

LHS® XTS™ PROPAGATION PREVENTION & THERMAL MANAGEMENT PRODUCT

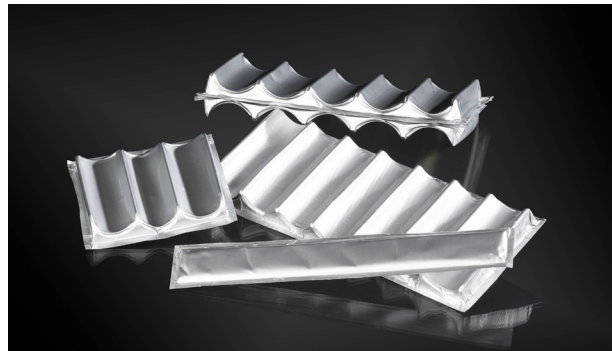
XTS POUCH

XTS products rely on a proprietary gel and novel containment design to address both thermal runaway and thermal performance concerns in lithium-ion battery (LiB) applications.

Key thermal properties have multiple functions for LiB thermal management:

- Enhanced specific heat capacity and thermal conductivity for tailored cooling behavior during normal pack operations
- Excellent thermal barrier and energy conversion properties through use of a high latent heat PCM which provides both cell-to-cell and ejecta thermal protection
- Custom design approach to achieve optimized thermal performance with reduced weight, which is scalable to a diversity of LiB formats

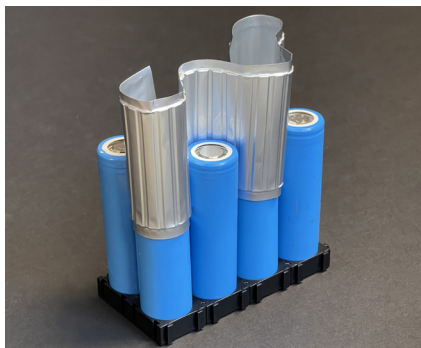
CUSTOMIZED XTS POUCH



CUSTOMIZED FOR:

- Cell Spacing
- Cell holder designs
- Connectors/BMS configurations

CONFORMABLE XTS POUCH



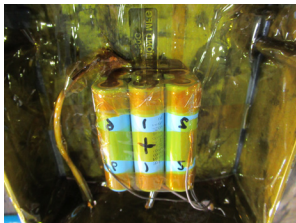
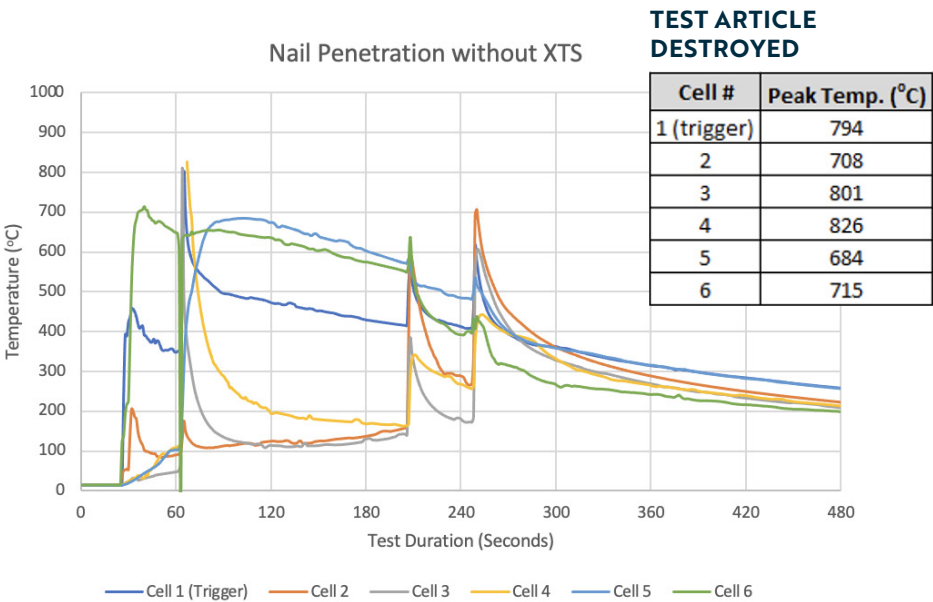
GEOMETRY APPLIED BASED ON:

