YOU CAN'T DESIGN ELECTRIC POWERTRAINS WITH POLYCARBONATES. WHY NOT?

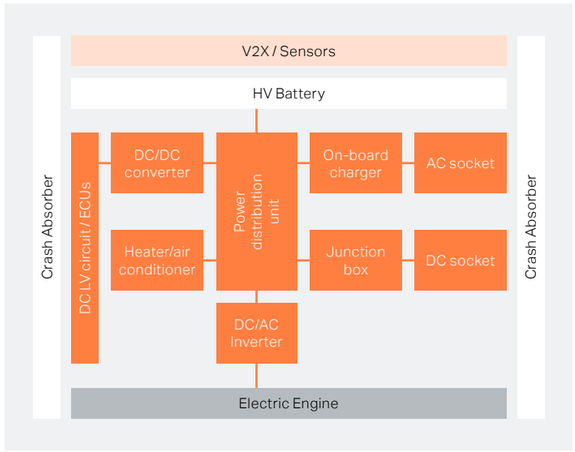
covestro

Amorphous materials in the electric powertrain

The automotive industry is undergoing a major transformation to become Connected, Autonomous, Shared and Electric (CASE). The change from internal combustion engines to hybrid and electric battery vehicles plays a major role in this transformation.

Due to their nature, amorphous materials had no stake in under-the-hood applications of ICE (Internal Combustion Engine) cars. Harsh conditions that included a mix of oils, fats and fuel in combination with very high ambient temperatures of the combustion engine made the use of polycarbonates impossible.

Electric vehicles operate under different conditions, having different temperature levels and lower exposure to aggressive substances that allow polycarbonates to enter the field of powertrain applications. Engineers can broaden their portfolio of applicable materials. Crash absorbers and Li-ion battery housings are a good example of the new opportunities that polycarbonates bring.



Covestro: your global innovation partner

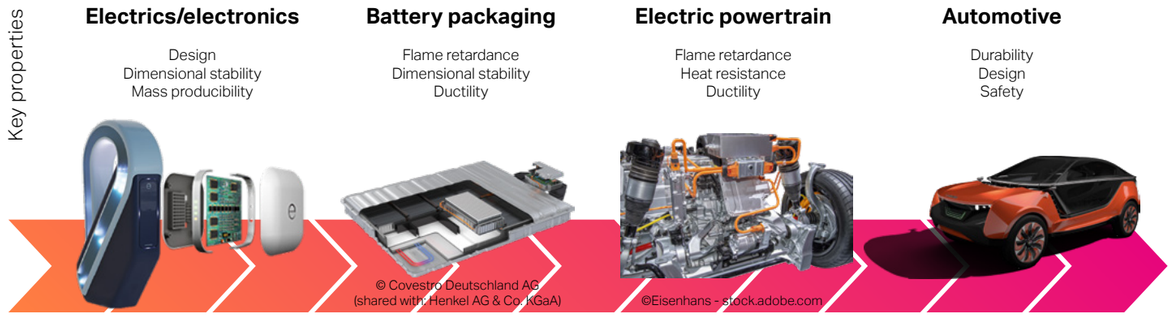
As the inventor of polycarbonates, Covestro has been one of the largest producers of theese materials for over 60 years on a global scale. We operate around 30 production sites in Europe, Asia and America – eight of which have world-scale plants.

Covestro contributes to the electrification trend

With millions of cars on the road supported by Covestro materials in the interior, exterior or lighting area, the company boasts a heritage of helping customers to transform creativity and innovations into reality.

In the electrical industry, light switches, cable channels, LED housing, smart meters, housing for 5G antennas and electric charging stations are also made of polycarbonate. Both the intrinsic flame retardance of polycarbonates and the phosphorous-based flame retardance technology of polycarbonate-ABS FR blends play an increasing role in this industry.

Driven by new technologies, the automotive industry is undergoing a global transformation. Tomorrow's electric vehicles will increasingly become a moving electric device, with the boundaries between classic car manufacturing and the electric industry shifting. The new requirements in the electric powertrain create new opportunities for amorphous materials such as **Makrolon®** and **Bayblend® FR**.



Unique properties of polycarbonates

Makrolon® polycarbonate (PC) is a well-known automobile material in interior, exterior and lighting applications because of its unique combination of transparency, impact and temperature resistance. For high temperature lighting applications, **Apec®** is an excellent choice.

Bayblend®, a PC+ABS blend, is characterized by its excellent balance of low-temperature toughness and processing behavior and is therefore used in both interior and exterior applications. **Makroblend®** (PC+PBT, PC+PET) delivers an excellent toughness as an engineering thermoplast.

