

Thermal Runaway Containment and Thermal Management Using Phase Change Material (PCM)

The NAATBatt Workshop on Li-ion
Thermal Safety

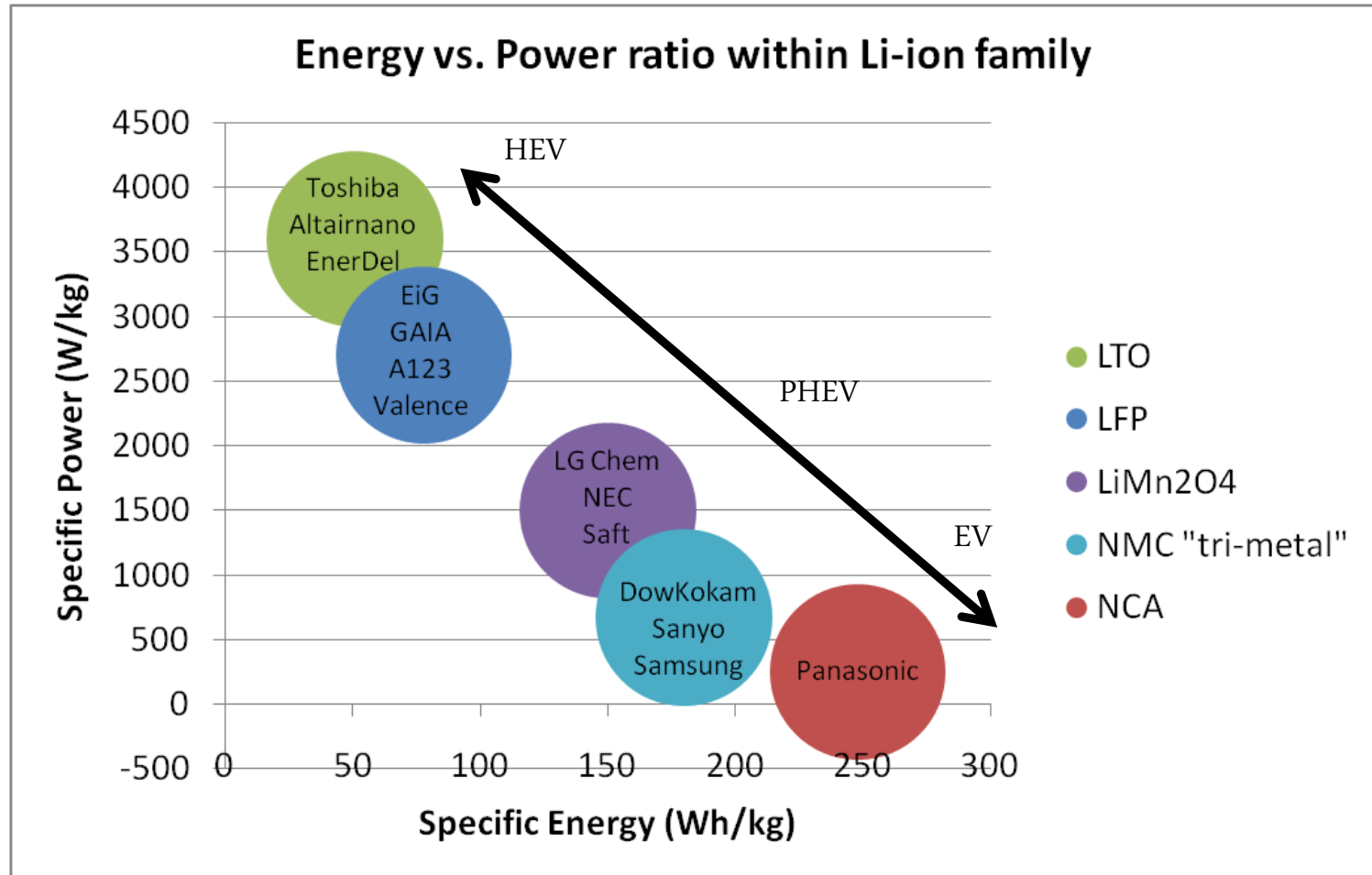
Austin, TX

January 16-18, 2013

Presentation Outline

- Li-ion battery characteristics
- What is PCM?
- Thermal Runaway Containment
 - Cylindrical Cells
 - Pouch Cells
- Thermal Management
 - Cylindrical Cells
 - Pouch Cells
- Concluding Remarks

Lithium-ion chemistry has large power/energy range

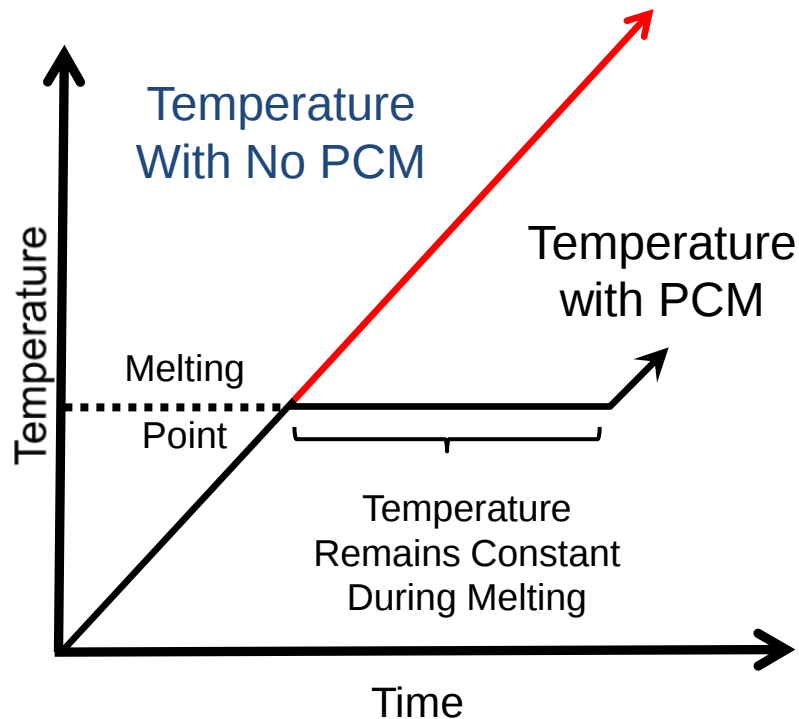


Cycle life and cost per kWh generally increase with specific power

How PCM-graphite works

Wax Absorbs Heat As It Melts

Graphite Distributes Heat Evenly



- Lightweight
- Thermally conductive
- Design flexibility
- Viscoelastic



Thermal Runaway Containment

System thermal management is the last line of defense

- Cell chemistry, packaging, and manufacturing advancements will continue to improve safety
- Additional safety mechanisms will always be necessary
- Phase change material (PCM) combined with thermal conductors (copper, graphite foil) offers simple, effective, multi-use solution

