ADVANCED SOLUTIONS FOR E-MOBILITY

RadiciGroup High Performance Polymers is ready to meet the new challenges and opportunities offered by electric mobility through an outstanding offer of specialty polyamides and high performance polymers.

The materials portfolio includes Radiflam®, Radilon®, Radistrong®, Raditeck® and Raditer®, compounds based on polyamides, PPA, PBT, PPS and Renycle®, low environmental impact grades based on post-industrial and post-consumer PA 6 and PA 6.6.

RADICI GROUP

Innovating e-mobility

RadiciGroup High Performance Polymers offers a portfolio of innovative products worldwide to meet the new electric mobility requirements, supporting the automotive and transport industry in the development of advanced solutions that respect the environment and safety standards.

In the response to CO_2 reduction targets, hybrid and electric cars designed according to ecodesign principles play a central role.

At RadiciGroup High Performance Polymers, innovation and research have always been guided by the principles of eco-sustainability, a fundamental value for the company. With the new challenges of electric mobility, sustainability issues take on even more importance.

The products of the Radiflam®, Radilon®, Radistrong®, Raditeck®, Raditer® and Renycle® (from post-industrial and post-consumer sources) ranges are formulated to meet even the most severe specifications, with additional attention to reducing the environmental impact.

RadiciGroup plants in Villa D'Ogna, Italy.

E-mobility requirements and RadiciGroup High Performance Polymers product range

The transition from internal combustion engine (ICE) vehicles to hybrid electric and full electric vehicles (HEV and EV) has brought new opportunities and technological challenges. New EV requirements have been introduced, while other requirements have been added to those for conventional ICE vehicles.

For many components today's trend is towards materials with peculiar features:

- Flame retardancy (UL V0 between 0.4 mm and 1.6 mm).
- Properties retention in hostile environments for prolonged periods of time.
- Electrical insulation even in the presence of high voltage (CTI > 600 V and in the future up to 1000 V).
- Need for certain components to guarantee electromagnetic shielding (EMI shielding).
- Battery protection in the event of a collision.
- Thermal resistance of power electronic components in the presence of high energy density.
- Corrosion and chemical resistance.
- Thermal management system efficiency to guarantee battery and other components performance.
- "Electrical friendly" materials.

The demand for low environmental impact products is growing, in particular today's orientation is towards halogen-free formulations. Additional requirements that may be required for electric and hybrid vehicles are thermal conductivity, high dielectric strength values even at high temperatures, products suitable for welding and laser marking.

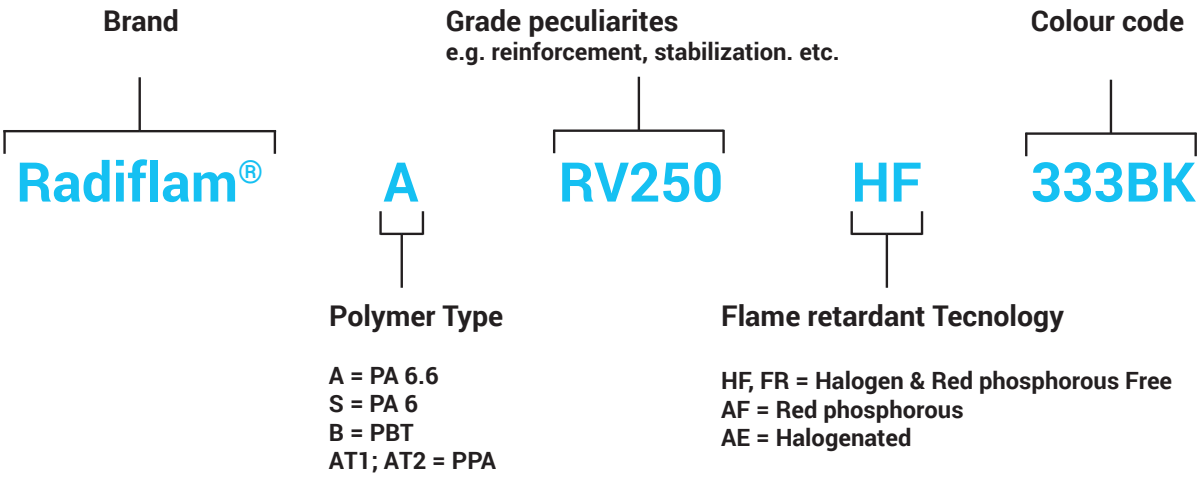
The **Radiflam®** product range comprises a wide selection of semi-crystalline compounds taking advantage of a variety of flame retardant technologies. Radiflam® is the brand name for PA 6, PA 6.6, specialty PAs and PBT thermoplastic compounds featuring excellent flame retardant properties, in addition to the highest UL ratings (V-0 and 5VA).
Radiflam® polyamides are formulated using various FR additives and include a wide range of halogen- and red-phosphorus-free products. As of today, Radiflam® B (PBT based) is produced in halogenated form (AE), and Radiflam® Aestus (PPA) is available in halogen- and phosphorus-free formulations (HF).

