MOBILITY INDUSTRY INSIDER

Q1 2020 | Pulse

Battery Energy Storage

FutureBridge

WHAT'S INSIDE!

The first quarter of 2020 saw the immense activity of research institutes into battery materials namely anode, cathode and electrolytes. The research saw the development of novel anode, cathodes and electrolytes resulting in an overall increase in battery performance.

We also observed a strong battery push by Europe in a bid to emerge as battery production and development hub so that reliance on Asian battery suppliers is reduced and demand of batteries is met.

In Q1'20, captured startups majorly focussed on battery recycling. We have also provided a global funding report for period of Jan'19 to Q2'20

We have also highlighted the impact of COVID-19 on the electrified mobility as whole globe is under lockdown.

FutureBridge

Covid-19's impact on Electrified mobility – Herein, we have compiled the impact of COVID-19 on the electrified mobility with respect to various divisions. Battery manufacturers however didn't report any negative impact so far. In fact, EV battery production in South Korea and Japan continues amid COVID-19 outbreak.

Equipment assistance

BYD	World's largest face mask manufacturing plant >>
Ford	Ventilators for COVID-19 patients >>
GM	30,000 Ventilators For U.S. Government >>
Tesla	Ventilators made from Model-3 components >>

Production halt/delay

Toyota	24 Mar	Halt production at 7 plants in Japan >>
Volkswagen	16 Mar	Suspend production at Bratislava plant >>
Tesla	20 Mar	Suspends production at U.S. vehicle factory >>
Volvo	21 Mar	Production halt at Europe, US plants >>
GM	01 April	2021 Bolt delayed >>
Daimler	18 Mar	Halts majority of its production in Europe >>
Tata Motors	22 Mar	Complete closure of plant in Pune, India >>
Rivian	21 Mar	Shuts down all facilities >>

No impact

Volvo	25 Mar	Begins production of the all-electric Polestar 2 in China >>
BMW, Mercedes-Benz	13 Mar	Expect seamless production amid Covid-19 impact >>

China's major Li-ion manufacturing players, CATL and BYD, are faced with a high probability of production delays. China's attempt to fight with the coronavirus outbreak has led to delayed production across a number of battery production facilities located in key coronavirus hit provinces. China's March car sales were down over 40%.

01 Emerging trends

Research in battery materials showed increased focus in Q1'20

CONTEXT

As the electrification of mobility has been gaining pace year after year, the efficiency of batteries to deliver maximum output is the area that is being under rigorous research. Extensive research is being carried out by researchers across the globe to come up with new, innovative and more efficient battery materials such as electrolyte, cathode and anode.

Batteries have experienced fast-growing interests driven by new demands for covering a wide spectrum of application fields. The update of batteries heavily relies on materials innovation where the involvement of governments, research entities, and manufacturers will accelerate the course.

The foray of researchers into battery materials can lead to the production of efficient, more lasting, stable and highly safe batteries for ~~the~~ future mobility.

Developments

- Researchers from Japan's National Institute of Materials Science (NIMS) have discovered a simpler way to fabricate silicon anodes for solid-state lithium batteries for use in EVs. They used spray deposition, a cost-effective, atmospheric fabrication mode to create a silicon anode for solid-state batteries that showed ***performance*** previously seen only in film electrodes developed by evaporation processes. (Read the paper here)
- Researchers at Rice University have combined a macroporous silicon anode and alumina-coated NMC cathode to provide stable cyclability using capacity-limited charging. The Si-NMC full-cell design with alumina passivation on cathode has exhibited a stable capacity of 1000 mAh/g, with 1.2 times ***higher energy density*** than the Si-NMC full-cell without cathode passivation. (Read the paper here)
- Researchers at Ulsan National Institute of Science and Technology (UNIST) have developed an ion concentrate electrolyte using a solvent containing fluorine atoms. The electrolyte evenly formed a protective film on the negative electrode and the positive electrode of the lithium metal battery, ***increasing the lifespan*** and ***output*** of the entire battery. (Read the paper here)
- Researchers at MIT have developed a new electrode design that could lead to batteries that can pack more power per pound and last longer, based on the long-sought goal of using pure lithium metal as one of the battery's two electrodes, the anode. The researchers developed a three-dimensional nanoarchitecture in the form of a honeycomb-like array of hexagonal MIEC tubes, partially infused with the solid lithium metal to form one electrode of the battery, but with extra space left inside each tube. (Read the paper here)

DEVELOPMENTS Emerging trend

Researchers of the Korea Institute of Science and Technology have developed silicon anode materials that can increase battery capacity **four-fold** in comparison to graphite anode materials and enable rapid charging to more than **80%** capacity in only **five minutes**. This kind of material research not only improves the battery but also helps in the broader goal of mass adoption of EVs.

Many Government Initiatives are being undertaken or are already in a process which focuses on research into advanced battery materials. The European Union's Advanced Materials for Batteries Partnership (AMBP) aims to develop joint R&D projects on topics of advanced materials, their characterization, durability, suitable for extreme working conditions. USA's Joint Center for Energy Storage Research (JCESR) is also focused on a similar aim.

FutureBridge Insight & What should you investigate ?

MOBILITY INDUSTRY INSIDER

FutureBridge on battery material research

- The Government bodies as well research institutes are funding various projects aimed at research into battery materials for improving the battery technologies. US DOE announced ~~a~~ funding of up to $44 million for research in lithium-ion batteries using silicon anodes. Faraday institute awarded a total of £55 million for cathode research out of which £11.2 million was awarded to the University of Bath to explore and develop new materials for next-generation lithium batteries that can be used for electric vehicles under the project name – CATMAT. Some more projects focusing on battery materials are Nextrode (University of Oxford) and FutureCat (University of Sheffield).
- To meet the demands in electric vehicles and stationary energy storage, it is necessary to prepare advanced lithium-ion batteries (LIBs) with high energy density and fast charge and discharge capabilities. Cathode materials, which account for 40%–50% of the cost of a whole battery, play a decisive role in cell voltage and capacity. Thus rational design and preparation of cathode, as well as anode materials with controllable microstructures, is very critical for achieving desired results.
- Electrolyte modifications should also be one of the prime objectives of research institutes as it determines various critical parameters such as transference number and conductivity of ions which ultimately determine the efficiency of the battery. One such example is Argonne National Laboratory's Advanced Electrolyte Research division which seeks to develop new functional organic materials as electrolytes, electrolyte additives, electro active catholyte, and anolytes and polymer binders to address key issues associated with a variety of energy storage chemistries including lithium-ion, lithium-sulfur, lithium-air, magnesium-ion, sodium-ion, and non-aqueous/aqueous organic redox flow batteries.