System must handle worst case heat release

- Trigger mechanism

- Internal short – short time frame
- External short
- Overcharge

- Cell chemistry

- LiNMC – high energy density
- LiMn_2O_4
- LiFePO_4

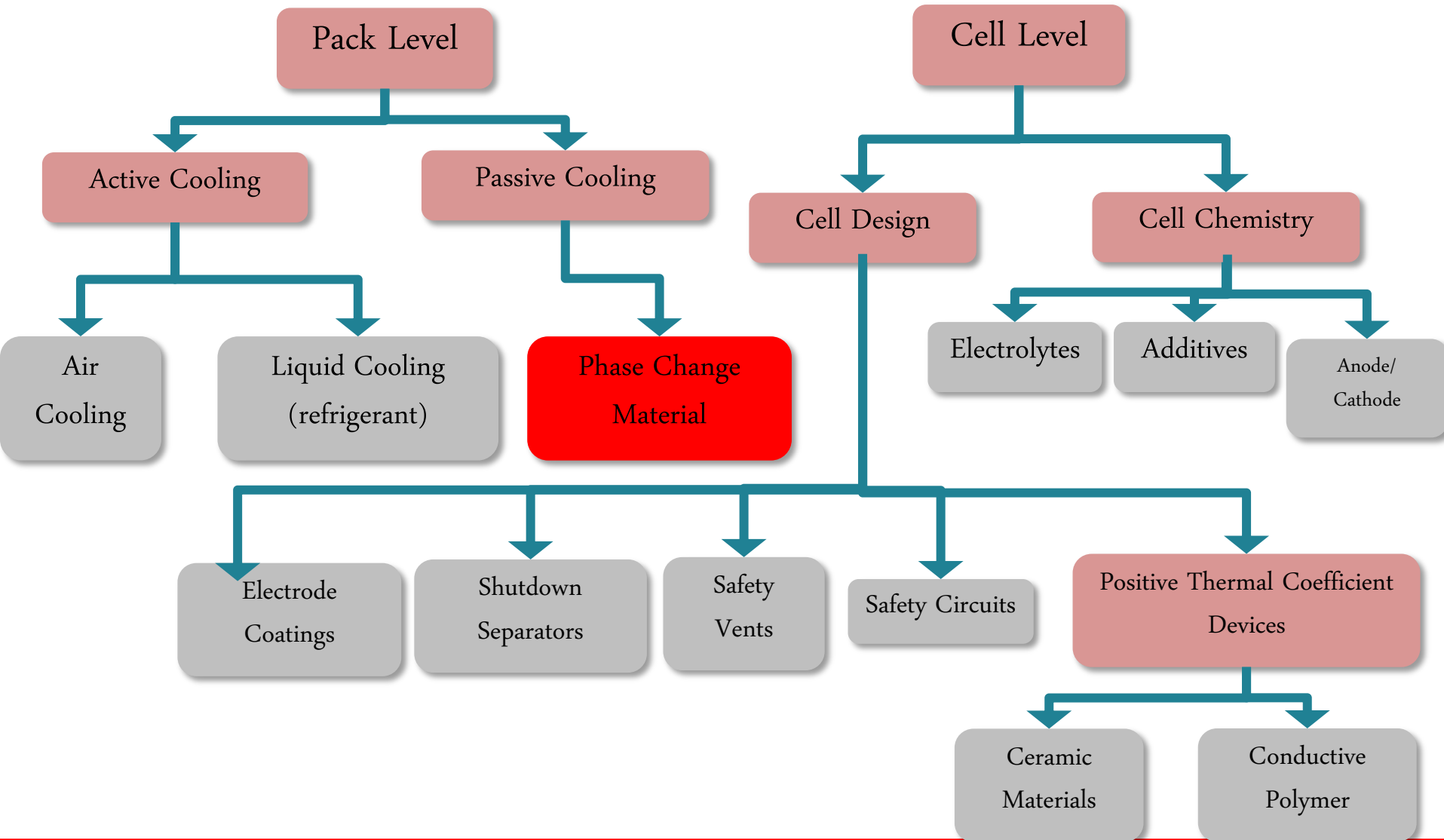
- Form Factor

- Cylindrical
- Prismatic (Hard Case)
- Pouch (weak structure, low thermal mass)

