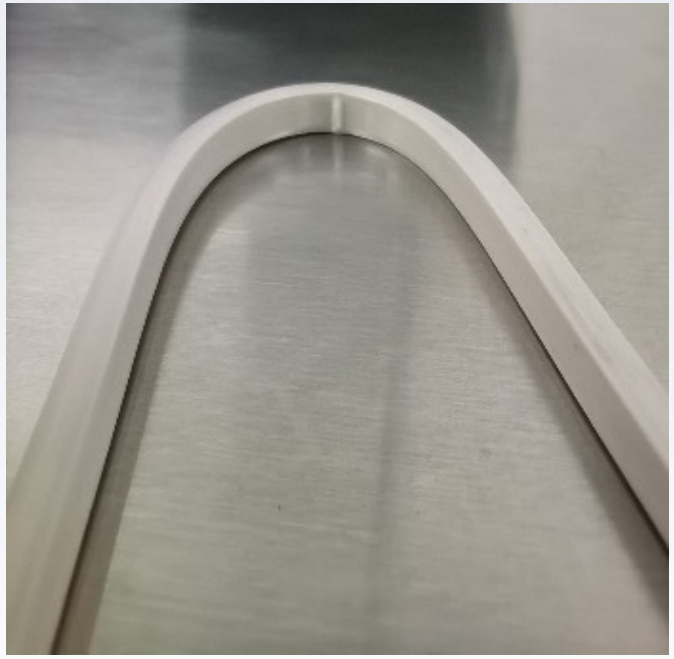
Flat wise + edge wise, 180° bending testing

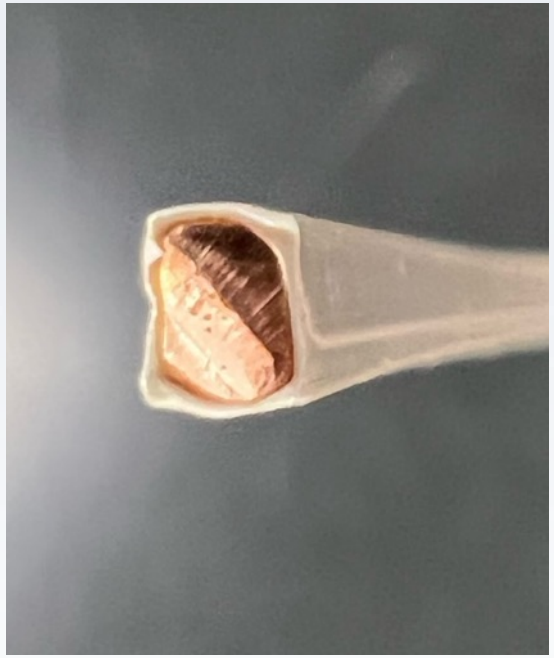
PEEK-Based Compound : mPEEK

Test		Unit	PEEK A	mPEEK Low Flow KB-2220	mPEEK Medium Flow KB-2020	mPEEK High Flow - 2
Physical	Melt flow rate (MFR) 372 °C/5kg	g/10min	22	8	23	123
Mechanical	Tensile strength	Mpa	96	78	71	54
	Tensile elongation	%	20	99	24	16
	Flex modulus	Mpa	3800	**3000**	**2800**	**2710**
	Impact strength – Izod at 23 °C	J/m	38	**No break**	**102**	**135**
	Impact strength – Izod at 40 °C	J/m	34	**95**	**38**	**91**
Electrical	Dielectric constant - εr 1kHz/1Mhz	-	3.2	**3.0**	**2**	**2.9**
	tanδ 1kHz/1Mhz	Tanδ	0.003	0.004	0.005	0.005

PEEK-Based Compound : PDX-K

- Better insulation properties, flexibility
- Better adhesion to polyimide and copper
- No damage, cracking or wrinkles
- Tests under evaluation (PDIV, adhesion)





