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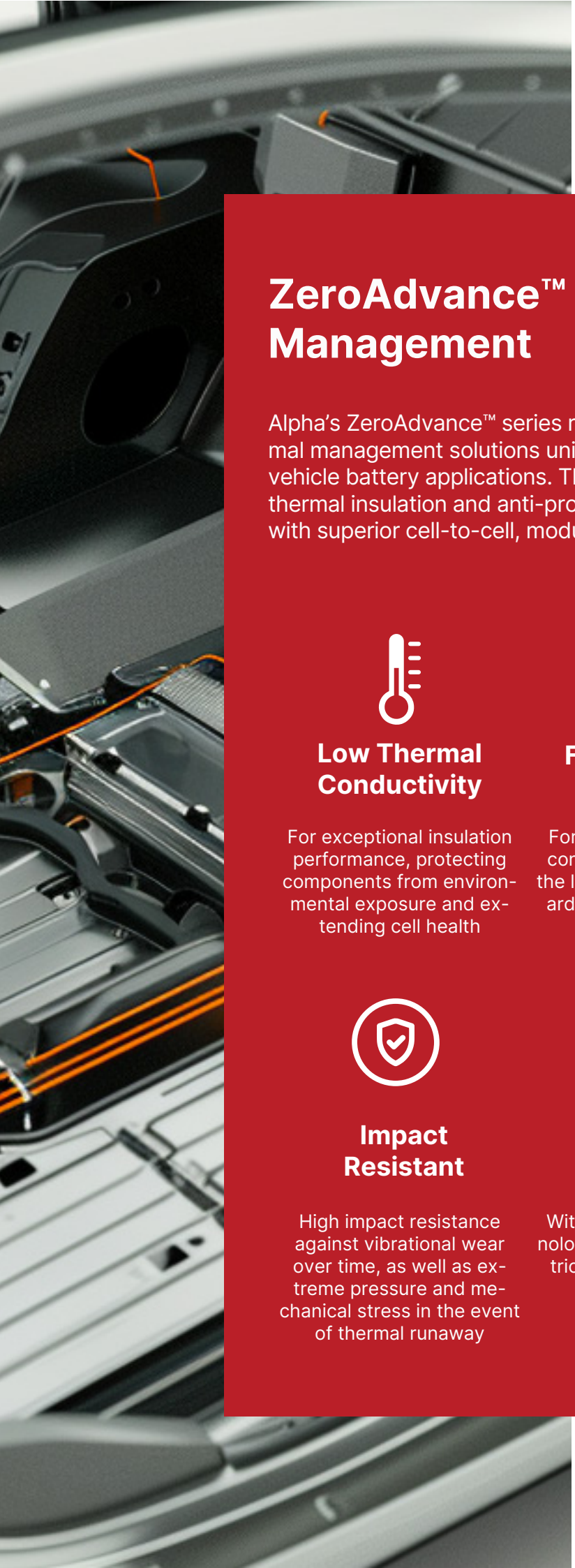
The Future of EV Thermal Management

ZeroAdvance™ Series



ZeroAdvance™ Series for EV Thermal Management

Alpha's ZeroAdvance™ series represents the newest generation of thermal management solutions uniquely designed for a wide range of electric vehicle battery applications. This family of products provides effective thermal insulation and anti-propagation to ensure safety and longevity with superior cell-to-cell, module, and pack-level protection.

Low Thermal Conductivity

For exceptional insulation performance, protecting components from environmental exposure and extending cell health

Flame Resistant

For excellent propagation control. Designed to meet the latest UL and VW standards for battery enclosure materials

Lightweight

Low-profile solutions that support vehicle lightweighting and are easy-to-install, reducing system complexity and cost

Impact Resistant

High impact resistance against vibrational wear over time, as well as extreme pressure and mechanical stress in the event of thermal runaway

Electrically Insulating

With a core polymer technology that provides dielectric performance up to 21 kV/mm