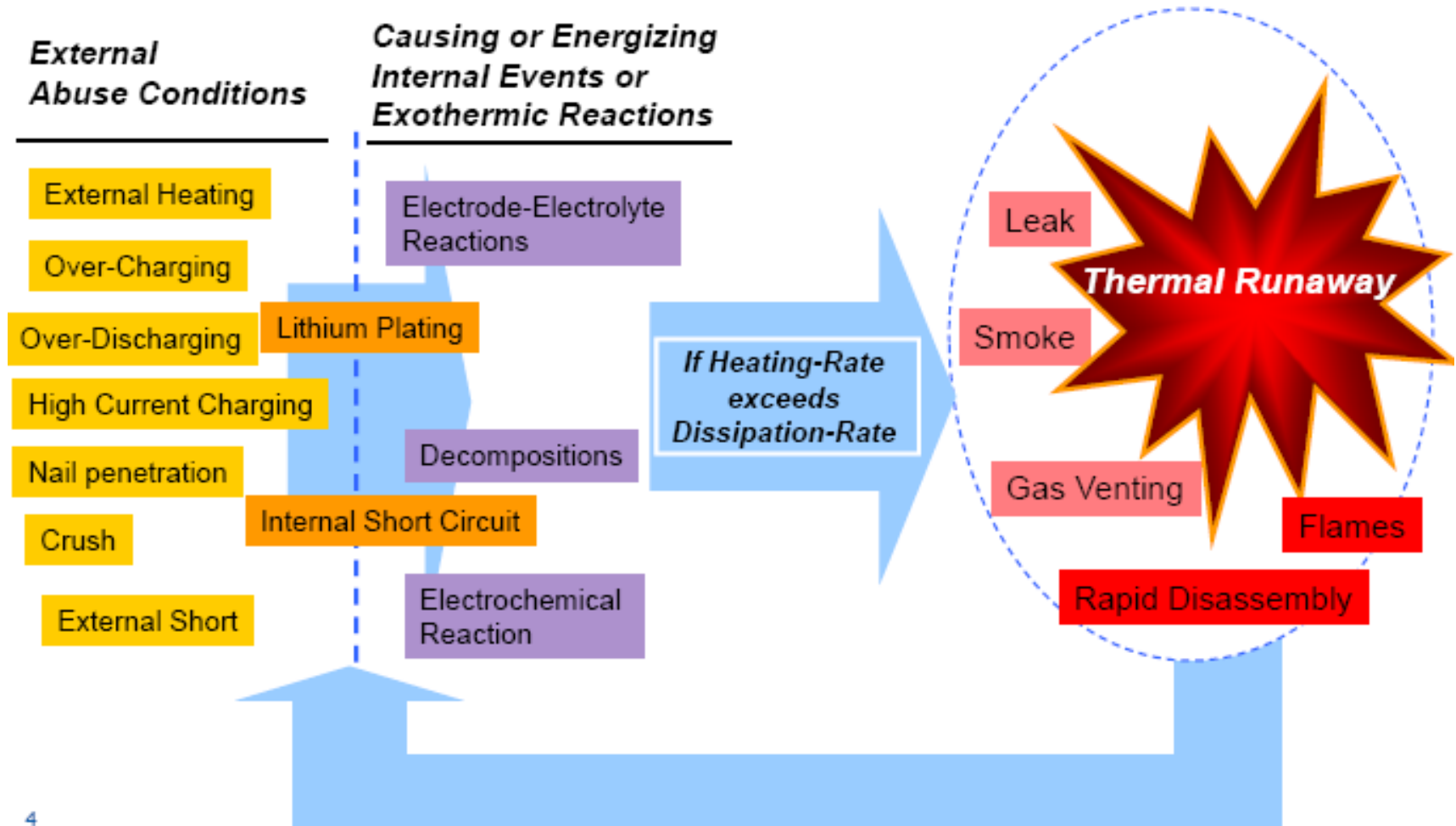
- Size

- Large Format – high amount of energy
- Small format

Safety improvements are being made on multiple fronts

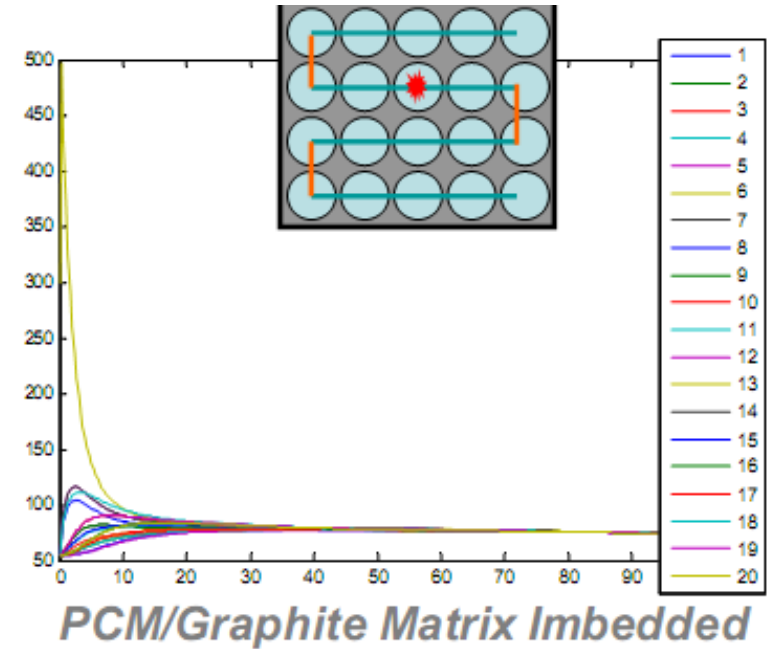
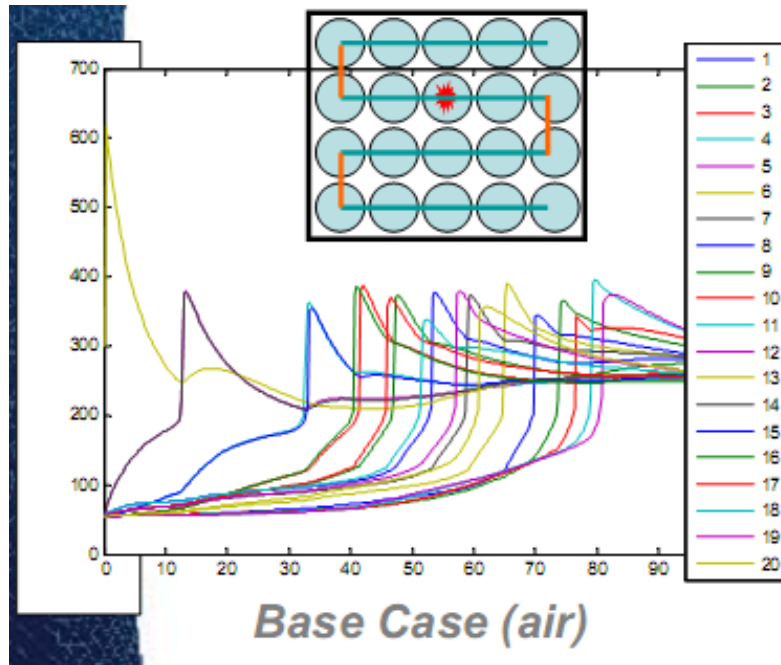


If heat removal is insufficient...