Electric powertrains can benefit from further advantages:

- Mechanical properties of polycarbonates **remain constant** over a wide temperature range without adding glass fibers. This decreases the density and therefore may **reduce** the **material costs**.
- Polycarbonates have **superior impact resistance properties and toughness**, in particular when used without inorganic fillers.
- The **low and predictable shrinkage** of polycarbonates enables the production of **dimensionally stable** injection molded parts.
- The **amorphous structure** of polycarbonates results in **excellent sensor transparency** (visible, LiDAR, radar).
- Due to phosphate based FR technology, **no electro-corrosion problems** are known in **current applications**.
- Because of their **excellent mechanical and electrical properties**, polycarbonates are standard materials in both the automotive and electrical industries.

Covestro material solutions

Makrolon®	Apec®	Bayblend®	Makroblend®
Amorphous, dimensionally stable and impact-resistant polycarbonate	Outstanding heat-resistant polycarbonate copolymer	PC+ABS or PC+ASA blends add excellent low-temperature toughness to polycarbonate	Ultra-tough engineering PC+PET or PC+PBT blends

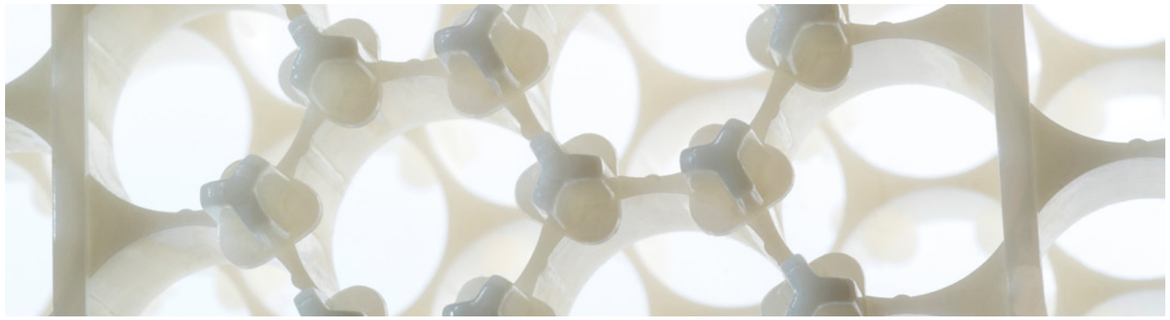
Available in different flowabilities and colors (incl. sensor transparent colors (ST) for **Makrolon®**). Additional flame retardant (FR) and reinforced grades exist.

Our vision for electric powertrain components

Covestro already makes dimensionally accurate battery cases and cell carriers from flame retardant polycarbonate (PC) and PC blends. We are now applying these materials for the first time to a new area of electric vehicles: **the electric powertrain.**

The materials may be used for the following electric powertrain components:

- inverters, converters and electric engines
- onboard chargers and connectors,
- power distribution units and junction boxes
- sensors, actuators, vehicle control units and connectivity devices
- heat exchangers, valves and pipes.