- Assembly process
- Safety vs performance needs
- Weight restrictions

THERMAL RUNAWAY PROTECTION

XTS is designed to prevent thermal runaway by:

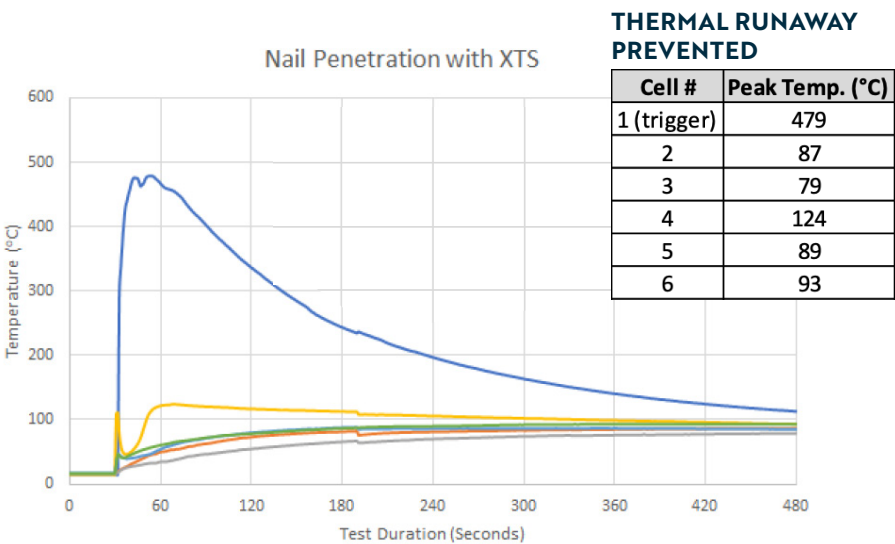
- Capture and Convert Thermal Energy
 - XTS vaporized into a non-combustible vapor that absorbs thermal energy
- Quench and Extinguish Flaming
 - Non-combustible vapor limits oxygen availability
- Blocking or Deflecting Ejecta
 - Novel heat deflection/thermal barrier properties can be tailored for specific needs. Its high specific heat capacity provides better thermal balancing during standard operating conditions



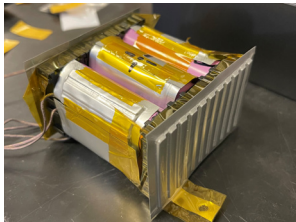
PRE-TEST



POST TEST



THERMAL RUNAWAY
PREVENTED

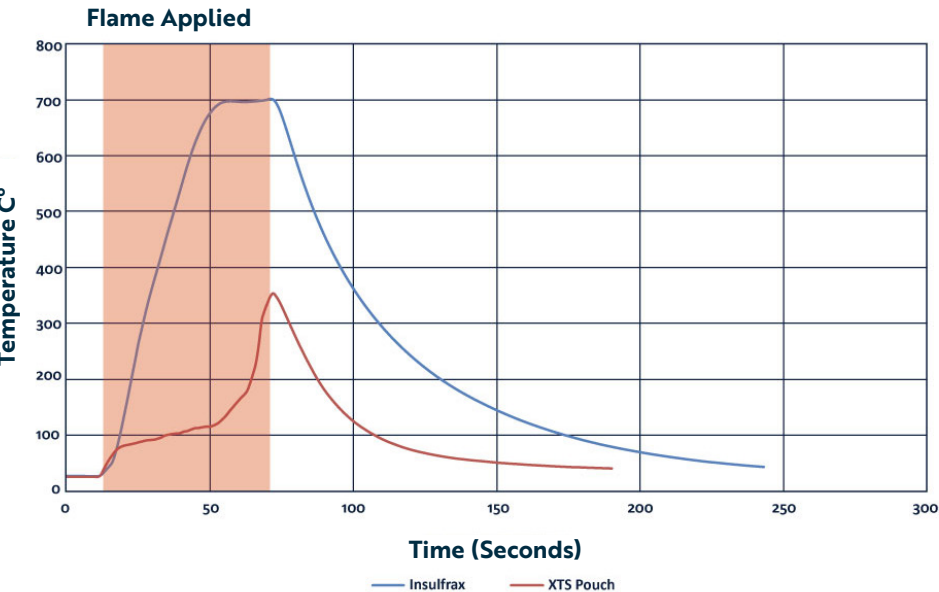


PRE-TEST

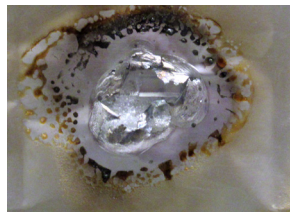


POST TEST

XTS Pouches can out compete traditional insulation materials and provide a more effective flame barrier:



AFTER TORCH TEST



Side exposed to flame



Backside

XTS pouch immediately self-extinguishes upon multiple applications of a propane torch at 1200°C. No flame penetration/damage on reverse side of flame application.