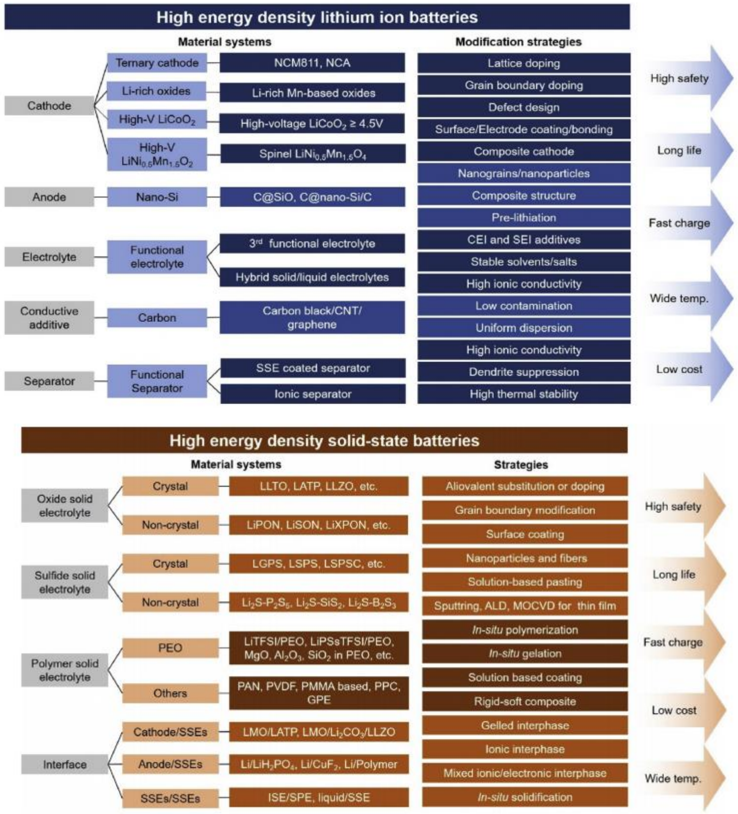
What should you investigate ?

What are the challenges that limit the practical application of the newly developed battery materials?

What is the feasibility of these materials for integration in current chemistries? What is the timeframe for their commercialization?

Current effective strategies for high-energy density Li-ion batteries

Source: Research Paper



These strategies are with respect to battery material modifications

Current effective strategies for high-energy density solid-state batteries

FutureBridge

Europe launching battery projects to accelerate the European Energy Transition

CONTEXT

To cut the reliance on the Asian battery suppliers, Europe has been launching various projects aimed at addressing the issues which are very critical in setting up an efficient European battery ecosystem.

Europe is launching various battery projects which cover numerous aspects related to setting up an efficient and durable battery ecosystem. These projects are aimed at setting up pilot lines for mass production of batteries, developing alternate battery chemistries with more power density compared to traditional lithium-ion batteries, researching into the areas such as battery design, flexibility etc..

The European Union is starting to act like China when it comes to building the batteries that will drive the next generation of electric vehicles.

Developments

- Germany's ***AgiloBat*** project seeks flexible battery production in terms of format, material and quantities. Researchers from the Karlsruhe Institute of Technology (KIT) with some other partners (ZSW and ICT) are developing an agile production system for batteries. The focus is on a holistically optimized cell in terms of resources, costs and performance so that the battery system adapts to the respective application and the available space.
- The European project ***NAIMA*** aims to develop a new generation of high-competitive and safe Na-ion cells for the current and future energy storage technologies. The NAIMA project will demonstrate that two new generations of highly-competitive and safe Na-ion cells developed and tested during the project are some of the most robust and cost-effective alternatives to substitute current and future Li-based technologies in dedicated storage applications.
- The ***LiPLANET*** project lays the foundation of the European network of research pilot lines for the production of battery cells. LiPLANET aims to build a more competitive Li-ion battery cell manufacturing ecosystem and increase the production of Li-ion cells towards industrial scale, by bringing together the most relevant European Li-ion cell pilot lines.
- Germany's ***ZellkoBatt*** project has the goal of optimizing large-format lithium-ion cells for automotive applications while reducing the costs of components and production processes. The project will be undertaken by the Centre for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW). The project also aims to establish manufacturing capacity in Germany to meet the growing demand for batteries.

DEVELOPMENTS Emerging trend

- Not all the projects are dedicated ~~for~~ manufacturing and improving batteries but efforts are also being done to optimize the dismantling of EV batteries which will be an important element of a resource-efficient and sustainable circular economy for electromobility. One such project is Germany's DeMoBat project.
- The European Energy Transition is not only being achieved through collaborative battery projects but by OEM partnerships as well. Total-PSA JV aims to produce EV batteries in Europe under a €5 billion program. Volkswagen-Northvolt JV aims to build a factory for lithium-ion batteries.

FutureBridge Insight & What should you investigate ?

Battery Energy Storage | Q1 2020 Pulse

FutureBridge on Europe launching battery projects to accelerate the European Energy Transition

- To realize the goal of making Europe a battery hub and compete with China, funding will play an enormous role. To ensure that Europe stays on the roadmap of becoming a battery hub, the European Commission has approved a €3.2 billion in funding for a pan-European research and innovation project in all segments of the battery value chain. The project participants will focus on core areas such as raw and advanced materials, cells and modules, battery systems and repurposing, recycling and refining to build a strong and efficient battery ecosystem.

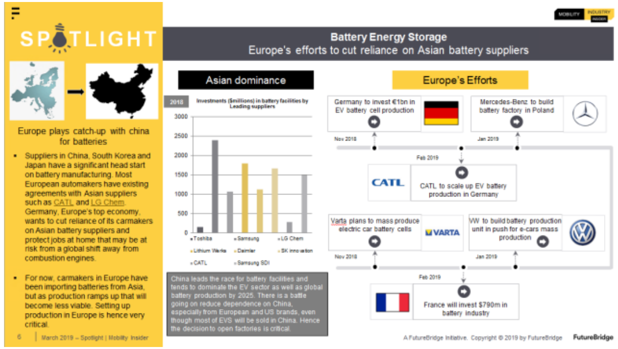
- Efforts from Governments will also be crucial to keep these projects up and running. Continuous investments in the projects will be needed to sustain the economical pressure associated with establishing a durable battery value chain. France and Germany invested €700 M and €1Bn respectively into projects to boost their capability and enable them to reach broader goals.

- Forming consortiums such as the European Battery Alliance (EBA) will prove pivotal in shaping the future of the European battery industry. The launch of Battery 2030+ by EBA will put Europe at the forefront of the race to develop the battery technologies of the future. The aim of Battery 2030+ is to develop ultra-performing, safe and sustainable batteries – which will be essential for electric vehicles and clean mobility, renewable energy storage, and a range of emerging applications (including robotics, medical devices, aerospace and many more).

What should you investigate ?

What are the costs and benefits of the European energy transition?

What is the timeframe ~~of~~ for these battery projects? How long will it take for Europe to establish itself as a major battery hub? Is Europe catching up with China?