The **Radilon®** product range comprises Radilon® S (PA 6), Radilon® A (PA 6.6), Radilon® D (PA 6.10), Radilon® DT (PA 6.12), Radilon® Aestus (PPA) and other Radilon® polyamides for high temperature applications and special blends that are used in numerous e-mobility applications due to their excellent mechanical, chemical and thermal resistance and ease of processing.

The **Raditeck®** range comprises high performance PPS compounds featuring inherently flame retardant properties, excellent retention of mechanical properties when exposed to high temperatures for prolonged periods of time, high dimensional stability thanks to very low water absorption and superior chemical resistance.

The **Raditer®** range includes PBT polyester engineering polymers featuring high stiffness and mechanical resistance, excellent hydrolysis resistance, good resistance to high temperatures, excellent electrical insulation properties and very low moisture absorption.

The **Renycle®** brand includes PA 6 and PA 6.6 compounds that contains post-industrial and post-consumer raw material from selected sources.



Radiflam® nomenclature

Typical application segments

The main targeted systems include: charging infrastructures, battery packs, power electronics, connectors, thermal management, electric motor and structural parts.

CHARGING SYSTEMS

In order to guarantee an efficient conversion of power, parts reliability and ensure all the functionality of these components, materials must be selected very carefully. The choice of materials will depend on the requirements of the charging system and also on the expected recharge speed.

There is an increasing demand for materials resistant to flame and cooling fluids (for high power fast charging); the color must remain stable in case of outdoor exposure; excellent electrical insulation properties are required with high CTI (over 600 V in fast charging systems).

EV CHARGER PLUG MADE OF RADILON® S ERV70T

EV CHARGER PLUG requirements:

- Enhanced impact resistance
- Good dimensional stability
- Different colours
- Suitable for outdoor exposure

Materials: Radilon® S ERV70T (PA 6 impact modified glass filled enhanced impact resistance)

RECHARGE SOCKET MADE OF RADIFLAM® A RV250HF

RECHARGE SOCKET requirements:

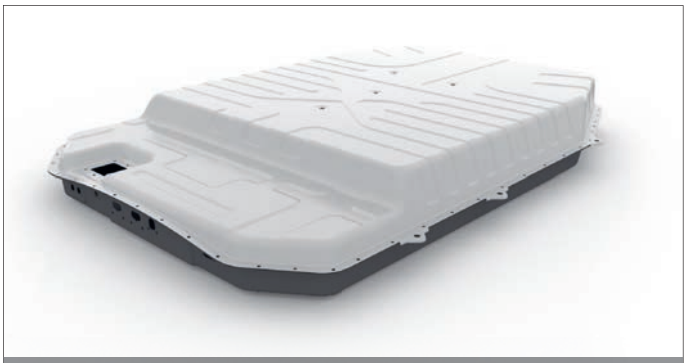
- Good dimensional stability
- Excellent flame resistant properties (UL V0 rating) and insulation properties (CTI 600V)
- High mechanical resistance
- Suitable for outdoor exposure according to UL 746C (f1)

Materials: Radiflam® A RV250 HF and other Radiflam® A HF grades (halogen and red phosphorous free PA 6.6)

BATTERY PACK

The greatest challenge of electric vehicles is boosting the energy density of the battery cells and lightweighting the whole system in order to increase vehicle efficiency.

