Key Materials for Aviation Batteries

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WORLD MATERIALS FORUM

saft
a company of
TOTAL

Who is Saft today?

Group profile

100+ years of history

Leadership position on 75-80% of revenue base

9.4% invested in **R&D**

€788m revenue FY 2018

14 manufacturing sites

3 Technologies

Nickel-Cadmium

Lithium-ion

Primary Lithium

Multiple Markets

- Aviation
- Metering
- Space
- Data Centers
- Rail
- Mobility
- Oil & Gas
- Renewables

Performance of rechargeable battery chemistries

Cell level comparison

Key characteristics	Lead-Acid	Nickel-Cadmium	Lithium-ion
Gravimetric energy density (Wh/kg)	35	50	250
Volumetric energy density (Wh/l)	71	90	550
Cycle life	400	600 – 2000	5000
Typical operating life	3 to 5 years	8 to 12 years for Aviation	>20 years
Self-discharge, %/month	5%	5 - 20%	1%

Requirements for batteries in Aviation

Today's applications

- APU start
- Backup function: on loss of engine power, battery starts APU & powers control electronics & flight surfaces

Tomorrow's applications

- APU start and backup function
- Hybrid: combines batteries with conventional engines for regional aircraft
- All electric propulsion for short flights (≤ 1 hour): Air mobility

Key Requirements

Start & Backup	
Power:	~30 C at wide temp range
Energy Density:	~ 50Wh/kg
Life:	8 to 12 years with little cycling
Reliability:	No uncontainable failure at equipment level
Mechanical:	Very high levels of vibration (~6g) & shock (~20g)
Safety:	FAA and EASA regulation

Hybrid	
Power:	~30 C at wide temp range
Energy Density:	350 to 400 Wh/kg pack level
Cycle Life:	7,500 cycles for 5 years
Reliability:	No uncontainable failure at equipment level
Mechanical:	Very high levels of vibration & shock
Safety:	Applicable standards to be developed

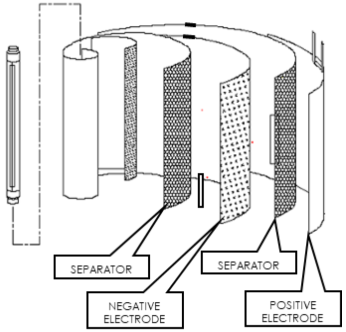
Propulsion	
Power:	~10 C at wide temp range
Energy Density:	350 to 400 Wh/kg pack level
Cycle Life:	3,500 cycles for 1 year
Reliability:	No uncontainable failure at equipment level
Mechanical:	Very high levels of vibration & shock
Safety:	Applicable standards to be developed

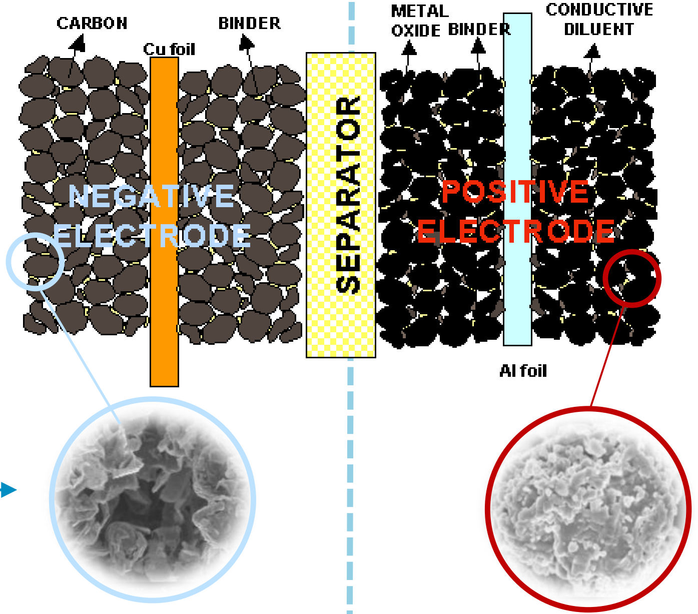
Requirements for EV vs. Aviation

Application		Electric Vehicles	Aviation
Requirements	Safety	5 minutes between detection & fire (time to evacuate)	**Critical:** casing containment of hazardous event inflight
	Casing today: aluminum. Tomorrow: composites & innovative materials		
	Energy	50 to 120 kWh	50 to 250 kWh
	Weight	170 Wh/kg pack level	**350 to 400 Wh/kg** pack level
		Obj: to decrease **$ per kWh**	Obj: to decrease weight
	Lifetime	10 years & 1,500 full cycles	1 year & 3,500 cycles
	Charge	Goal: 80% in less than 15 min	Goal: 80% in less than 15 min Or swapping
	Rapid charging needs materials that provide electrical insulation & thermal conductivity at same time		