Read about Europe's efforts to cut reliance on Asian suppliers in our March 2019 spotlight

BATTERY 2030+ Roadmap

Research areas	Short term (3 years)	Medium term (6 years)	Long term (10 years)
BIG-MAP	Put in place a pan-European interoperable data infrastructure and user interface for battery materials and interfaces. Establishing integrated experimental and computational workflows. Demonstrating BIG-based hybrid physics- and data-driven models of battery materials. Deploy autonomous modules and apps for on-the-fly analysis of data characterisation and testing using AI and simulations. Developing multi-modal high-throughput/high-fidelity interface characterisation approaches.	Fully implementing BIG in MAP to integrate computational modelling, materials autonomous synthesis, and characterisation. Integrate data from embedded sensors into the discovery and prediction process. Develop and apply predictive hybrid models for the spatio–temporal evolution of battery interfaces/interphases to perform inverse materials design. Demonstrating transferability of the BIG-MAP approach to novel battery chemistries and interfaces. Integrating novel experimental and computational techniques targeting the time and length scales of electron localization, mobility, and transfer reactions.	Demonstrate the integration of manufacturability and recyclability parameters into the materials discovery process. Integrate battery cell assembly and device-level testing into BIG-MAP. Implement and validate digital twin for ultra-high-throughput testing on the cell level. Establish and demonstrate full autonomy and chemistry neutrality in the BIG-MAP. Demonstrate a 5–10-fold improvement in the materials discovery cycle and interface performance.
Sensing	Apply non-invasive multi-sensing approaches transparent to the battery chemical environment offering spatial and time resolution. Integrating sensors into existing battery components (e.g., separator, current collector, and electrode composite). Deploy sensors able to detect various relevant phenomena (e.g., interface dynamics, electrolyte degradation, dendritic growth, metals dissolution, and materials structure change).	Miniaturise and integrate the identified (electro)chemically stable sensing technologies with multifunctions at the cell level and in real battery modules, in a cost-effective way compatible with industrial manufacturing processes. Deliver proof of concept of higher quality, reliability, and lifetime on the cell and module levels.	Master sensor communication with an advanced BMS relying on new AI protocols by wireless means to achieve a fully operational smart battery pack.
Self-healing	Establising a new research community that includes a wide range of R&D disciplines to develop self-healing functionalities for batteries. Developing autonomous and non-autonomous (on demand) self-healing functionalities for specific battery chemistries, targeting loss of capacity and loss of power.	Integrating self-healing functionalities into battery components (e.g., separator or electrode composite). Electrochemically stable non-autonomous self-healing functionalities triggered via an external stimulus obtained from an advanced BMS.	Established efficient feedback loops between cell sensing, BMS, and/or AI modules to appropriately trigger, by external stimulus, the self-healing functions already implanted in the cell. Designing and manufacturing low-cost biosourced and/or biomimetic membranes with controlled functionalities and structure as autonomous self-healing functionalities.
Manufacturability	Improving simulation tools, such as multiphysics models for reducing the computational burden of the manufacturing process. Demonstrating the implementation of current AI technologies through deep learning and machine learning methods for cell design (for Li-ion chemistries). Implementation of the AI-driven methodology for manufacturing (Li-ion chemistries) – including digitalisation. Improving and scaling-up of new manufacturing processes (3D printing, dry processing).	Proof of concept of a digital-twin of a cell design (based on Li-ion chemistries). Proof of concept of a digital twin of a cell manufacturing process (based on Li-ion chemistries). Input from BIG, MAP, sensing, self-healing, recycling and other innovation areas integrated into the design and manufacturing process. Digital twin methodology adapted to the manufacturability of new battery technologies and innovative new manufacturing processes.	An AI-driven methodology established for manufacturing, by integrating cell design sub loops that converge in a fully autonomous prototype system nourishing from BIG-MAP. The new concept is deployed to the industry and academia. This methodology, which will help found a new commoditised state of the art, will be progressively deployed in industry and academia.
Recyclability	Integrated design for sustainability and dismantling. Demonstration of new technologies for battery packs/modules sorting and re-use/re-purposing. Establising a European system for data collection and analysis. Demonstration of new technologies for battery packs/modules sorting and re-use/re-purposing. Developing automated disassembly of battery cells.	Demonstrating automated cell disassembly into individual components. Sorting and recovery technologies for powders and components and their reconditioning to new active battery-grade materials demonstrated. Significantly improve, relative to current processes, the recovery rate of critical raw materials Testing of recovered materials in battery applications. Develop prediction and modelling tools for the reuse of materials in secondary applications	A full system for direct recycling is developed and qualified.

Source: EBA

Major developments during Q1’20 – Q1'20 saw large number of partnerships aiming at producing batteries of various types. There was also high amount of funding activity in both research and production

Investments/Funding

- NAWA Technologies: Raises € 13M and moves to mass production >>
- Ford: €42 million in Valencia for new hybrid models and battery assembly operations >>
- Department of Energy, United States of America: Awards up to $40M for batteries and electrification >>
- Department of Energy, United States of America: Awards up to $65.9M for batteries towards lowering the cost of battery energy storage through manufacturing innovation >>

Partnerships

- Fortum, BASF → Nornickel
- Tesla: Cobalt-free batteries for Chinese-made cars >> → CATL
- Hydro Québec: Development of solid-state battery >> → Mercedes-Benz
- IndianOil: Manufacture of metal-air batteries >> → Phinergy
- Total: Produce EV batteries in Europe >> → PSA Groupe
- Panasonic: Build prismatic batteries for EVs >> → Toyota

Research activities

- The Hong Kong University of Science and Technology: High-capacity, long-life Li-S battery >>
- Rice: Alumina-passivated cathode to improve stable cyclability of Si-NMC battery >>
- UCL: Fast-charging, long-running and flexible supercapitor >>
- PennState: Safe, high power and 1 million mile battery >>
- UC San Diego Jacobs School of Engineering: Draining safety feature for Li-metal batteries >>
- UNIST (Ulsan National Institute of Science and Technology): New catalyst that boosts metal-air battery performance >>

Launches

- Renault: Twingo Z.E. revealed with 250 Kms of city range owing to lithium ion battery >>
- Tata: Lithium-ion battery-powered Nexon >>

02 Quarterly review of early-stage research

Enabling fast charging of high energy density Li-ion cells with high lithium ion transport electrolytes (1/6)

(May 2019, **Zhijia Du, David L.WoodIII and Ilias Belharouak,** Oak Ridge National Laboratory)

Background

- Energy density, cost and safety are, more than ever, the most significant barriers to overcome in order to increase the wide acceptance of Li-ion batteries in electric vehicles.
- The U.S. Department of Energy (DOE) has set ultimate goals for battery electric vehicles (BEVs), which include reducing the production cost of the battery pack to $150/kWh, increasing the electrical range of the battery to 300 miles, and decreasing the charging time to 15 min or less.
- Fast charging is very necessary as it will address the range anxiety concern of customers and help towards achieving the aim of mass adoption of EVs.
- Some major issues in battery extreme fast charging (XFC) is the plating of lithium metal over graphite anodes due to sluggish kinetics and degradation of battery life.

Aim of the study

- The present aim of the research is the evaluation of salt, ***lithium bis(fluorosulfonyl)amide*** (LiFSI) , as a potential alternative candidate for the salt, lithium hexafluorophosphate (LiPF6), in cells designed for fast charging.

How to enable fast charging from electrolyte point of view?

- Enhancement of Li-ions mass transport in electrolytes such that enough li-ions are available for intercalation in graphite.
- The mass transport of li-ions can be evaluated by two characteristic values:
  - Li-ion conductivity (Total flux of charge carriers)
  - Li-ion transference number (Fraction of total current carried by Li-ions)

FutureBridge Analysis

Relevance to Client	Disruptiveness	Feasibility	Timeframe / Maturity	Rank
High	High	High	Immediate	1

Note: The paper was chosen from top 50 papers

Refer Appendix for details

Enabling fast charging of high energy density Li-ion cells with high lithium ion transport electrolytes (2/6)

(May 2019, **Zhijia Du, David L.WoodIII and Ilias Belharouak,** Oak Ridge National Laboratory)

Significance: **Moderate**

Experiment details

ELECTROLYTE

- The electrolytes were made of 1.5 M lithium salts dissolved in a combination of ethylene carbonate (EC) and ethyl methyl carbonate (EMC) (30:70 wt%).
- The lithium salts were ***LiPF6*** and ***LiFSI***.