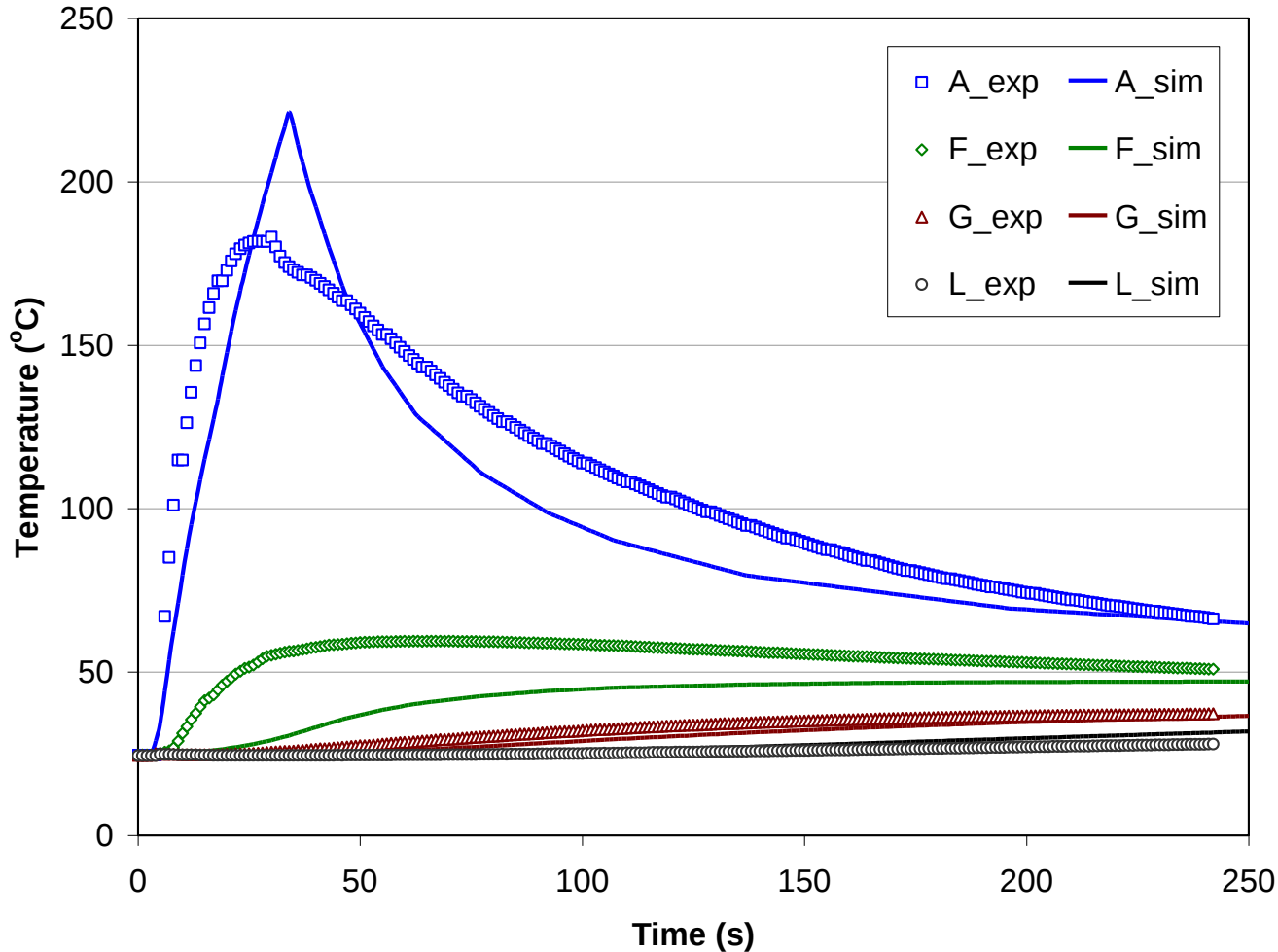
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AllCell PCM can prevent thermal runaway propagation with cylindrical cells



R. Kizilel ,R. Sabbah, J. R. Selman, S. Al-Hallaj, "An Alternative Cooling System to Enhance the Safety of Li-ion Battery Packs", *Journal of Power Sources*, 194, (2009), 1105-1112

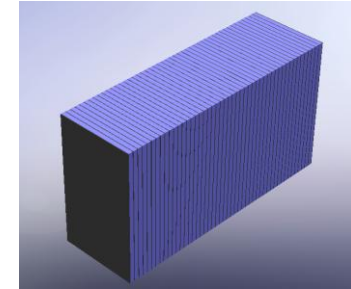
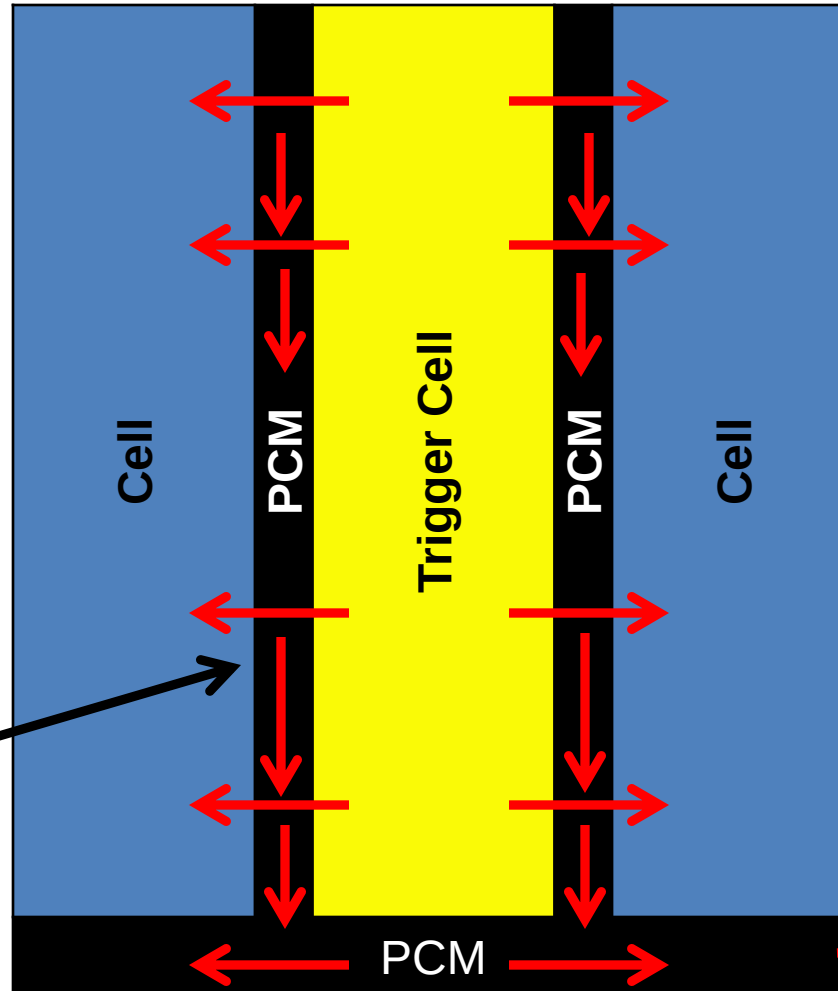
Simulation and experimental work agrees