Electrical powertrain solutions from Covestro

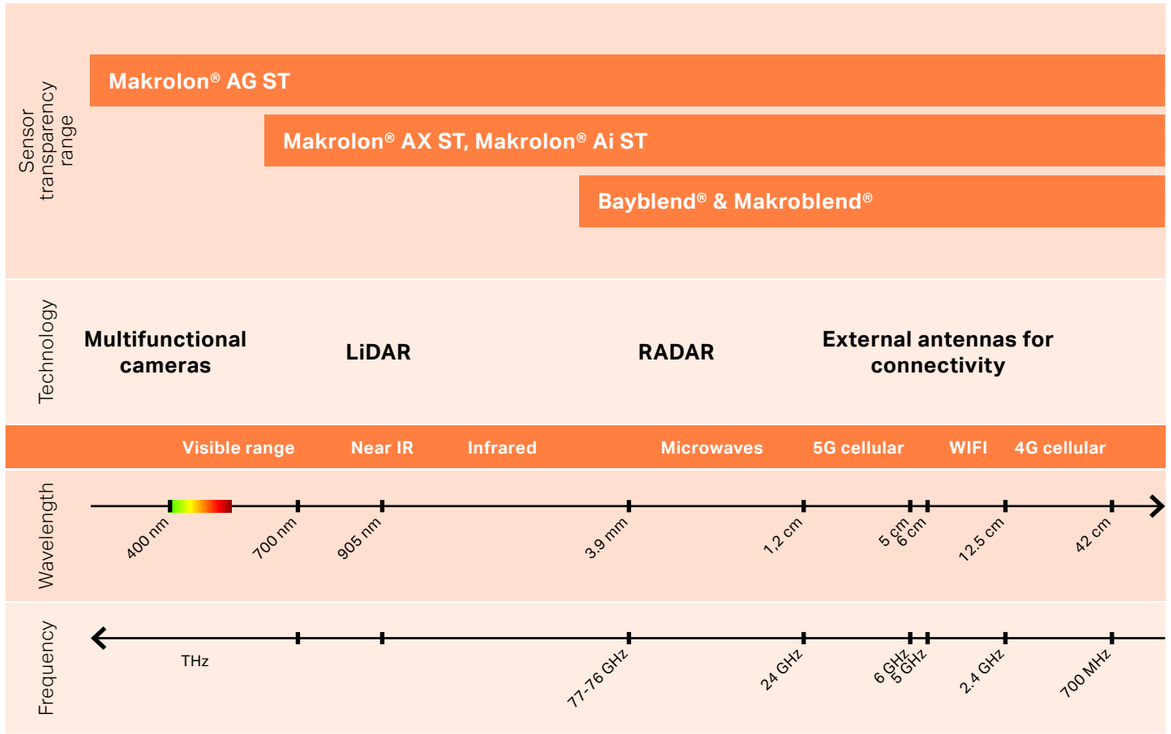
		Makrolon® 6485	Makrolon® FR6005	Makrolon® TC110 FR	Bayblend® FR3040 HR	Makroblend® KU2 7912/4	Makroblend® TP1038*
Material		PC FR	PC FR	PC TC FR	PC+ABS FR	PC+PBT	PC+PBT FR
Special feature				Thermal conductive 0.8/0.2 W/mK[1] Electric insulating	High ductility & CTI	Improved chemical resistance	
Potential use		Inverters EE	Control units	Connectors, bus bars, junction boxes	Electrical housings insulating material group IIIa	Crash absorbers, housings insulating material group II	Housings insulating material group IIIa
Tensile modulus	[MPa] 1 mm/min	2400	2300	6000	2600	2050	2300
Burning behavior	UL94V [mm]	V0 @ 1.5 5VA @ 3.0	V0 @ 1.0 bk V0 @ 1.5 ac	V0 @ 1.5	V0 @ 1.0 5VB @ 2.0	HB @ 1.6	V0 @ 2.4 [1]*
GWFI	[°C] IEC60695-2-12	960 @ 0.75 mm	960 @ 1.5 mm	–	960 @ 0.75 mm	700 @ 2.0 mm	–
HDT B/A	[°C] 0.45 / 1.8 N/mm²	136 / 124	136 / 121	143 / 132	~100/ ~90 (expected values)	106 / 82	– / 77 *
Dielectric strength	[kV/mm] EC 60243-1	34	n/a	35	35	35	32 *
CTI	Solution A IEC 60112	225	200	275	250	500	–
Surface resistivity	[Ω] IEC 60093	$1 \cdot 10^{16}$	$4 \cdot 10^{17}$	–	–	$1 \cdot 10^{17}$	$8 \cdot 10^{16}$ *
Volume resistivity	[Ωm·m] IEC 60093	$1 \cdot 10^{14}$	$9 \cdot 10^{16}$	–	–	$1 \cdot 10^{15}$	$2 \cdot 10^{14}$ *

*This is a trial product. Further information, including amended or supplementary data on hazards associated with its use, may be compiled in the future. For this reason no assurances are given as to type conformity, processability, long-term performance characteristics or other production or application parameters. These values are typical values only. Unless explicitly agreed in written form, they do not constitute a binding material specification or warranted values. [1]Covestro test bk = black ac = all colors

Special technology: sensor transparency (ST)

The amorphous structure of polycarbonates produces excellent sensor transparency. This is a major benefit for LiDAR and radar technologies, which are essential to electric autonomous driving.

Nearly all OEMs have already begun designing parts for assisted and autonomous driving vehicles. Today, vehicles in the mid-range and premium segments already include a growing number of driving assistance functions. New regulations increasingly require for safety functions to be included in vehicle designs, such as brake assistant, emergency calls and driver recognition. Meanwhile, V2X (Vehicle To Everything) communication functions will be broadly implemented in the near future.