ANODE COMPOSITION

- The negative electrode composition was 92 wt% graphite, 2 wt% carbon black and 6 wt% polyvinylidene fluoride (PVDF).
- The areal loading was 8.0 mg/cm^2 (2.6 mAh/cm^2) after calendaring to 30% porosity

CATHODE COMPOSITION

- The positive electrode composition was 90 wt% NMC811, 5 wt% carbon black and 5 wt% polyvinylidene fluoride (PVDF).
- The areal loading of the electrode was 14.1 mg/cm^2 (2.35 mAh/ cm^2) after calendaring to 30% porosity.

CELL STATE

$LiNi_{0.8}Mn_{0.1}Co_{0.1}O_2$ (NMC811) and graphite electrodes were fabricated at the US. Department of Energy (DOE) Battery Manufacturing R& D Facility (BMF) at Oak Ridge National Laboratory

Enabling fast charging of high energy density Li-ion cells with high lithium ion transport electrolytes (3/6)

(May 2019, **Zhijia Du, David L.WoodIII and Ilias Belharouak,** Oak Ridge National Laboratory)

Significance: **Very high**

Results

Conductivity

Analysis of the effect on conductivity of electrolytes, measured at 20, 30 and 40 °C, as a function of LiPF6 or LiFSI concentrations in the solvent system (EC:EMC) (30:70 wt%)

Li-ion transference number

Analysis of lithium-ion transference number in the two salts under experiment

Faster charging capability

Analysis of fast charging capability of the cell under 1C, 2C, 3C and 5C comprising $LiNi_{0.8}Mn_{0.1}Co_{0.1}O_2$ (NMC811) as the cathode and graphite as the anode and in the presence of the LiFSI and LiPF6 based electrolytes

Capacity retention

Analysis of corresponding discharge voltage curves at the C/2 rate for the cells charged under 1C, 2C, 3C and 5C rate

Cyclic performance

Analysis of cycling performance of under 12-minute fast charging through 500 cycles.

Physical results

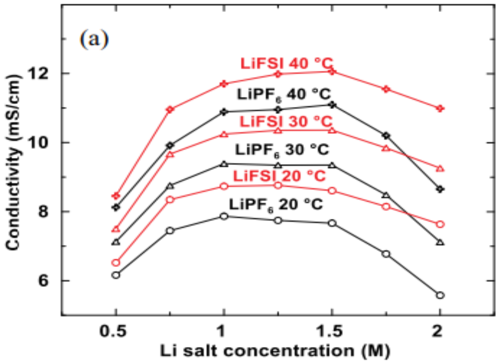
Analysis of the aftereffects in the cell after 500 cycles by opening inside an Ar-filled glove box after discharging to 2.0 V for observation

High priority | Medium priority

Enabling fast charging of high energy density Li-ion cells with high lithium ion transport electrolytes (4/6)

(May 2019, **Zhijia Du, David L.WoodIII and Ilias Belharouak,** Oak Ridge National Laboratory)

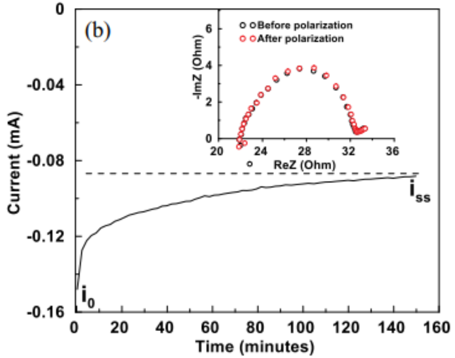
Analysis of Conductivity



- With increase in concentration of the lithium salts from 0.5M to 1M, the conductivity increased due to increased number of dissociations ions in electrolyte solutions.
- With further increase in salt concentration, the cationic and anionic species pair and hence do not contribute to conductivity.
- With increase in temperature, maximal conductivity values shifted from 1M at 20°C to 1.5M at 40°C owing to higher thermal agitation that increases dissociation of ion pairs.
- Conductivity drop for LiFSI from 1.5M to 2.0M concentration was less severe than for LiPF6 which is due to the ease of electrolyte depletion issue when fast charging and discharging is applied to Li-ion cells.

✓ ***LiFSI shows higher conductivity than LiPF6 under same concentration and temperature***

Analysis of Li-ion transference number (t_+)



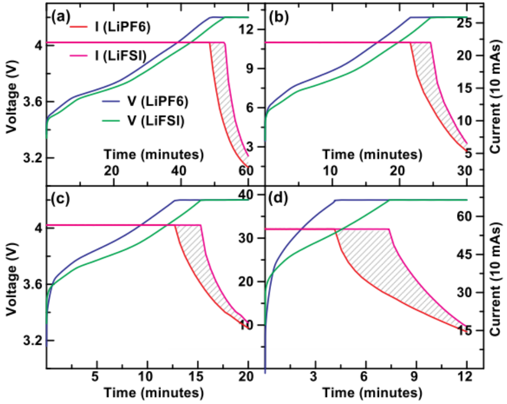
- The electrolyte with LiPF6 salt has a t_+ of **0.382** and t_+ of LiFSI based electrolyte is **0.495**.
- LiFSI more t_+ is due to ***higher dissociation*** of LiFSI salt in electrolyte and ***larger size*** of the FSI$^-$ anion.
- Higher dissociation indicates that Li-ions can move more freely due to less attractive forces by anions.
- Larger size of FSI- (95A°^{3})compared to PF6- (69A°^{3}) suggests slower movement of FSI- and as s result li-ions are able to move faster in presence of FSI- ions.

✓ ***LiFSI shows higher conductivity than LiPF6 under same concentration and temperature***

Enabling fast charging of high energy density Li-ion cells with high lithium ion transport electrolytes (5/6)

(May 2019, **Zhijia Du, David L.WoodIII and Ilias Belharouak,** Oak Ridge National Laboratory)

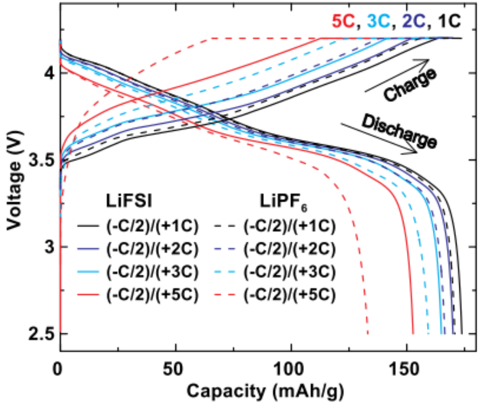
Analysis of faster charging capability



- Under 1C rate, cell voltage reached the cut-off voltage (4.2V) at constant current (CC) charging at around 49.5 min for LiPF6 and 53.1 min for LiFSI.
- Under 2C and 3C rate, cells with LiPF6 electrolyte attained the cut-off voltage ***earlier*** than the ones with LiFSI electrolyte.
- Under 5C rate, the gap widened further. In this case, cell with LiPF6 electrolyte had only 4.2min under CC charge while the one with LiFSI electrolyte had 7.4 min under the CC charge.