TYPICAL PHYSICAL PROPERTIES

Density:	0.97-1.00 g/cm ³
Thermal Conductivity:	0.74 W/mK (xy-plane)
Specific Heat Capacity:	3.5 J/g/°C
Phase Transition:	95-110°C
Thermal Dissipation:	1600-2000 J/g
Coefficient Thermal Expansion (volumetric):	Pliable; reference 300-400 x 10 ⁻⁶ /K @ 30-70°C
Bulk Electrical Resistivity:	6 x 10 ¹³ Ω cm
Shore Hardness:	Pliable
Laminate Thickness:	115µm +/-5%
Laminate Strength:	>22.5N/15mm
ROHS Compliance:	Compliant

XTS POUCH: ALTERNATIVE FILL OPTIONS

XTS pouches can also be designed with other fill materials to meet specific thermal management needs, specifically using traditional solid-to-liquid based PCMs including Fill & Flow products.

TYPICAL PHYSICAL PROPERTIES

Density:	0.85-0.97 g/cm ³
Thermal Conductivity:	0.74-1 W/mK (xy-plane)
Specific Heat Capacity:	1.85-2.35 J/g/°C*
Phase Transition:	35-85°C**
Thermal Dissipation:	160-200 J/g***
Thermal Expansion (volumetric):	Pliable; up to 3% volume change @PTT
Bulk Electrical Resistivity:	6x10 ¹³ Ω cm
Shore Hardness:	Pliable depending on fill material
Laminate Thickness:	115µm+/-5%
Laminate Strength:	>22.5N/15mm
ROHS Compliance:	Compliant

*Reference F&F table below for typical heat capacity ranges

**Reference F&F table below for typical PTT ranges

***Reference F&F table below; based on 10% of total mass being pouch material

LHS Product	LHS F&F-89	LHS F&F-90R	LHS F&F-91	LHS F&F-92	LHS F&F-93
Temperature (PPT):	35-39 °C	42-46 °C	49-51 °C	53-57 °C	59-63 °C
Latent Heat:	210-230 kJ/kg	180-200 kJ/kg	200-220 kJ/kg	200-220 kJ/kg	210-230 kJ/kg
Specific Gravity @ 22°C:	0.8	0.8	0.8	0.8	0.8
Viscosity Above PTT (CPS):	25-100	25-100	25-100	25-100	25-100
Operating Temp. Range:	-10-120°C	-10-120°C	-10-120°C	-10-120°C	-10-120°C
Volume Resistivity:	1.1 x10 ¹⁵ Ωcm	4.3 x10 ¹³ Ωcm	4.5 x10 ¹³ Ωcm	4.5 x10 ¹³ Ωcm	4.5 x10 ¹³ Ωcm
Dielectric Constant:	2.04	3.05	3.05	3.05	3.05
Dielectric Strength**:	21.71 MV/m	36.63 MV/m	35.63 MV/m	35.63 MV/m	35.63 MV/m
RoHS Compliance:	Compliant	Compliant	Compliant	Compliant	Compliant
Avg. Specific Heat Capacity, Cp-Below PTT*	1.85 J/g ·°C	1.90 J/g ·°C	1.90 J/g ·°C	1.90 J/g ·°C	1.90 J/g ·°C
Avg. Specific Heat Capacity, Cp-Above PTT*	2.35 J/g ·°C	2.45 J/g ·°C	2.45 J/g ·°C	2.45 J/g ·°C	2.45 J/g ·°C
Avg. Thermal Conductivity, - Below PTT*	0.35 W/m·k	0.35 W/m·k	0.35 W/m·k	0.35 W/m·k	0.35 W/m·k
Avg. Thermal Conductivity, - Above PTT*	0.25 W/m·k	0.25 W/m·k	0.25 W/m·k	0.25 W/m·k	0.25 W/m·k

*viscosity determined at 20°C above the transition temperature

*Other phase transition temperatures up to 130°C are available

*Similar to most solid and liquid materials, the specific heat capacity and thermal conductivity have insignificant change above and below the transition temperature.