Trigger cell

R. Kizilel, R. Sabbah, J. R. Selman, S. Al-Hallaj, "An Alternative Cooling System to Enhance the Safety of Li-ion Battery Packs", *Journal of Power Sources*, 194, (2009), 1105-1112

Pouch cell pack has different thermal behavior



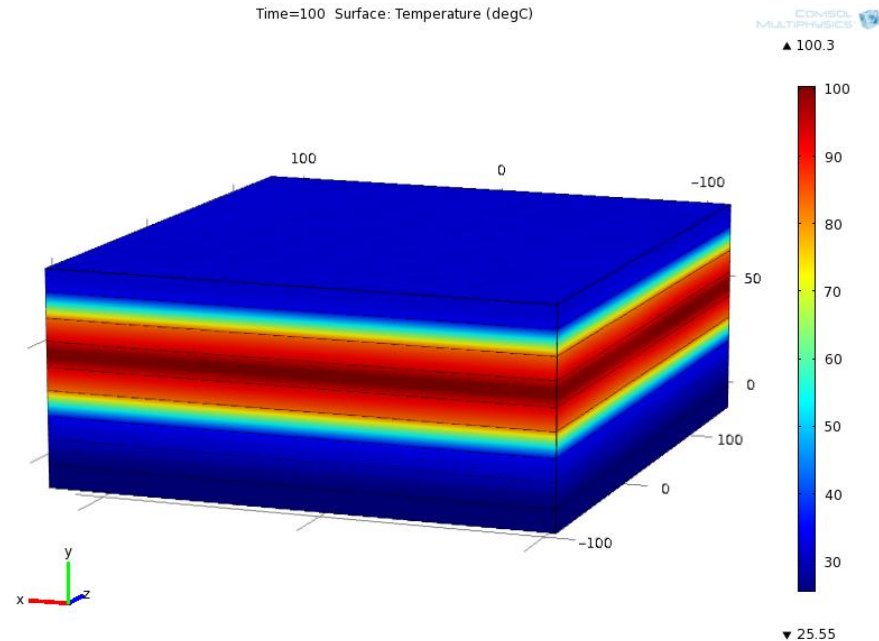
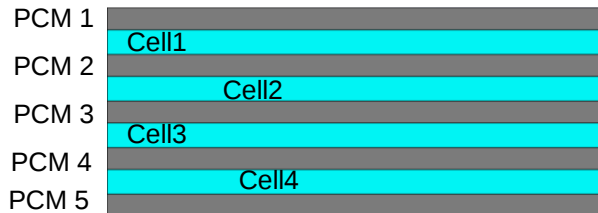
PCM Critical Specifications

- Thermal conductive : replace cooling plates
- High latent heat: heat sink
- Vescoelastic: replace foam separators

Option: Remove heat to external PCM heat sink using heat pipes

AllCell PCM can prevent thermal runaway propagation with pouch cells

Thermal runaway triggered for Cell #2



- Peak temperature on face of cell 1: ~ 80C
- Peak temperature on face of cell 3: ~ 80C
- Kept neighboring cells to below 90C, per SAE J2929 safety standards



Thermal Management

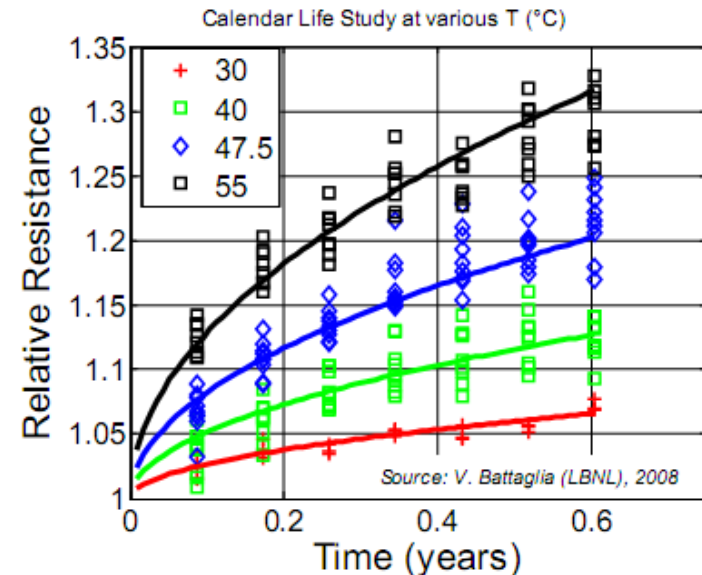
Thermal degradation is a hot button issue

“As a result, the LEAF pack will have temperatures ‘all over the place,’ causing it to suffer ‘**huge degradation**’ in cold environments and basically ‘**shut off**’ in hot environments.” – **Elon Musk, CEO Tesla**