✓ ***The large gap in the cut-off voltage indicates that more capacity can be stored when the cell has longer CC charging time under intended C-rate***

Analysis of capacity retention



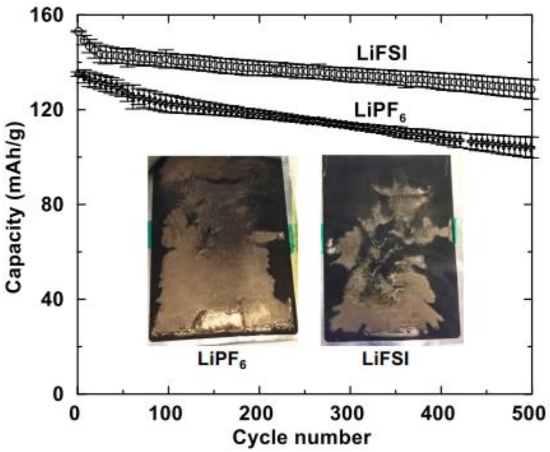
- When the cells are charged at 1hr, they delivered 173.8 and 170.8 mAh/g capacity in presence of LiFSI and LIPF6 electrolyte respectively.
- When charged at 5C and time shortened to 12min, the cells with LiFSI electrolyte had capacity retention of 153.2 mAh/g which is 13% improvement over the LiPF6 electrolyte (135.4 mAh/g).

✓ ***LiFSI shows higher capacity retention compared to LIPF6 with decrease in values when charging rate is increased***

Enabling fast charging of high energy density Li-ion cells with high lithium ion transport electrolytes (6/6)

(May 2019, **Zhijia Du, David L.WoodIII and Ilias Belharouak,** Oak Ridge National Laboratory)

Analysis of cyclic performance



- Cells with LiFSI electrolyte exhibited minimal capacity fading over the 500 cycles with 134.3 mAh/g capacity (84% retention).
- Cells with LiPF6 electrolyte showed rapid capacity fading during first 100 cycles and then decreased steadily on further cycling. The cells only had 110.6 mAh/g capacity retention (77% retention).

Physical results

- Both cells showed Li-plating after repeated fast charging cycles.
- The Li-plating area on the graphite electrode for LiPF6 cell was much smaller than LiPF6 cell which is attributed to better Li-ion transport properties of LiFSI based electrolyte compared to the LiPF6.
- No corrosion can of cathode Al current collector was observed after 500 cycles for LiFSI cell as there was minimal (1ppm) in LiFSI and hence eliminated any corrosion.

Conclusion

LiFSI is a better Li salt for faster-charging Li-ion cells compared to **$LiPF_6$** due to high conductivity, high ion transference number, and good electrochemical performance

03 Startups Tracker highlights in Q1'20

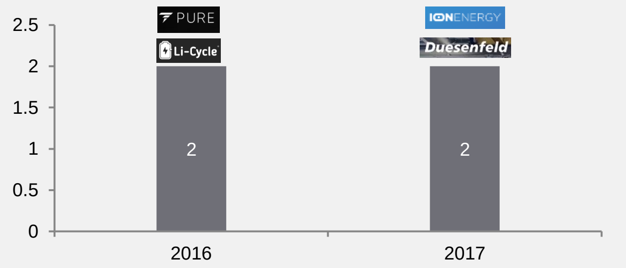
Startup Tracker summary: For more information access our Startup Tracker

Of the 171 startups we monitor, 51% are working on Metal-ion battery. USA leads as the major startup hub followed by Germany and China

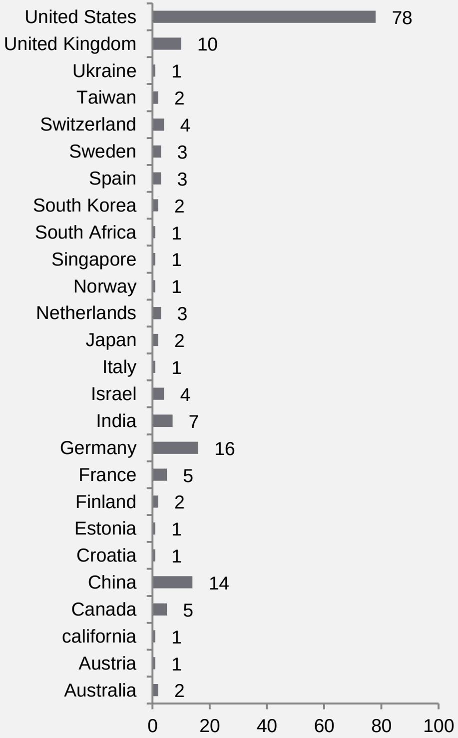
Four new startups added in Q1’20

IONENERGY	Battery Management Systems
PURE	Lithium-Ion battery
Li-Cycle	Li-ion battery recycling
Duesenfeld	Li-ion battery recycling