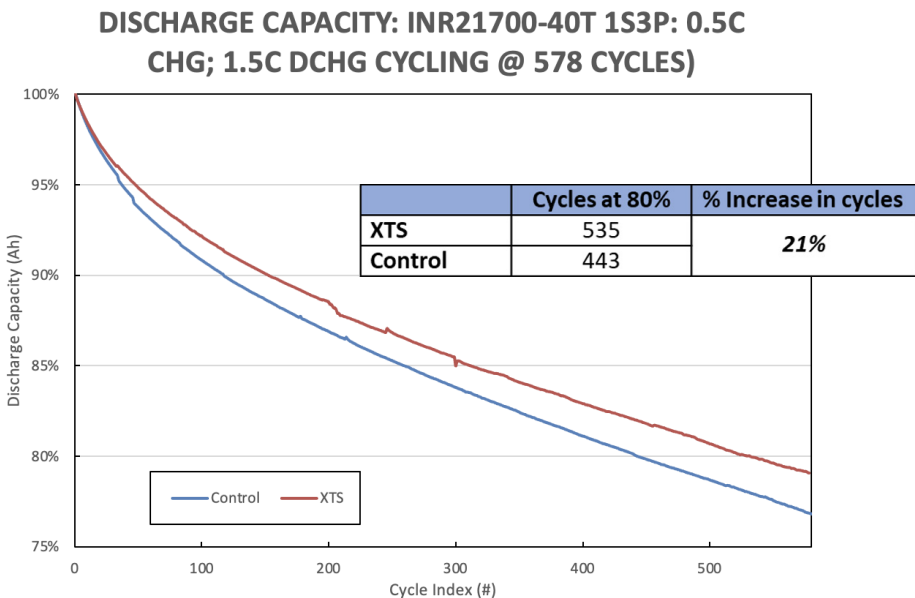
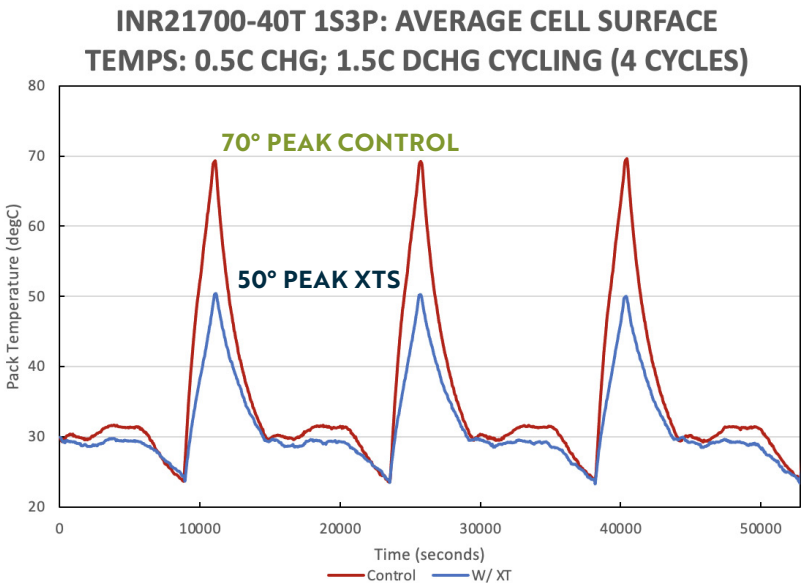
**Tested at 3 mm thickness

XTS THERMAL MANAGEMENT

XTS pouches provide a passive thermal solution to challenges observed in many battery applications where heat generation during standard operation can have lasting damage to the battery.