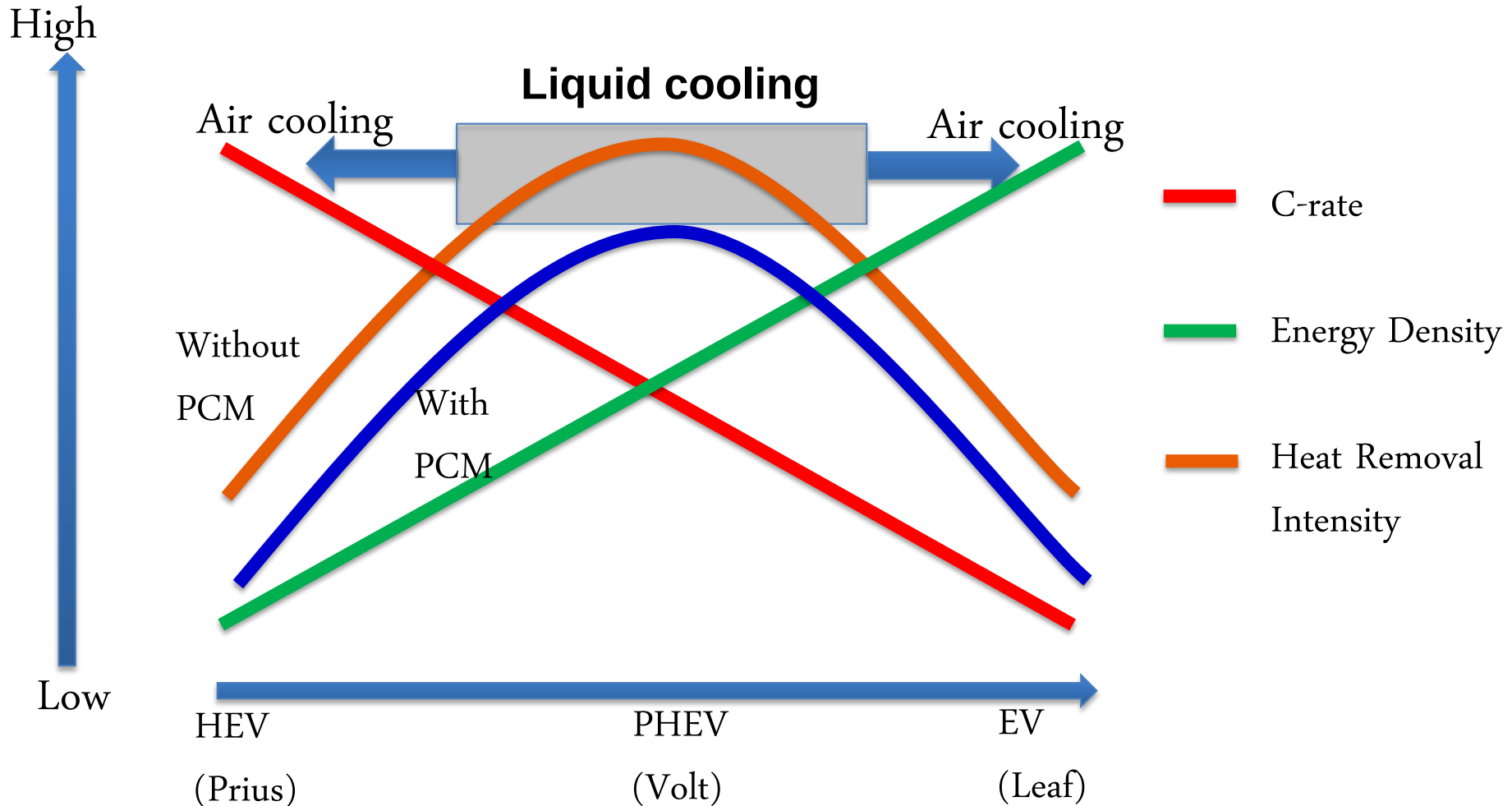
“Thermal management of the system...all of those little details go into effect to **take it to the next level**” – **Jay Iyengar, Global Director & Chief Engineer for Electrified Powertrains, Chrysler**

“Thermal management of lithium-ion battery systems is **critical to the success of all-electric vehicles** because extreme temperatures can affect performance, reliability, safety and durability.” – **V. Anand Sankaran, Executive technical leader, Ford Energy Storage & High Voltage Electrical Systems**

“The different chemistries have different thermal characteristics and so we’ve been able to incorporate how to **make sure from a thermal perspective that we’ve got it...**” – **Denise Gray, Advanced Battery Director of GM**



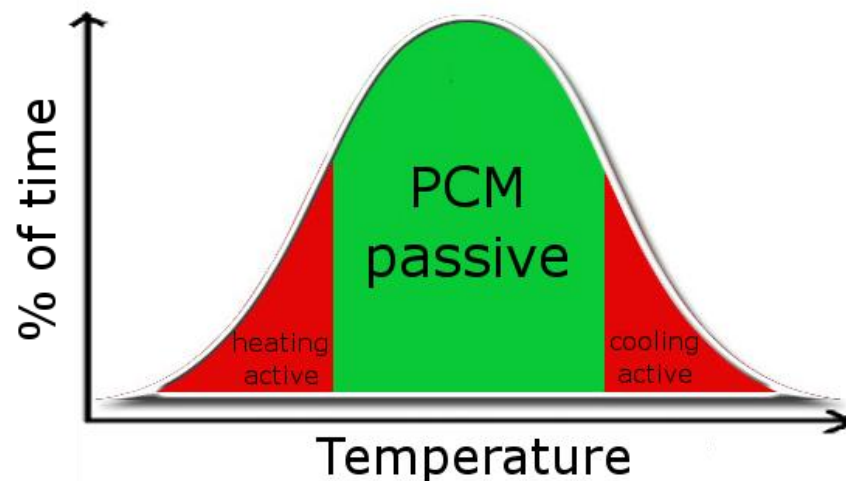
When is liquid cooling used?



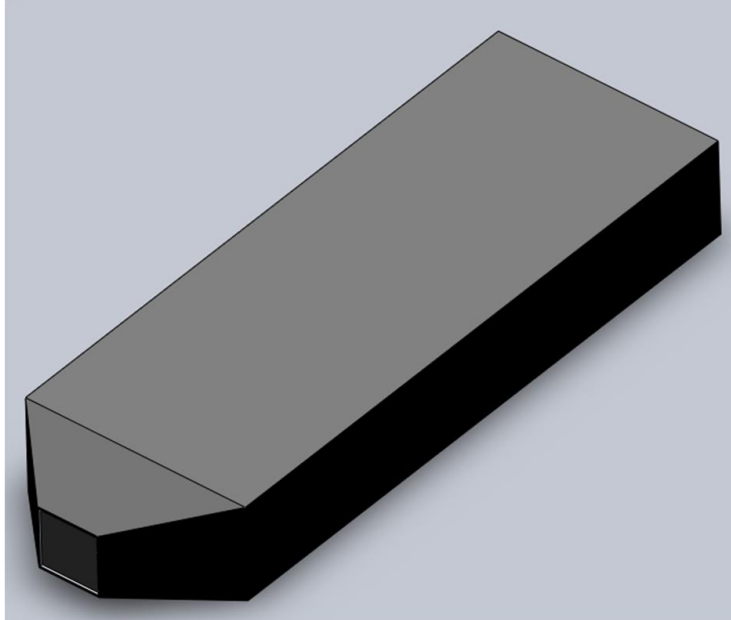
Hybrid air/PCM cooling for hybrid and EV normal operation