Highly Flexible

Easily conformable for complex geometries, 3D formable capability

ZeroAdvance™ Vs. Competitor

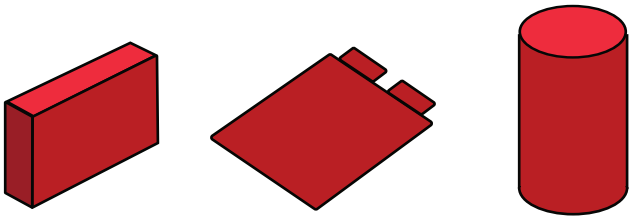
	ZeroAdvance™ Composites	Mica Sheet	Aerogel Sheet	Ceramic Paper	Rigid Fiber Composites
LOW DENSITY	✓	✗	✓	✓	✗
DURABILITY AGAINST VIBRATIONAL WEAR	✓	✗	✗	✗	✓
HIGHLY FLEXIBLE FOR COMPLEX 3D GEOMETRIES	✓	✗	✗	✗	✗
IMPACT RESISTANT, ROBUST MECHANICAL STRENGTH PROPERTIES	✓	✓	✗	✗	✓
COMPRESSIBLE TO ACCOMMODATE VARIABLE CELL PRESSURES	✓	✗	✓	✓	✗
MANUFACTURED IN THE USA	✓	✗	✓	✓	✗

Why ZeroAdvance™?

- ✓ **Best in class balance of effective thermal and electrical insulation, mechanical strength, fire resistance, flexibility, and lightweighting.**
- ✓ **Effective thermal management solutions that take up as little space and weight as possible allow OEMs to increase energy density and maximize range.**
- ✓ **All ZeroAdvance™ materials can be designed with a UL 94 V-0 rated PSA backing for easy peel & stick assembly.**
- ✓ **Alpha's team has a unique expertise in combining the right materials to maximize performance with a complete, cost-effective solution addressing a complex set of challenges.**

Solutions For Every Battery Format and Application

- **Cell-to-Cell Thermal Isolation**
- **Module Protection**
- **Pack Level Thermal Runaway Protection**
- **Full Vehicle Fire Blankets**
- **Specialty Protective Tapes**



Versatility for Prismatic, Pouch, and Cylindrical Cell Formats

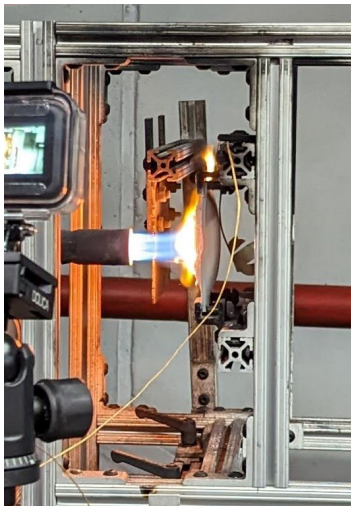
Cell-Cell & Module Protection	Pack Level Thermal Runaway Protection	Specialty Solutions
0.1 – 0.8mm typical Very low profile, lightweight Isolates thermal runaway to single cell failure Economical protective solutions	1.5 – 3.0 mm typical Extreme temperature, pressure, and mechanical stress exposure Maximizes risk reduction for vehicle system safety Higher functionality, Higher value	Broader applications within the pack Specialty coatings, Intumescent Technology Silicone foam composites Custom converting for more versatile parts

Pack Level Thermal Runaway Protection

Product / Material Property	Gen-2 Multilayer Composite (gray/red)	I-FR Performance Composite (black/red)	Gen-3 Multilayer Composite (white/red)
Density, g/cm3	1.07	1.26	1.40
Thickness, mm	1.5	2.0	2.0
Tensile Strength, lb/in. (cm-kgf)	615 (110)	700 (135)	700 (135)
Max coolside temp after 10 min 1000 °C exposure, °C	470	370	355
Thermal Conductivity, W/mK	0.148	0.254	TBD
Additional Value Areas	High dielectric strength; highly flexible, lowest density	Graphite element for effective heat spreading and expansion; low TC	High impact resistance, UL TaG results yield 5th Grit Cycle Breach
Common Value Areas	Highly flexible, resistant to vibrational wear, Low contamination risk (no dust)		

Torch and Grit (TaG) test method for battery enclosure materials screening for UL 2596. Constant 1300C high pressure torch applied with 5 second AlOx grit blast every 15 seconds. 3+ cycles before breach is indicative of better performance in full module test.

Designed as a more relevant method to replicate combination of high temperature, pressure, and mechanical impact during a thermal runaway event.