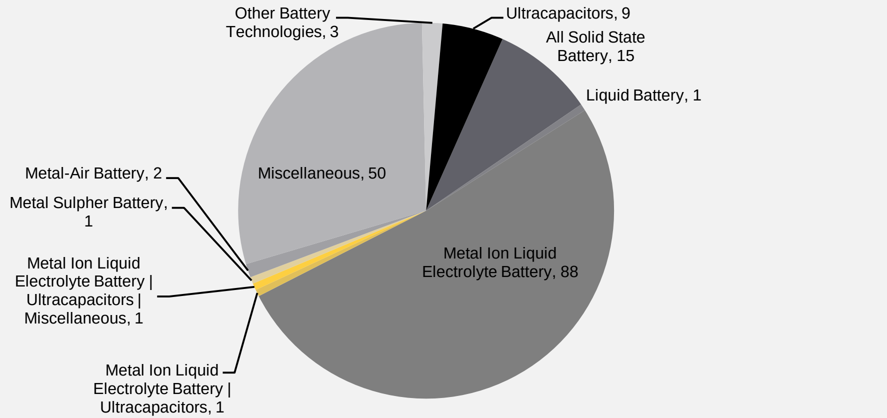
Founding year of new startups added



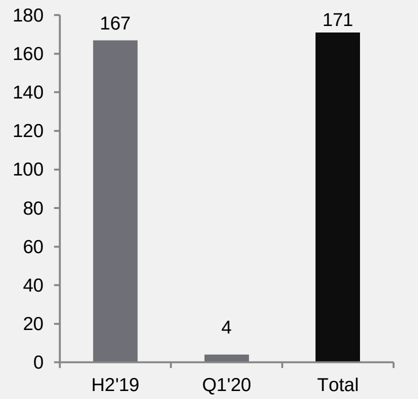
Startups by geography



Startups by technology



Number of Startups Tracked



FutureBridge

What are the hubs of startup innovation for Battery Energy Storage

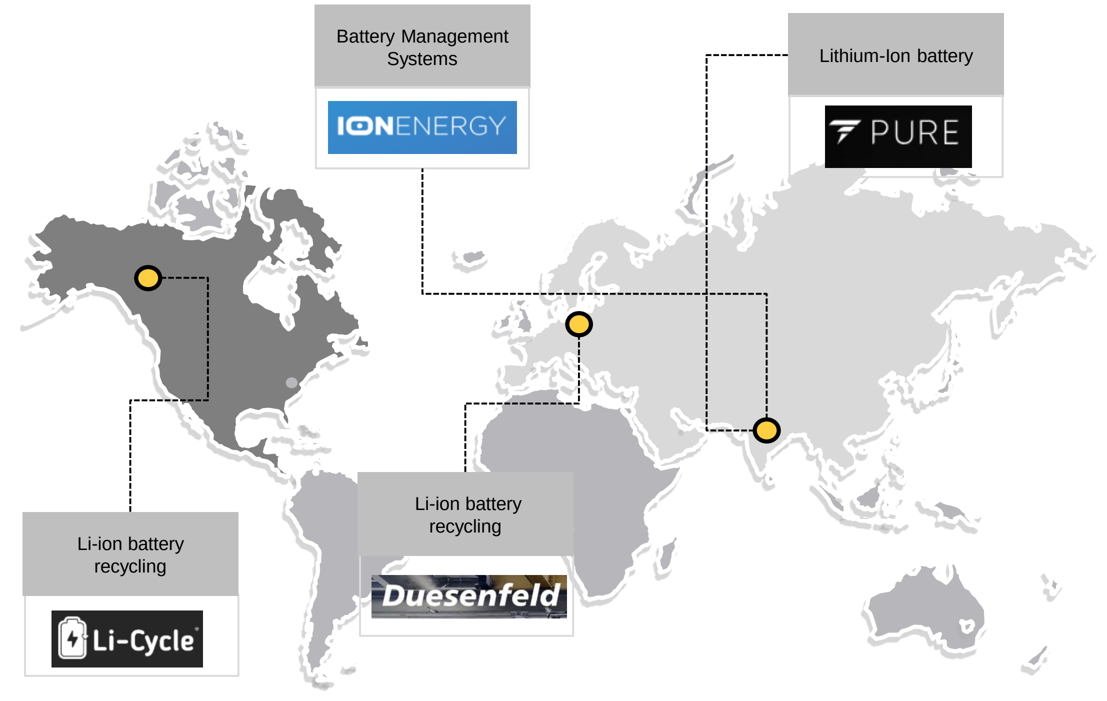
Q1'20 witnessed an increased activity of startups on Lithium-ion battery recycling as it forms a critical parameter in the battery energy storage value pool.

- Out of the **4** new startups we have included in our Tracker in **Q1 2020**, 50% focus on lithium-ion battery recycling and 25% each focus on Battery management Systems and manufacturing lithium-ion battery respectively.

- The reason for increased activity of startups for lithium-ion battery recycling can be attributed to the fact that their limited availability of scarce materials used in batteries such as Lithium, Cobalt and Nickel and hence it becomes necessary to put a major focus on recycling of batteries. Li-Cycle has proven its efforts by delivering the first commercial shipment of recycled materials.

- The startups covered are hailing from India, Canada and Germany. Out of 4 new startups, 2 are from India which shows the commitment of India towards a sustainable future.

Key startups from major hubs in automotive Battery Energy Storage



Key Player in Battery Energy Storage – Enevate (Silicon dominant Li-ion battery) ENEVATE

Official website: https://www.enevate.com/

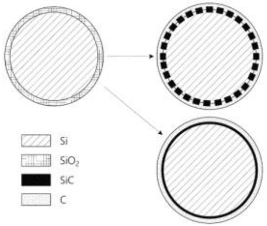
Link to the Mobility Insider platform for Enevate's profile:
https://industryinsider.futurebridge.com/company/details/5db6bda4857ad8a94a737977

PATENTS

US10541412B2

Surface modification of silicon particles for electrochemical storage

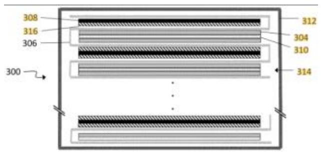
Patent relates to composite materials that include silicon and carbon. Silicon particles for active materials and electro-chemical cells are provided.



US20200014068A1

Electrolyte compositions for batteries

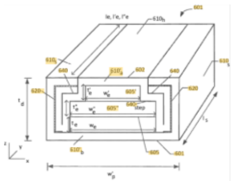
Patent relates to electrolytes and composite materials including silicon particles for use in battery electrodes.



EP3433890B1

Stepped electrochemical cells with folded sealed portion

Patent relates to stepped electrochemical cells and packages to house electrochemical cell components.



TECHNOLOGY

Extreme fast charging technology :

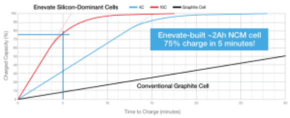
- Enevate batteries are uniquely engineered for incredibly fast charging, as convenient as fueling a gas car. Li-ion cells with Enevate's HD-Energy technology can complete a charge in just 5 minutes..

Enevate technology is built on a three-pillar foundation:

- Pure silicon anode
- Electrolyte
- Cell design.

Enevate's anode active materials use significantly more than 70% pure elemental silicon. Its anodes have more capacity than Li-ion cells found in today's electric vehicles (EVs). Enevate's silicon-dominant anode material has about 3,000 mAh/g available specific capacity. This is almost an order of magnitude higher than a conventional graphite cell used in today's EVs.

- **Advantages:**
- Improved safety
- Low temperature
- Lower cost
- High energy density



ACTIVITIES

Investment/Acquisition/Funding

- Funding
  - Sep, 2018 | $21.5M / Funding | Alliance Venture and Bangchak
  - Aug, 2018 | $6M / Series D | LG Chem
  - Mar, 2017 | $13.8 / Series C
  - Apr, 2019 | - / Corporate Round | Bangchak

Collaboration/Partnership

No collaborations reported

Competitors

SILA NANOTECHNOLOGIES, FARASIS, nexeon

News

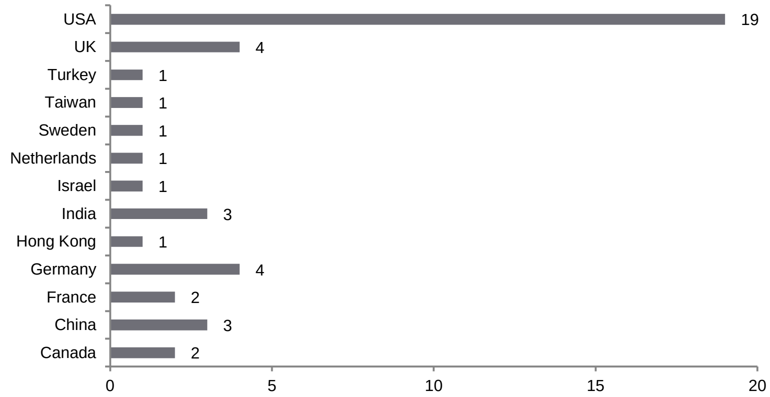
- Jan 14, 2020 | Enevate commercializing new low cost battery technology providing extreme fast charging and long range for electric vehicles
- Feb 18, 2020 | Enevate battery technology advances next generation power cells for the power tool market

Global funding report: Q1’19 – Q2’20 (1/2)

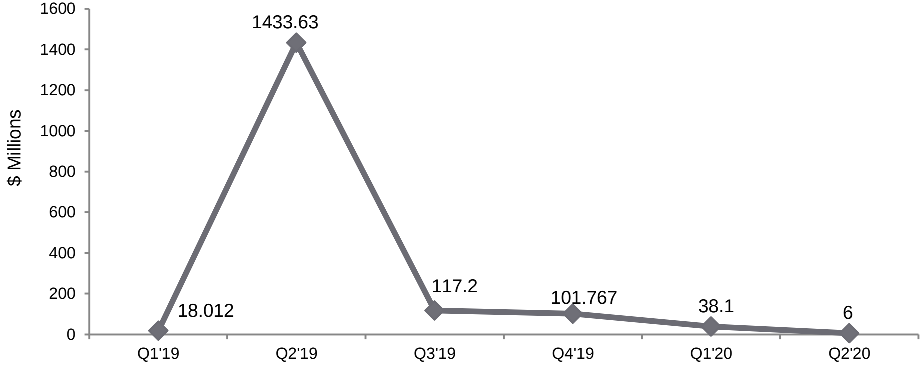
Refer Appendix for details

In total, 43 startups globally received funding with respect to batteries and here we present detailed analysis of the funding report.