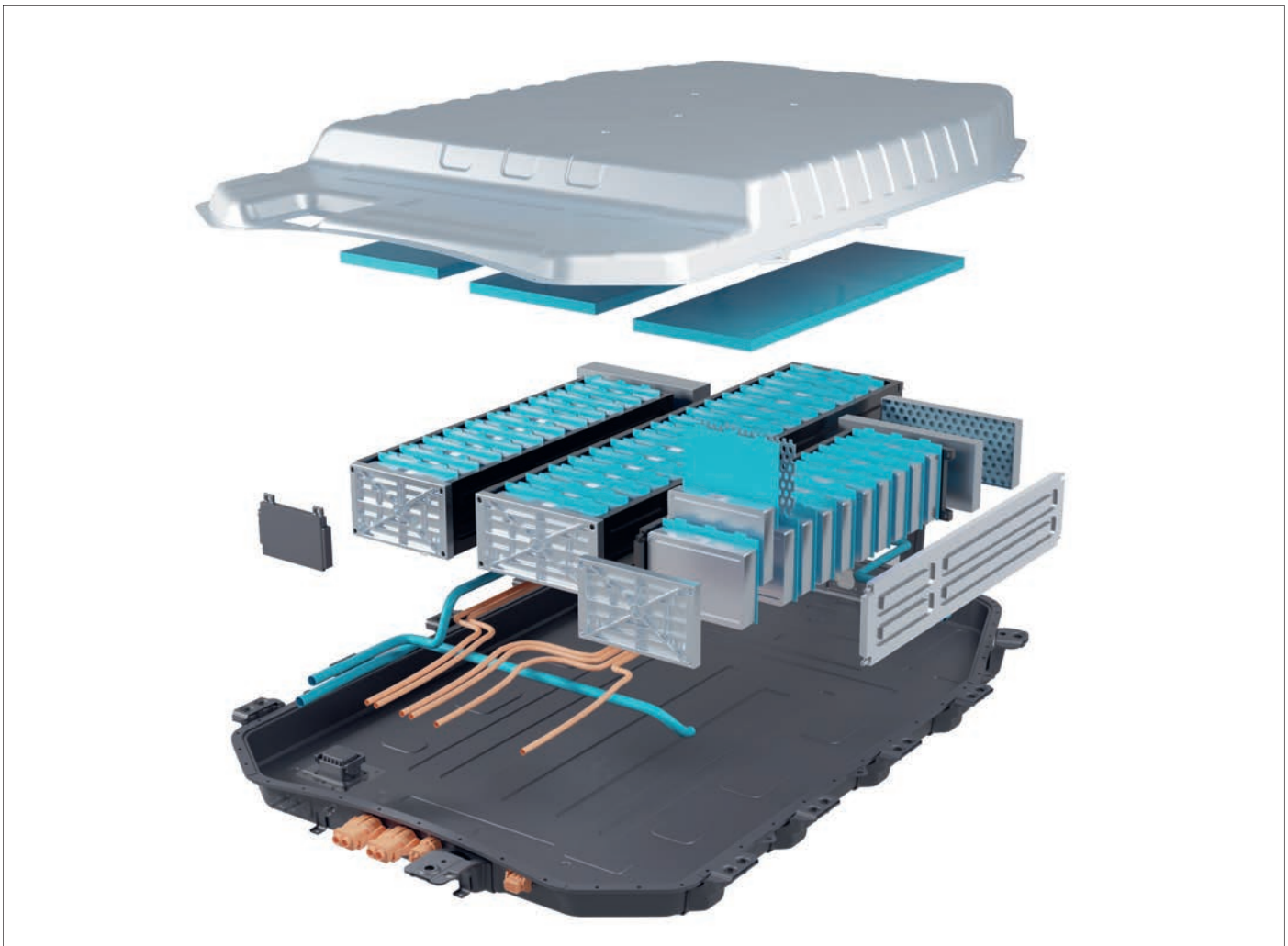
A battery pack is a complex system consisting of various components, such as interconnected battery modules configured to perform their energy storage function.
Included are cells and modules, power electronic, power supply circuitry and overcurrent shut-off systems.
Here are the main requirements for the battery system:



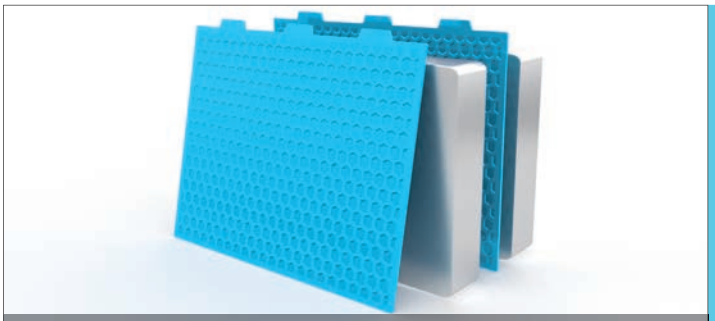
BATTERY PACK

- Flame resistance, for which reason there is a growing demand for halogen and red phosphorus-free materials.
- Electrical insulation (CTI up to 600 V and beyond, in the future).
- Superior mechanical characteristics, including creep and fatigue resistance.
- EMI shielding properties for some components.
- Electrically friendly materials.
- Resistance to electrolytes in case of accidental contact with battery electrolyte.
- Resistance to prolonged contact with cooling fluids, oils or other fluids.

Moreover, ease of processing, dimensional stability and reduced warpage are fundamental requirements for other parts, such as battery covers, battery module covers, battery cell frames and battery spacers.



OPEN BATTERY PACK



CELL SPACER MADE OF RADIFLAM® A RV250 HF

CELL SPACERS requirements:

- Flame retardancy
- Easy moulding
- Chemical resistance
- Creep resistance

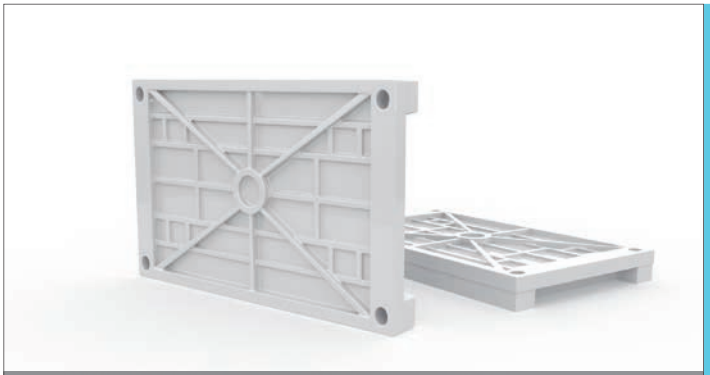
Materials: Radiflam® A HF, Radiflam® A FR or Radiflam S FR (halogen and red phosphorous free PA 6.6 and PA6 grades respectively

BATTERY MODULE COVER MADE OF RADIFLAM® A RV250 HF

BATTERY MODULE COVER requirements:

- Flame retardancy
- Planarity
- Easy moulding
- Good stiffness and mechanical strength

Materials: Radiflam® A HF (halogen and red phosphorous free PA 6.6)



END PLATES MADE OF RADIFLAM® A RV250 HF

END PLATES requirements:

- Flame retardancy
- Planarity
- Easy moulding
- Good stiffness and and creep resistance