- PCM eliminates the need for active cooling and heating during the majority of operating time – combined with cabin air system for remainder of situations

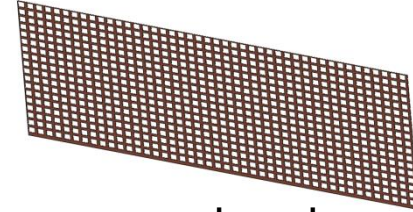
Ambient	EV	HEV
Cold	Delays cool down. Adds minimal heating time/energy.	Delays cool down. Heat with engine heat.
Moderate	No active management required	Peak shaving of heat removal requirement
Hot	Keeps battery below ambient during hot days	Peak shaving of heat removal requirement



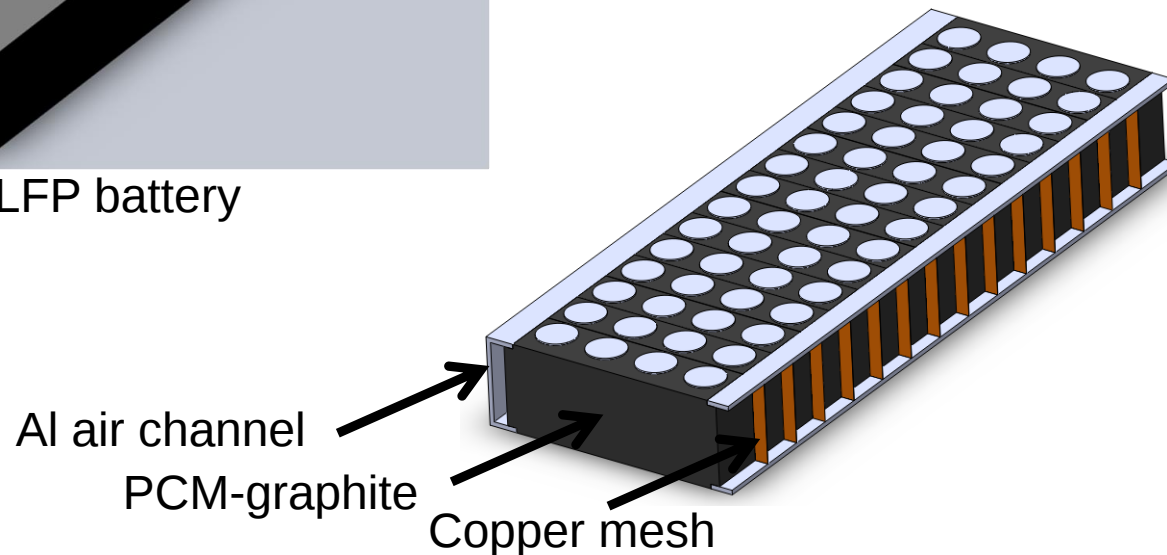
AllCell system simplifies design



500 Wh LFP battery



Copper mesh enhances heat transfer to air

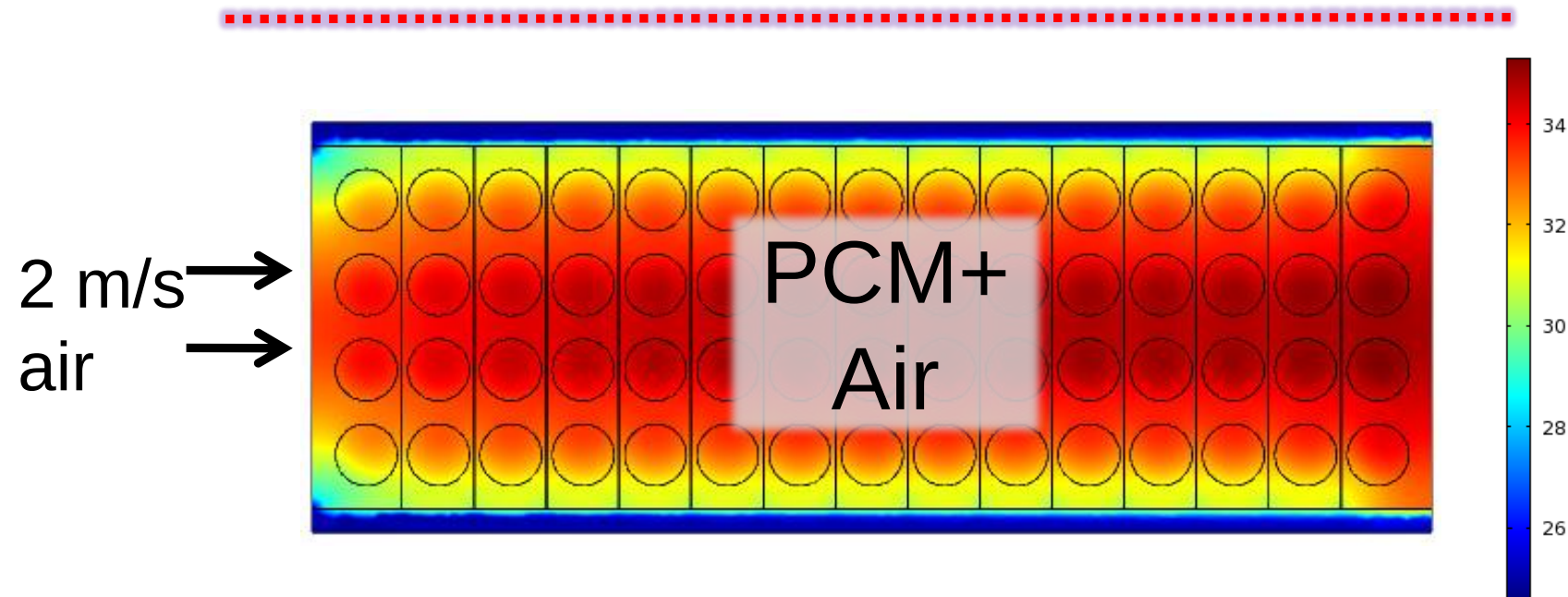
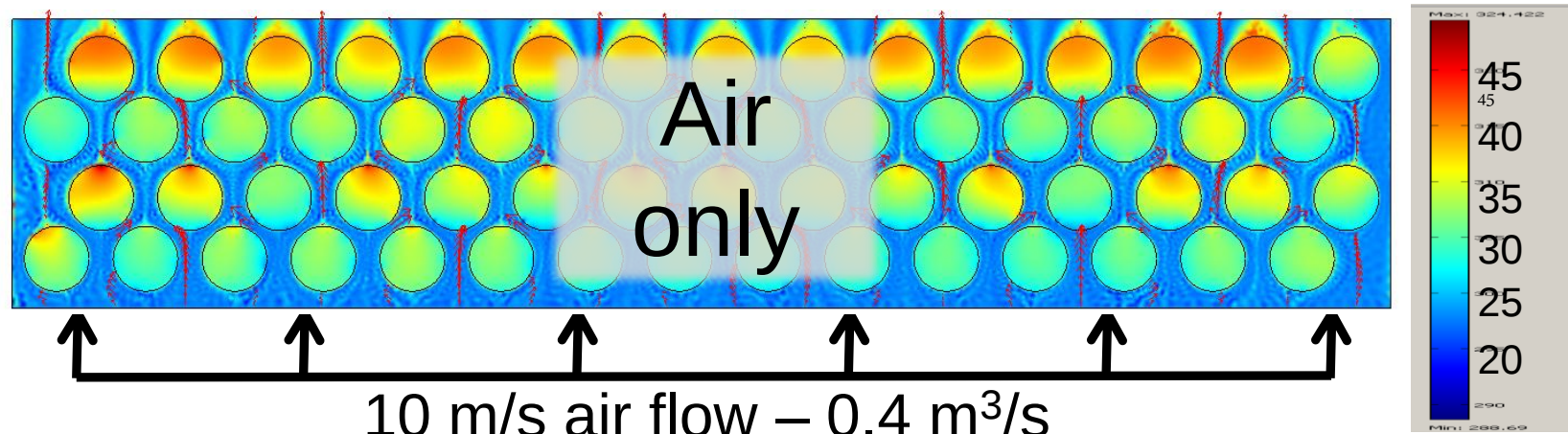