Flat wise + edge wise, 180° bending testing

PEEK-Based Compound : PDX-K

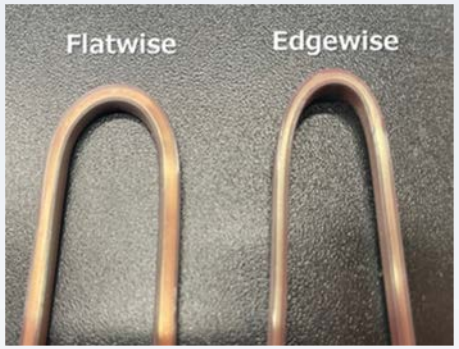
Test		Unit	PEEK A	PDX-K-22026	PDX-K-22027	PDX-K-22029
Physical	Melt flow rate (MFR) 375C/5kg	g/10min	22	10	25	42
Mechanical	Tensile strength	Mpa	96	98	93	80
	Tensile elongation	%	20	26	31	28
	Flex modulus	Mpa	3800	**2616**	**2663**	**2748**
	Impact strength at 23C	J/m	38	**No break**	**180**	**86**
	Impact strength at -40C	J/m	34	**161**	**125**	**52**
Electrical	Corona resistance	Hour	-	**>200**	**>200**	**>200**
	Dielectric constant - εr	-	3.2	**2.7**	**2.7**	**2.7**
	Tanδ 1kHz/1MHz	tanδ	0.003	0.004	0.002	0.002

PEEK-based Compound: PDX-K

Mandrel winding test (IEC 60851-3)

Test machine





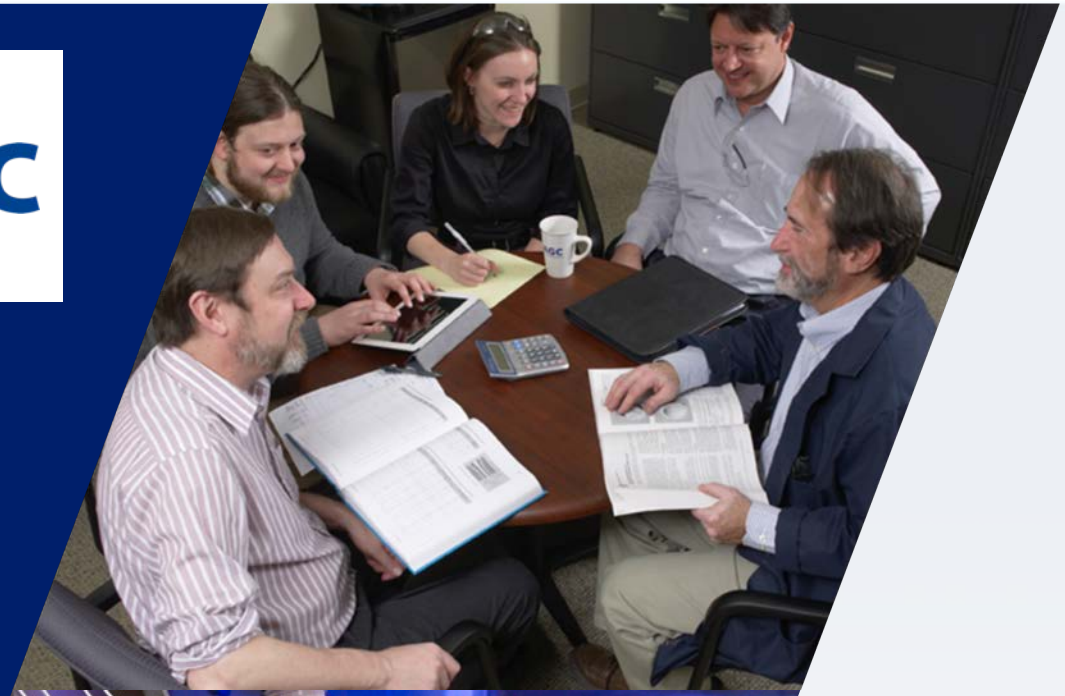
Material:PDX-K-22027

Conductor:1.8*2.3 (mm)
Insulation thickness:apprx.0.12mm

No damage
No cracking
No wrinkles

- ε_r/PDIV
- Flexibility
- Adhesion to Cu/PI

Some tests under evaluation (PDIV, adhesion, etc.)





Contact Us for More Information

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Learn more

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