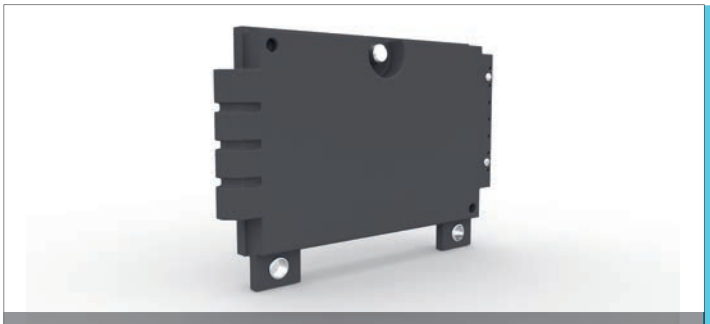
Materials: Radiflam® A HF (halogen and red phosphorous free PA 6.6). Fore more demanding applications, RadiciGroup High Performance Polymers offers Radiflam® Aestus RV300 HF, a partially aromatic polyamide (halogen and red phosphorous free PPA)

POUCH CELL FRAMES MADE OF RADIFLAM® A RV250 HF

POUCH CELL FRAMES requirements:

- Flame retardancy
- Dimensional stability
- Easy moulding
- Good stiffness, creep and mechanical strength

Materials: Radiflam® A HF (halogen and red phosphorous free PA 6.6)



CELL MANAGEMENT CONTROLLER HOUSINGS MADE OF RADIFLAM® A RV 250 AF

CELL MANAGEMENT CONTROLLER HOUSING requirements:

- Flame retardancy
- Good dimensional stability
- Low warpage
- High stiffness and mechanical resistance

Materials: Radiflam® A HF (halogen and red phosphorous free PA 6.6), Radiflam® A AF grades (red phosphorous based PA 6.6)

An electric vehicle has many supporting and connecting parts, such as cable brackets and cable channels. The choice of materials best suited for these components may vary according to where they are positioned and the specific function they perform.

Radiflam® S RV300HF, a halogen and red-phoshorus-free 30% glass-fibre reinforced PA 6 grade, is used for cable channels, thanks to its high flame resistance (UL V-0) and high mechanical resistance.

In the case of applications not requiring high flame resistance, for which materials with a UL V-2-HB rating may be adequate, Radilon® A products, particularly the impact modified grade Radilon® A USX016W, can be valid alternatives.

CABLE CHANNEL MADE OF RENYCLE® S GF1501K 3030 BK

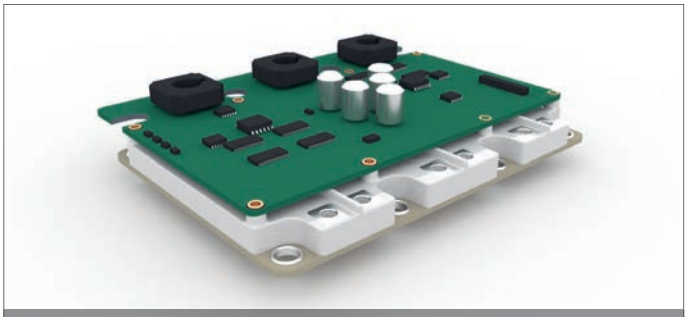
Renycle® range products, obtained from post-industrial and post-consumer raw materials, are perfectly adequate for supporting parts.

Renycle® A and S are used for the production of cable channels, in different formulations.

POWER ELECTRONICS

Engineering polymers used in power electronic systems must meet specific requirements, including:

- Flame resistance with a UL V-0 flame rating at 0.4 mm.
- Excellent electrical insulation (CTI 600 V).
- High dielectric strength at high temperatures (>10 kV at 150°C).
- Adequate thermal conductivity to ensure the integrity of electrical and electronic components at high temperatures.
- EMI shielding properties.
- Good mechanical resistance.



IGBT BASEPLATES MADE OF RADIFLAM® A RV300 HF

There is also a growing demand for halogen and red phosphorus-free materials, according to environmental sustainability principles.
RadiciGroup High Performance Polymers also provides experimental polyamide grades, such as Radiflam® S RV100 FR with a measured thermal conductivity of 1 (W/m°K, in plane and through plane, according to ASTM E1461 at 23°C). One of RadiciGroup High Performance Polymers's future objectives is to develop more thermally conductive polyamides to be used in converter components, for instance.