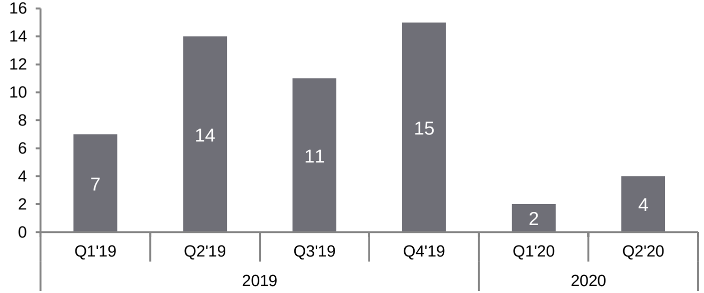
Startups by country



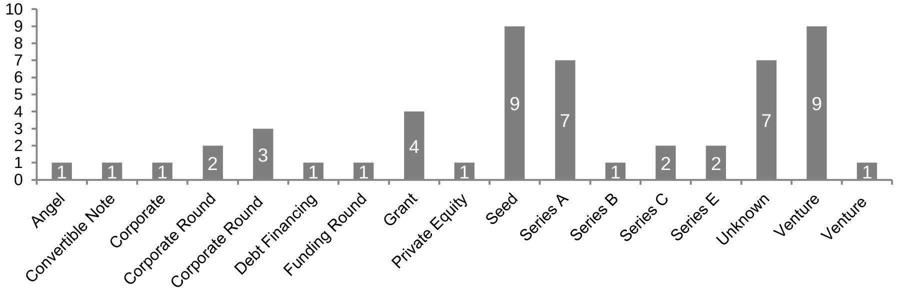
Amount of funding as per quarter



Quarter-wise startup number



Transactions through type



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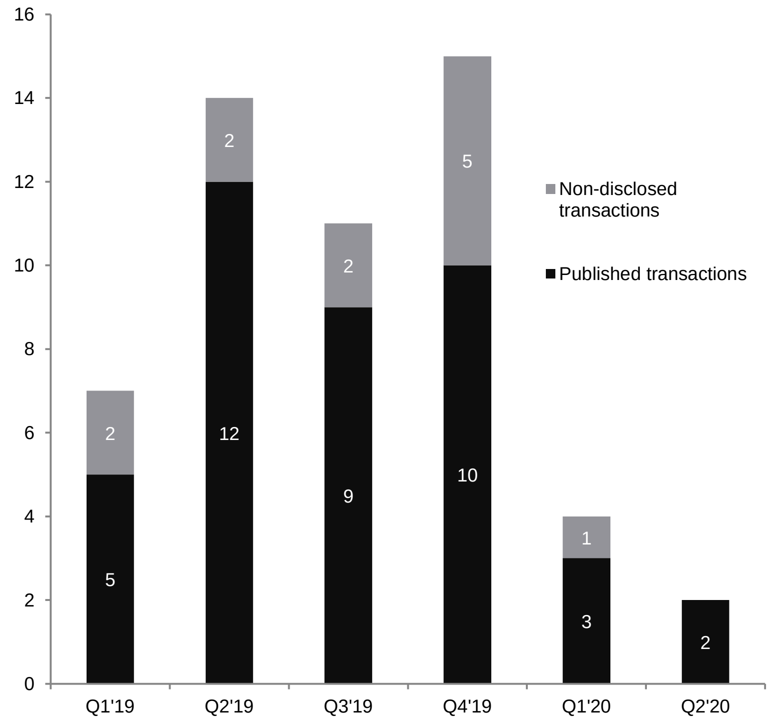
Global funding report: Q1'19 – Q2'20 (2/2)

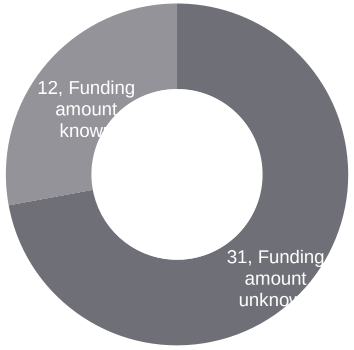
Refer Appendix for details

In total, 43 startups globally received funding with respect to batteries and here we present detailed analysis of the funding report.

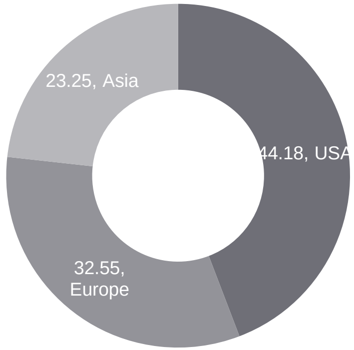
Funding status of startups as per Quarter



Total known and Unknown transactions



Top 3 continents share (%) of startups



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Global funding report: Key insights

Things to know

Overall estimated funding
$ 1.714 billion in batteries

Sweden leads in the investments due to major deal in **NorthVolt** (~$1.1 billion) by European Investment bank (EIB), Siemens AG, BMW, Volkswagen Group, Goldman Sachs, IKEA

The **USA** ended runner-up with an overall investment of ~$472 million due to major deals in **Sila Nanotechnologies, Romeo Power** and **Motiv Power Systems**

China ended behind the USA owing to major deal in **Phylion Battery** (~$136.8 million)

Nawa Technology is the startup to keep an eye on as they recently closed $14 M in funding. Are ultracapacitors on their way to mass production?