To meet the needs of this new generation of vehicles, established electronic companies are becoming increasingly active in the automotive sector. Today's cars offer more digital functions than ever before. This creates a growing need for reliable high-performance sensor-transparent materials like polycarbonates.

Our portfolio

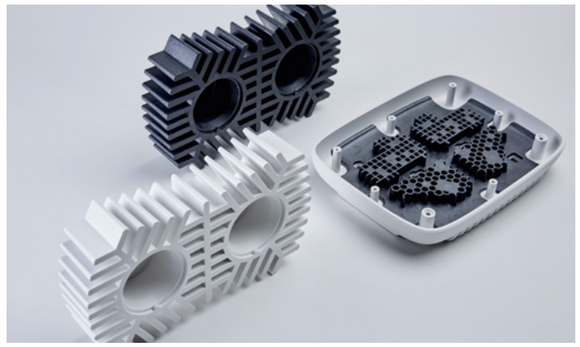
Makrolon® AG ST	Makrolon® AX ST	Makrolon® Ai ST	Bayblend®	Makroblend®
Light or dark transparent polycarbonate for exterior use in radar, LiDAR and camera covers with light integration	Black, infrared-transparent polycarbonate for exterior use in black radar and LiDAR covers	Transparent, colored or dark grey tinted polycarbonate for interior use in IR cameras and IR light covers	PC+ASA additive blends with high ductility and low, homogeneous Dk and Df for antenna covers	PC+PBT, PC+PET, mineral-filled polycarbonate for antenna covers with low CLTE, low, homogeneous Dk and Df and good paintability

Special material: thermoconductive Makrolon® FR

The **Makrolon®** TC portfolio was specially designed for high heat applications and offers excellent thermal management while weighing almost 50% less than aluminum. Injection molding gives designers greater freedom in creating new forms, as well as by in-mold decorations and optimized joining techniques.

Specialty: **Makrolon®** TC110 FR
Thermoconductive, electrically insulating (white) & flame retardant

- Special mineral-filled polycarbonate
- For electrical housings and components for moderate heat dissipation
- Flame retardance UL94V-0 @ 1.5 mm (Covestro test)
- Charpy impact strength 90 kJ/m² (RT)
- Vicat softening temperature 145°C (B/50)
- HDT A / B: 132 / 143 °C (1.8 / 0.45 MPa)
- Thermal conductivity ASTM 1461-01 (in/through plane) 0.8/0.2 W/mK



Our portfolio

Property	Standard / condition / unit	TC629[1]	TC611[1]	TC210[2]	TC110[2]	TC110 FR[2]
Thermal conductivity • in plane • through plane	ASTM E 1461-01 / 23°C / [W/m·K]	15 1.1	16 1.5	1.4 0.3	1.0 0.3	0.8 0.2
UL-94 rating	Class [mm]	V0 @ 2.0	V0 @ 2.0	HB	HB	V0 @ 1.5 5VA @ 2
Glow wire flammability index	IEC 606695-2-12 / 1.5 mm / [°C]	960	960	850	875	960
Charpy impact strength	ISO 179-1eU / 23° / [kJ/m²]	<10	<10	12	70	90
Density	ISO 1183 / - / [kg/m³]	1380	1400	1560	1450	1450
Vicat softening temperature	ISO 306 / 50 N, 50°C/h / [°C]	144	130	146	145	145

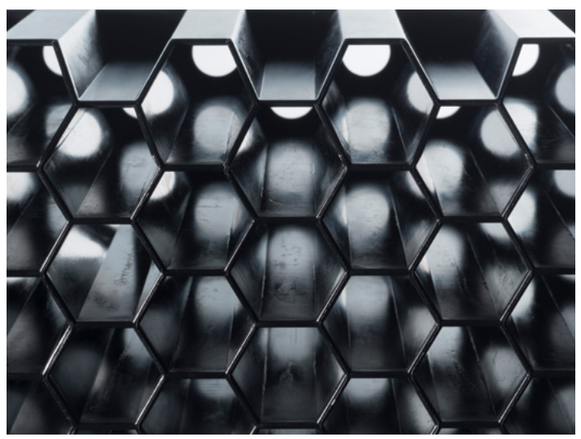
[1]electrically conductive, [2]electrically insulating

Special technology: crash absorbers

Covestro developed a crash absorber based on **Makroblend®** polycarbonate blend to protect EV batteries during collisions.