Core Design Focus

		Product					
Properties	Test Method	ZA070	ZA075	ZA031	ZA033	ZA090	ZA032
Thickness, mm	DIN EN ISO 5084	0.75	0.95	1.5	1.9	3.3	1.5
Density, g/cm3	DIN EN ISO 1183	1.33	1.05	1.07	1.26	0.36	1.56
Thermal Conductivity, W/mK	DIN EN 1094	0.622	0.072	0.148	0.254	0.120	0.400
Dielectric Strength per unit thick-ness, kV/mm	IEC 60243	2.7	2.7	21.0	9.4	3.9	12.8
Tensile Strength, kgf/cm	ISO 4606	106	135	110	135	22.5	107
Puncture Resistance, cm-kgf	ISO 3036	351	350	360	365	190	350
Thermal Insulation Performance, Δ°C	1000°C exposure, 10 minutes	575	410	560	640	525	570
Design Features		Ultra-thin and flexible for cell-to-cell protection; excellent insulative performance relative to thickness	Ultra-thin and flexible for cell-to-cell and module protection; abrasion and fire resistant for EV fire blankets	Multilayer design for pack level thermal runaway protection. Exceptional thermal and electrical insulation properties, highly flexible to conform to complex 3D geometries.	Multilayer design for pack level thermal runaway protection. Graphite element for effective heat spreading and expansion, combined with low thermal conductivity to insulate	Extremely flexible and low density with excellent insulating properties. Compressible to accommodate variable cell pressures, preventing overexpansion and cell damage.	Multilayer design for pack level thermal runaway protection. Exceptional thermal and impact resis-tance; reinforc-ing elements for mechanical toughness and flexibility.

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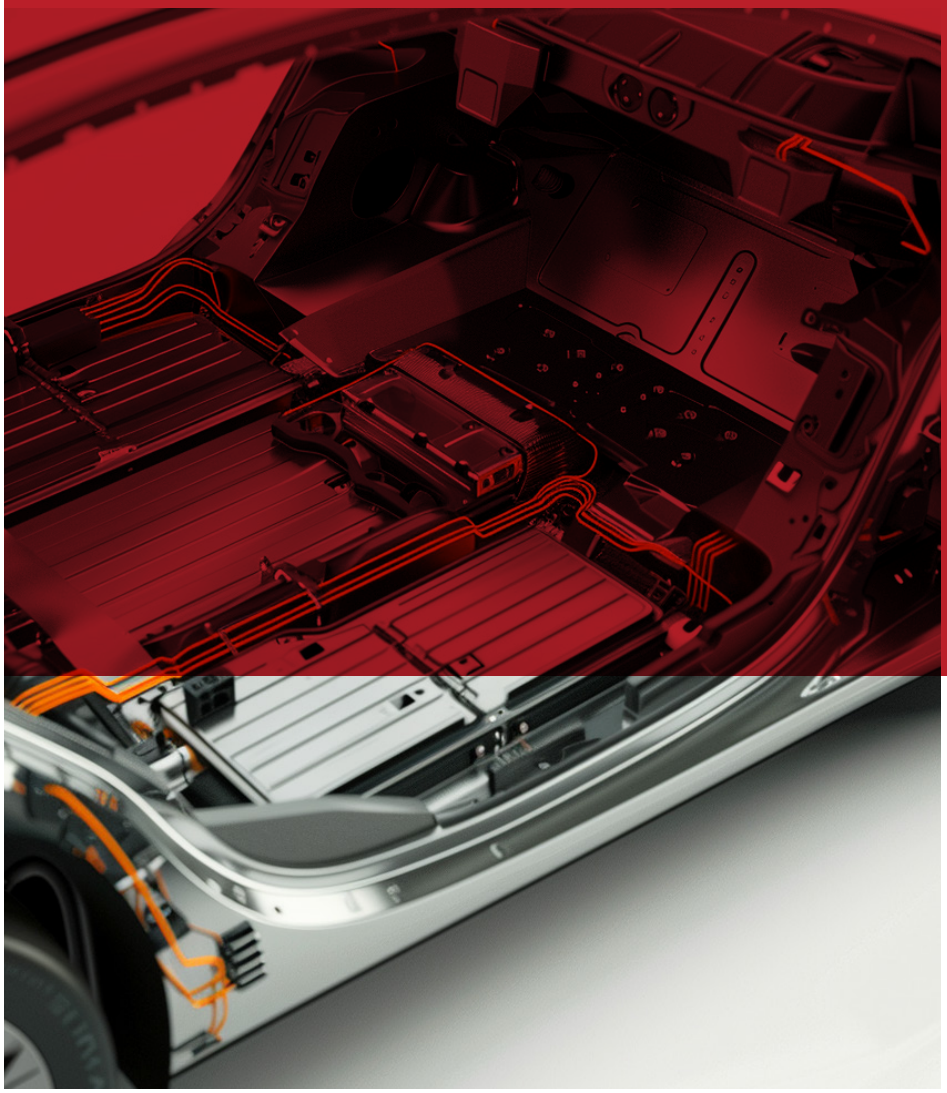

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