RadiciGroup High Performance Polymers is also working on new EMI shielding solutions through the development of innovative compounds and advanced materials. The picture below show an IGBT baseplate made of 30% glass filled PA 6.6 halogen and red phosphorous free.

CONNECTORS

To enable signal transmission, connectors must be reliable, stable and resistant. Moreover, to ensure the proper functioning of these parts, the materials used to manufacture connector housings must meet specific requirements, for example:

- Flame resistance with a UL V-0 rating at thicknesses of 0.4 mm
- Excellent insulation properties (CTI up to 600 V).
- Orange colour stability after prolonged exposure to heat.
- Dielectric strength > 10 kV at 150°C, sometimes required.
- Excellent fluidity for optimal filling of thin-walled parts during injection moulding.
- Suitability for laser marking.

CONNECTORS MADE OF RADIFLAM® A RV250 HF

For this application, RadiciGroup High Performance Polymers offers the Radiflam® A HF and Radiflam® S HF product lines, with halogen and red phophorous-free PA 6.6 grades and PA 6, respectively.

For more stringent requirements, the ideal choice is Radiflam® Aestus T2 RV300HF, a 30% glass-fibre reinforced PPA with a UL V-0 fire retardant rating.

This product combines excellent property retention even after high temperature heat ageing, with enhanced chemical resistance and low water absorption.

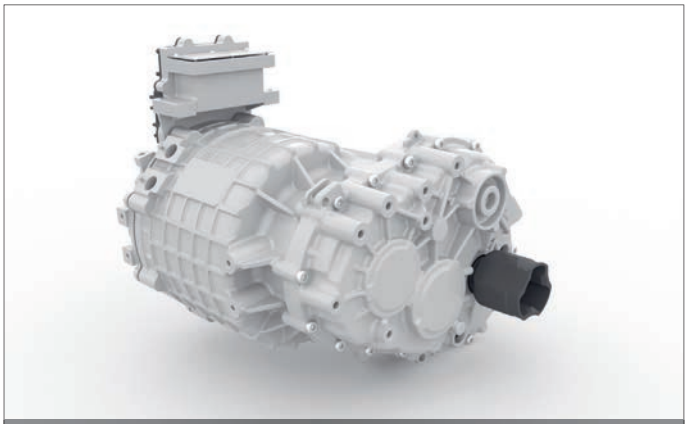
If self-extinguishing properties with the highest rating are not required, the electrically neutral glass-fibre filled PA 6.6 and PA6 Radilon® A or Radilon® S grades are adequate to cover the needs for connnector components. For this kind of application, the PBT compounds of the Raditer® family can also be successfully used, in particular, the specially formulated Raditer® B ERV300TKB with enhanced hydrolisis resistance.

E-MOTOR

RadiciGroup High Performance Polymers' contribution to this segment is the supply of specialty polyamides with high mechanical resistance properties, which are valid alternatives in metal replacement applications. One example is the replacement of thermoset materials in the stator holder.

To achieve maximum structural performance in engine supports, RadiciGroup High Performance Polymers offers PA 6.6 specialty materials containing high glass-fibre fill, such as Radilon® A RV500RW and Radistrong® A RV500W.

For e-engine components where high temperature may be present, a Radistrong® special version has been introduced.



E-MOTOR

THERMAL MANAGEMENT

To assist customers in selecting the most suitable materials for use in cooling systems, RadiciGroup High Performance Polymers has developed diverse formulations that exactly meet the technical requirements for this kind of application.

For thermal management system applications that require excellent hydrolysis resistance, superior chemical resistance and resistance to road salts, RadiciGroup High Performance Polymers has developed specialty grades in the Radilon® D, Radilon® DT, Radilon® Aestus and Raditeck® P ranges.

The Radilon® D range comprises PA 6.10 grades for injection moulding and extrusion. In the latter case, PA 6.10 polymer is made from 64% renewable source materials and features special characteristics such as excellent chemical resistance (better than PA 6 and PA 6.6), temperature resistance higher than PA 12, excellent hydrolysis resistance, low water absorption and good dimensional stability.