Makroblend® KU2-7912/4
Engineering thermoplast for sophisticated applications

- (PC+PBT) blend, unreinforced
- For Li-ion battery-protecting crash elements, bumpers and body panels
- Izod notched impact strength 60 kJ/m² (RT)
- Nominal strain at break > 50 %
- Vicat softening temperature 120°C (B/120)



Powertrain components are sensitive to high mechanical loads (e.g. crashes). Damaged components may cause electrical shocks. Automotive OEMs, designers and engineers can turn to **Makroblend®** KU2-7912/4 for a flexible, cost-effective crash absorber that helps powertrain components endure impacts. The crash element absorbs the kinetic energy in the side sills (e.g., between the wheel arches at the bottom of the vehicle's body). Space is valuable, so this structure needs to be as slim as possible to make room for other components. Compared to metal crash absorbers, those made of **Makroblend®** KU2-7912/4 are more cost-effective and give designers and engineers more flexibility. The **Makroblend®**-based crash absorber lays the foundation for further developments.

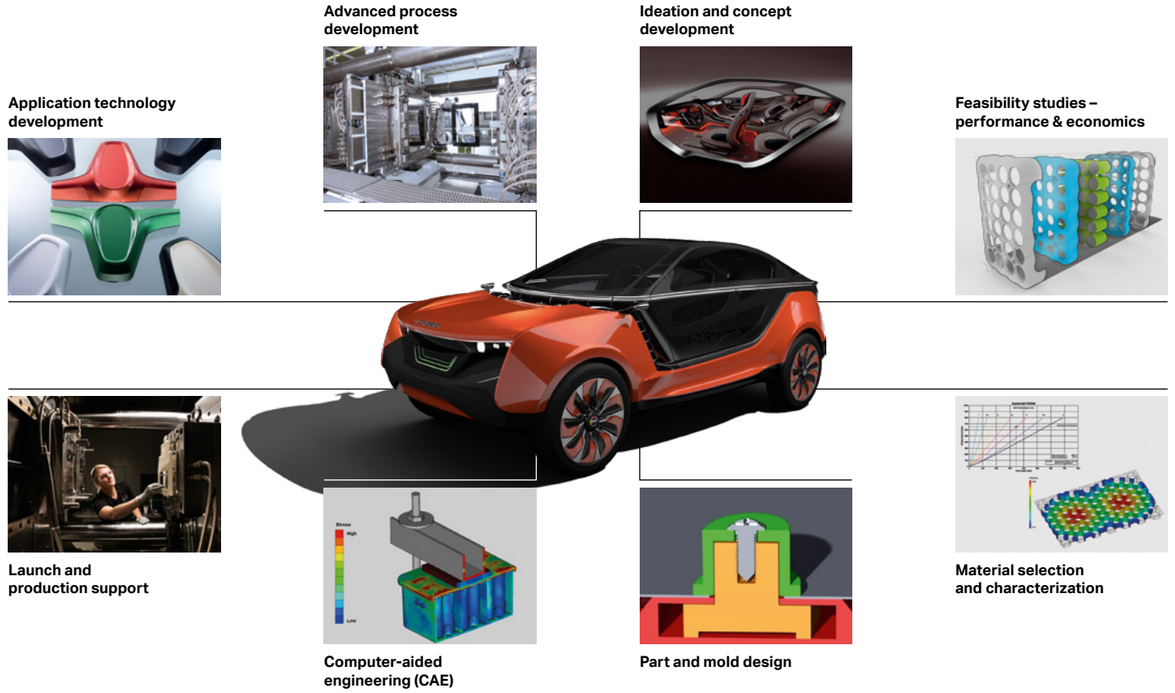
Global support in application development

Customer centricity is the principle of our daily business. We can only be successful when we put our customers first. A strategic pillar in customer centricity is our Global Application Development. With three R&D hubs in North America, Europe and Asia/Pacific, we are globally connected and can serve our customers on a regional basis.

Global Application Development consists of three divisions: Global Technology Development, Global Digital Engineering and regional Application Development division.

Emerging technologies and strategic technology developments are handled and supported by our **Global Technology Development** group.

During the conception and design phase, our **Global Digital Engineering** division can support the development with comprehensive mechanical and rheological simulations. To ensure mechanical integrity of the application, we can cover static and dynamic mechanical simulations. Tool and part design is supported by rheological simulations to guarantee processability of the part. When it comes to production, our **Application Development** division provides support with comprehensive technical labs and equipment from smaller injection molding machines with as well as large, highly automated ones for pilot production support. In addition, our technical field representatives provide local support at the production facilities of our partners to support commissioning or solve issues during mass production.



Seamless mobility: Building an autonomous and electric future

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