EV batteries	Aviation batteries
High volume / standardized / low cost	Low volume/ customer specific/ high value
High energy cell / safe system	High performance cell / lightweight system / intrinsically safe system

Structure of a Li-ion cell





Negative particle

Positive particle

Supporting materials
Al foil
Cu foil
Polymer separator

Popular Anode Materials
Carbon
Si and SiOx
LTO ($Li_4Ti_5O_{12}$)

Popular Cathode Materials
LCO ($LiCoO_2$)
NCA ($LiNiCoAlO_2$)
NMC ($LiNiMnCoO_2$)
LFP ($LiFePO_4$)

How to get more energy for more-electric & all-electric aircraft

Positive active materials:
Drive for more energy through nickel-rich cathodes

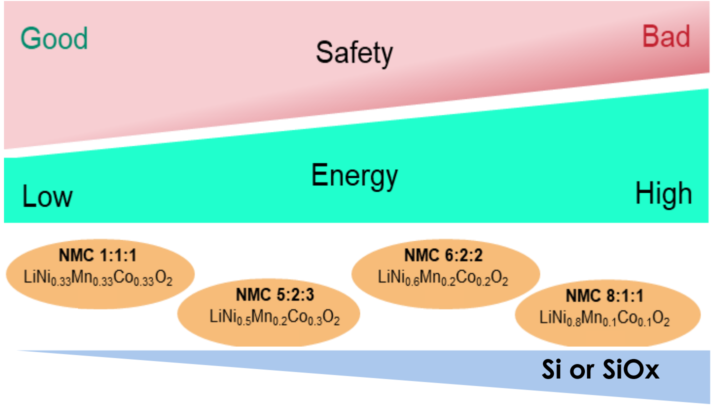
NMC
Nickel Manganese Cobalt
($LiNiMnCoO_2$)

More Nickel means energy

More Manganese means safety

More Cobalt means conductivity

Example: Impact of Choice of Materials



Supporting materials:
Al and Cu current collector foils, polymer separator

Thin foils and separator for more energy

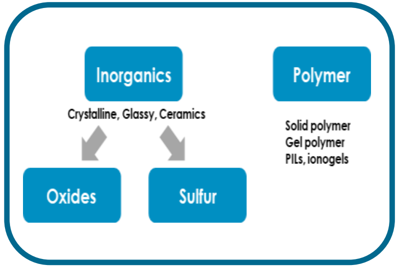
Negative active materials:
Drive for more energy by adding Silicon & Silicon Oxide to carbon

More Silicon means energy

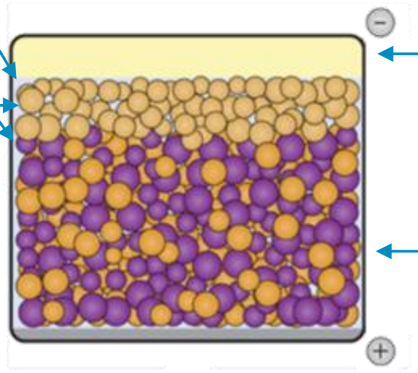
Solid State Battery - a disruptive technology for Aviation

Solid State battery technology will bring better performance, lower cost and intrinsic safety

very thin Li foil ~20µm
& SSE layer ~25µm



SS Electrolyte



Li metal

Cathode with
SS Electrolyte

Dramatic increase in specific energy & power
3800 mAh/gram vs.
372 mAh/gram for Carbon

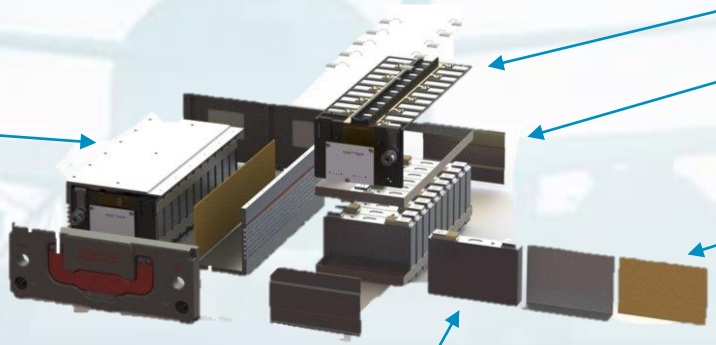
- High Nickel NMC
- Low porosity cathode

Challenges: good Li+ conductivity at room and even low temp

Additional materials' challenges in Solid State

Cell and Battery? Both are critical for Aviation

- A lightweight and mechanically strong battery case and battery components using the right materials is vital for meeting **weight and safety objectives**



Conclusion

- Designing the right battery for next generation of Aviation requires major progress in key materials
- Cell designers & battery manufacturers work hand-in-hand with material developers to create the optimized solution
- European ecosystem is ready to deliver the Aviation battery of tomorrow

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THANK YOU!