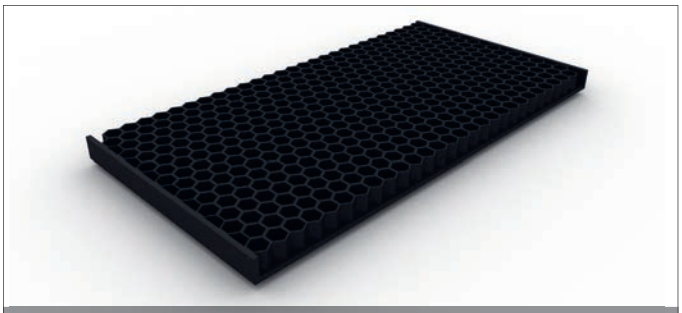
BATTERY COOLING MODULE CORRUGATED TUBE MADE OF RADILON® DT 40E50USR

The Radilon® DT portfolio consists of PA 6.12 grades, among which experimental grade Radilon® DT LX19067 and Radilon® DT 40E50USR are particularly recommended for extrusion applications. PA 6.12 has the advantage of excellent chemical resistance, even in contact with calcium chloride and zinc chloride solutions. Radilon® DT has passed all the tests required by the normative standards for the various types of lines, even in contact areas between pipes and fittings where the material is under permanent stress and strongly affected by stress cracking.

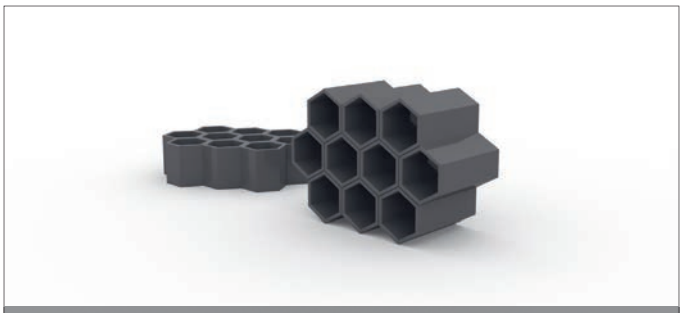
The PPA grades in the Radilon® Aestus range, specifically Radilon® Aestus T1 RV330RG, and the PPS grade in the Raditeck® P range have proven to be suitable materials for use in thermal management applications, by virtue of their superior dimensional stability, mechanical and heat resistance, and property retention over time.

Other applications

RadiciGroup High Performance Polymers products are also used in e-mobility applications other than automobile parts. Some examples include battery pack supports for e-bikes and e-motorbikes and industrial uses. Radiflam® A FR and Radiflam® A RV 250 HF are the products of choice for these components.



BATTERY PACK SUPPORTS FOR MOTORBIKES AND INDUSTRIAL APPLICATIONS MADE OF RADIFLAM® A RV 250 HF



BATTERY PACK SUPPORTS FOR E-BIKES AND E-MOTORBIKES MADE OF RADIFLAM® ROBOTO CONDENSED BOLD

A comprehensive global technical support based on competence

The RadiciGroup High Performance Polymers Global Technical Service Team assists customers in selecting the best materials for their specific applications. A wide range of materials and efficient customer-focused technical support are the keys to success in the challenging development of the essential complex components that will shape the future of e-mobility.

Furthermore, for more innovative projects, including metal replacement applications, the RadiciGroup High Performance Polymers CAE Service Team can provide customized service, by taking advantage of its advanced tools for computer aided engineering simulation.