Al air channel

PCM-graphite

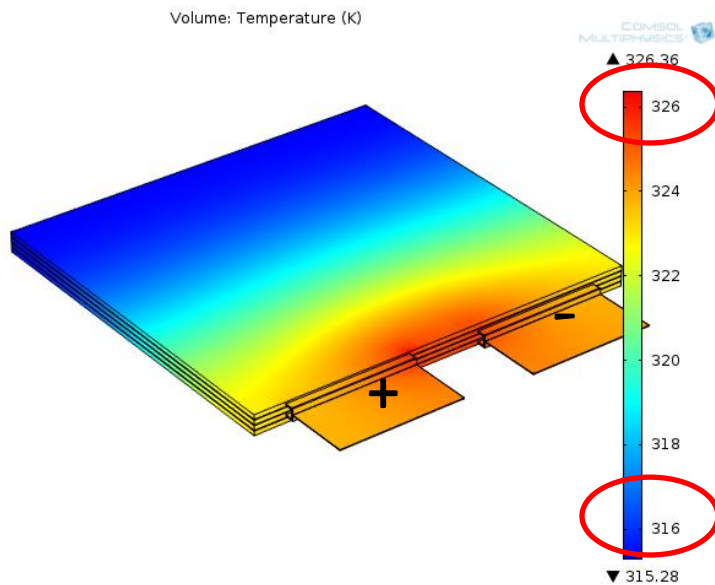
Copper mesh

Battery can be used more aggressively without needing liquid cooling



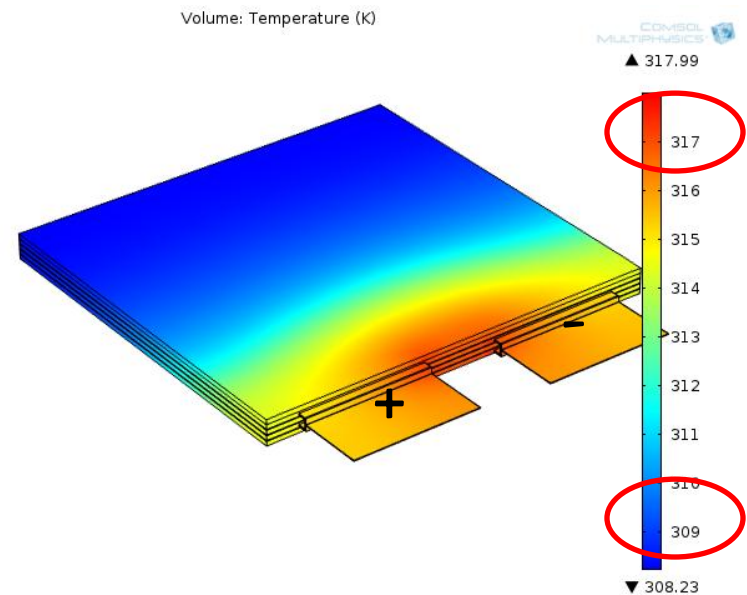
Can be used with pouch cells as well

Large format cell discharge simulation – Images taken after a complete 4C discharge in ambient 298K air



No PCM

Note the difference in temperature scales – PCM reduces peak temp by ~8K and reduces the largest temperature difference from 10K to 8K



With 3 mm of PCM on top face

Concluding Remarks

- One size does not fit all...**variety of cell types** and applications necessitates customized solutions
- Chemistry advances are only one piece of solution...thermal management and intelligent electronics play significant role
- Safety problems still exist...high energy and toxic chemicals pose real risk

Company Contacts

Said Al-Hallaj, Chairman & CEO

Tel: (+1) 773-922-1155 x201

salhallaj@allcelltech.com

Greg Albright, Director of Product Development

Tel: (+1) 773-922-1155 x211

galbright@allcelltech.com

AllCell Technologies LLC

Corporate Headquarters

2321 West 41st Street

Chicago, IL 60609 USA