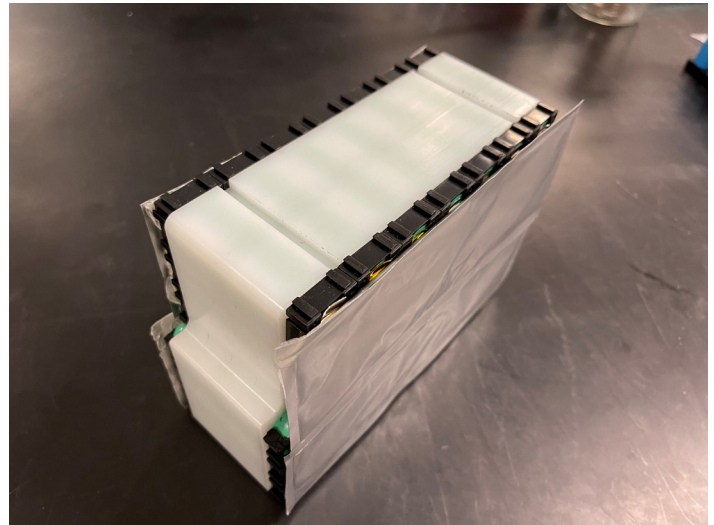
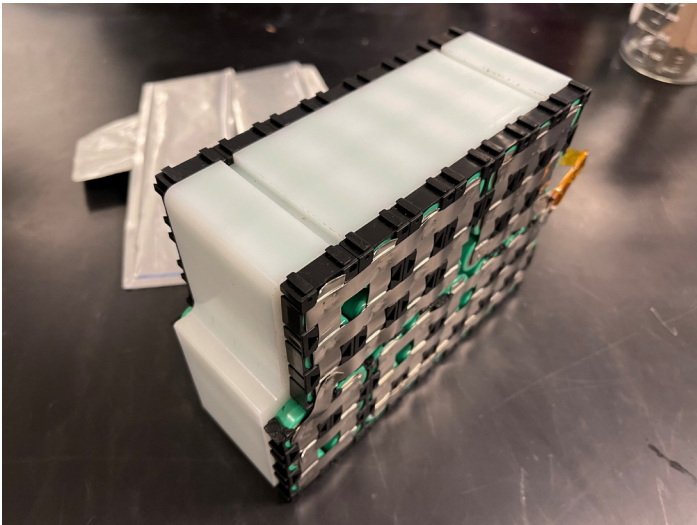
XTS specifically addresses this through:

- Tailorable heat absorbing materials using either the XTS gel or other PCM-based fill materials
- Achieving maximum heat absorption at the lowest possible weight due to configurable pouch design
- Higher overall effective thermal conductivity compared to traditional passive solutions



XTS SCI & SCI-FR COMPOSITE

- The XTS SCI & SCI-FR products are shape-stable PCM composites designed for use in thermal runaway situations where additional structural support against side wall rupture events in Li-ion cells is needed
- It is designed to be used as an interstitial thermal barrier in tandem with XTS pouches as a complete thermal runaway protection package
- These products behave as typical engineered thermoplastic resins and can be extruded, molded, and/or machined using typical thermoplastic processing equipment and are available as a finished good or as a pellet form, raw material.



XTS SCI products require XTS pouches for ejecta/venting management during thermal runaway events.

TYPICAL PHYSICAL PROPERTIES		XTS-SCI	XTS-SCI-FR
Density (g/cm3)		0.961	1.08
TYPICAL THERMAL PROPERTIES			
Specific Heat Capacity (J/g°C)		2.0	2.0
Heat of Fusion (J/g)		240	170
Phase Transition (°C)		122	122
CTE Linear @ 23°C (µm/m°C)		116	111
Thermal Conductivity (W/m*K)		0.65	0.52
TYPICAL MECHANICAL PROPERTIES			
Tensile Strength @ Break (Mpa)		31	11.5
Tensile Strength @ Yield (Mpa)		27	16.4
Yield Elongation (%)		15	6.3
Break Elongation (%)		600	34
Tensile Modulus (Mpa)		1200	1020
Flexural Modulus (Mpa)		1351	869
Hardness, Shore D:		65	65
TYPICAL ELECTRICAL PROPERTIES			
Dielectric Constant		2.45	3.45
Dielectric Strength (V/mil)		769	719
Volume Resistivity (Ohm per sq.)		4.00E+15	3.34E+13
Surface Resistivity (Ohm per sq.)		1E+14	8.87E+13
FR RATING			
Vertical Burn Test 1.5 mm		N/A	UL94-V0
Vertical Burn Test 3.0 mm		N/A	UL94-V0