BRAND	PRODUCT	DESCRIPTION	ELECTRICAL AND FIRE BEHAVIOUR					
			UL94	GWIT IEC 60695-2-1/3	GWFI IEC 60695-2-1/2	CTI IEC 6011	RTI (E) UL 746	
RADIFLAM®	**Radiflam® AT2 RV300HF**	**PPA GF30** (f1) suitable for oudoor exposure according to UL 746C	V0 (0.4 mm) 5VA (1.5 mm)	825 (3mm)	960	600	-	
	Radiflam® A RV250 HF	**PA 6.6 GF 25** (f1) suitable for oudoor exposure according to UL 746C	V0 (0.75 mm) 5VA (1.5 mm)	875 (3 mm)	960	600	140	
	Radiflam® A RV 250 AF	**PA 6.6 GF 25** (f1) suitable for oudoor exposure according to UL 746C	V0 (0.75 mm) 5VA (1.5 mm)	800 (3 mm)	960	500	115	
	Radiflam® A FR	**PA 6.6** unfilled	V0 (0.4 mm)	960 (0.4 mm)	960	600	130	
	Radiflam® A FR X	**PA 6.6** unfilled	V0 (0.25 mm)	960 (0.4 mm)	960	600	130	
	Radiflam® S RV300HF	**PA 6** GF30	V0 (0.8 mm)	775 (2 mm)	960	550	-	
	Radiflam® S FR	**PA 6** unfilled	V0 (0.4 mm)	960 (1 mm)	960	600	-	
RADILON®	**Radilon® AT1 RV330RG**	**PPA** GF33	HB	-	-	-	-	
	Radilon® A USX016W	**PA 6.6** unfilled	HB	-	650	-	-	
	Radilon® A RV500RW	**PA 6.6** GF50	-	725	700	-	-	
	Radilon® S ERV70T	**PA 6** GF7	HB	-	650	450	-	
	Radilon® D RV300 RG	**PA 6.10** GF30	HB	-	-	-	-	
	Radilon® DT 40E50USR	**PA 6.12** unfilled	-	-	-	-	-	
RADISTRONG®	**Radistrong® A RV500W**	**PA 6.6** GF50	-	-	-	-	-	
RADITECK®	**Raditeck® P RV400K**	**PPS** GF40	V0 (0.4 mm) 5VA (1.5 mm)	960 (0.75 mm)	960	-	-	
RENYCLE®	**Renycle® S GF1501K 3030 BK**	**PA 6** GF15 partially recycled	-	-	-	-	-	
RADITER®	**Raditer® B ERV300TKB**	**PBT** GF30	HB	-	700	450	-	

* THE FIRST VALUE REFERS TO DAM (DRY AS MOLDED) STATE, THE SECOND TO CONDITIONED STATE ; ** FOR UNFILLED GRADES IS STRESS AT YIELD

MECHANICALPROPERTIES				APPLICATIONS						
*CHARPY NOTCHED IMPACT STRENGHT , 23°C [KJ/M²] ISO 179/1EA	* **STRESS AT BREAK [MPA] ISO 527-2/1A	*STRAIN AT BREAK ISO 527-2/1A	*TENSILE MODULUS [MPA] ISO 527-2/1A	CHARGING SYSTEM	BATTERY SYSTEM	CABLE BRACKETS/CHAN-NELS	POWER ELECTRONICS	E-MOTOR	CONNECTORS	COOLING PIPES
10/11	155/135	2.4/2.2	11100/11000	•	•		•	•	•	
-	135/-	2.8/-	8700/-	•	•		•	•	•	
7.8/11	130/90	2.8/3.2	7900/5150		•					
4.5/6.5	77/50	12/>50	3450/2600		•				•	
4.5/-	71/-	3/-	3700/-		•				•	
7/15	150/95	3/4.5	11200/7200			•			•	
5/-	75/-	12/-	3500/-		•					
13/12	215/195	2.6/2.5	11900/11800							•
55/65	50/35	20/30	1900/900			•				
18/25	245/190	3/3.1	17000/14250					•		
18/-	70/-	8.2/-	3200/-	•						
15/17	150/120	4.5/6	8500/6800							•
75/-	31/-	-	950/-							•
15/17	250/190	2.3/3	17600/14500							
8	190	1.6	14500							•
5.5/11	126/70	3/12	5950/3500			•				
75	115	3.5	9500						•	

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