Global Top 3

northvolt

- **$1.1 Bln**
- **Corporate and venture round**
- **European Investment ban, BMW, Volkswagen Group**

SILA NANOTECHNOLOGIES

- **$215 Mln**
- **Series E**
- **Daimler**

PHYLION

- **$136.8 Mln**
- **Private Equity**
- **Boxin Capital, CCB Int., Legend Holdings, PCCW, Yingke**

The Bigger picture: Recent E-mobilty news

Volkswagen to buy 20% of Chinese battery maker Guoxuan amid electric push

Germany auto sales in January 2020: All cars down 7%, EVs up 62%

Total, Groupe PSA forming JV to produce EV batteries in Europe under €5B expenditure program

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04 Appendix for supporting research and funding

Academic paper: Appendix (1/5)

Technology domain	Type of paper	Publication Title	Research Authors	Research University	Source
Lithium ion battery	Fast charging	Improved fast charging capability of graphite anodes via amorphous Al2O3 coating for high power lithium ion batteries	Dae SikKim, Yeong EunKim, HansuKim	Hanyang University Haengdang-Dong	Link
Lithium ion battery	Fast charging	Enabling fast charging of high energy density Li-ion cells (NMC811/graphite) with high lithium transport electrolytes	ZhijiaDu, David L.WoodIII, IliasBelharouak	Oak Ridge National Laboratory	Link
Lithium ion battery	Fast charging	Fast-charging effects on ageing for energy-optimized automotive LiNi1/3Mn1/3Co1/3O2/graphite prismatic lithium-ion cells	Abdilbari Shifa Mussa, Anti Liivat, FernandaMarzano, Matilda Klett, BertrandPhilippe, CarlTengstedt, GöranLindbergh, KristinaEdström, Rakel WrelandLindström, PontusSvens	KTH Royal Institute of Technology, Uppsala University	Link
Li-S battery	High performance	Polydopamine-coated hierarchical tower-shaped carbon for high-performance lithium-sulfur batteries	ZhixuJian, HongleiLi, RuiCao, HeliangZhou, HuaizheXu, GuangjinZhao, YalanXing, ShichaoZhang	Beihang University	Link
Lithium ion battery	novel Cathode	Tailoring NaVO3 as a novel stable cathode for lithium rechargeable batteries	LongChen, HonglunWu, HuimingWang, LiangChen, XiangjunPu, ZhongxueChena	Wuhan University, Hunan Institute of Science and Technology	Link
Lithium ion battery	Novel Anode	Using and recycling V2O5 as high performance anode materials for sustainable lithium ion battery	LingyuDu, HuijuanLin, ZhongyuanMa, QingqingWang, DeshengLi, YuShen, WeinaZhang, KunRui, JixinZhu, WeiHuangab	Nanjing Tech University, Northwestern Polytechnical University	Link
Li-S battery	Electrochemical properties	The effect of cerium oxide addition on the electrochemical properties of lithium-sulfur batteries	YadongLia, QinWang, DaoguangZheng, WeipingLi, JianxinWang	Ningbo University, Chinese Academy of Sciences	Link
Lithium ion battery	Electrolyte	Flowable polymer electrolytes for lithium metal batteries	ItziarAldalur, MariaMartinez-Ibañez, AnnaKrztoń-Maziop, MichalPiszcz, MichelArmand, HengZhanga	Parque Tecnológico de Álava, Warsaw University of Technology	Link
All solid state battery	Electrolyte	Formation of interfacial contact with ductile Li3BO3-based electrolytes for improving cyclability in all-solid-state batteries	KenjiNagao, AtsushiSakuda, AkitoshiHayashi, MasahiroTatsumisago	Osaka Prefecture University	Link
Solid state Lithium ion battery	Electrolyte	A solid-state single-ion polymer electrolyte with ultrahigh ionic conductivity for dendrite-free lithium metal batteries	ChenCao, YuLi, YiyuFeng, CongPeng, ZeyuLi, WeiFeng	Tianjin University	Link
Solid state Li-S battery	Electrolyte	A new high ionic conductive gel polymer electrolyte enables highly stable quasi-solid-state lithium sulfur battery	JinqiuZhou, HaoqingJi, JieLiu, TaoQian, ChenglinYan	Soochow University	Link

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Academic paper: Appendix (2/5)

Lithium ion battery	Electrolyte	Solid polymer electrolytes based on lithium bis(trifluoromethanesulfonyl)imide/poly(vinylidene fluoride -co-hexafluoropropylene) for safer rechargeable lithium-ion batteries	R.Gonçalves, D.Mirand, A.M.Almeida, M.M.Silva, J.M.Meseguer-Dueñas, J.L. GomezRibelles, S.Lanceros-Méndez, C.M.Costaad	University of Minho, Polytechnic Institute of Cávado and Ave, Universitat Politècnica de València	Link
Li-S battery	novel Cathode	Fe-functionalized mesoporous carbonaceous microsphere with high sulfur loading as cathode for lithium-sulfur batteries	ShaLi, QinXiang, Muhammad KashifAslam, YuanCen, ChaozhongGuo, JiahongHu, WeiLi, ChangguoChen	Chongqing University	Link
Solid state Lithium ion battery	Cycle life improvement	Stable cyclability of porous Si anode applied for sulfide-based all-solid-state batteries	RyotaOkuno, MariYamamoto, YoshihiroTerauchi, MasanariTakahashi	Nara Institute of Science and Technology, Osaka Research Institute of Industrial Science and Technology	Link
Solid state Lithium ion battery	Electrolyte	Li1.4Al0.4Ti1.6(PO4)3 nanoparticle-reinforced solid polymer electrolytes for all-solid-state lithium batteries	LehaoLiu, LihuaChu, BingJiang, MeichengLi	North China Electric Power University	Link
Lithium ion battery	Novel Anode	MOF-derived rod-like composites consisting of iron sulfides embedded in nitrogen-rich carbon as high-performance lithium-ion battery anodes	HaoWang, XuKunQian, HongyuWu, RuihuaZhang, RenbingWu	Fudan University, Lishui University, South China University of Technology,	Link
Li-S battery	Novel Anode/Novel cathode	Anchored monodispersed silicon and sulfur nanoparticles on graphene for high-performance lithiated silicon-sulfur battery	RunweiMo, ZhengyuLei, DavidRooney, KeningSun	Harbin Institute of Technology, Queen's University Belfast	Link
Li-S battery	Novel Cathode	Lithium sulfide-based cathode for lithium-ion/sulfur battery: Recent progress and challenges	Mohammad RejaulKaiser, ZhaojunHan, JiLiangbShi-Xu, DoubJiazhaoWang	University of Wollongong, The University of New South Wales, The University of New South Wales, CISRO	Link
Lithium ion battery	Electrolyte	Solid polymer electrolytes based on lithium bis(trifluoromethanesulfonyl)imide/poly(vinylidene fluoride -co-hexafluoropropylene) for safer rechargeable lithium-ion batteries	R.Gonçalvesa, D.Miranda, A.M.Almeida, M.M.Silv, J.M.Meseguer-Dueñas, J.L. GomezRibelles, S.Lanceros-Méndez, C.M.Costa	University of Minho, Universitat Politècnica de València	Link
solid state lithium ion battery	Electrolyte	Cathode-doped sulfide electrolyte strategy for boosting all-solid-state lithium batteries	LeiZhou, Muhammad KhurramTufail, LeYang, NiazAhmad, RenjieChen, WenYang	Beijing Institute of Technology	Link
Li-S battery	Novel Cathode	A linear molecule sulfur-rich organic cathode material for high performance lithium–sulfur batteries	HongfeiXu, YongzhengShi, ShubinYang, BinLi	Beihang University	Link

Academic paper: Appendix (3/5)

Lithium ion battery	Novel Anode	Aqueous lithium-ion batteries with niobium tungsten oxide anodes for superior volumetric and rate capability	Aniruddha S.Lakhnot, Tushar Gupta, Yashpal Singh, Prateek Hundekar, Rishabh Jain, Fudong Han, Nikhil Koratkar	Rensselaer Polytechnic Institute, Lawrence Berkeley National Laboratory	Link
Lithium ion battery	Novel Anode	A binder-free high silicon content flexible anode for Li-ion batteries	Hanwei Wang, Jinzhou Fu, Chao Wang, Jiangyan Wang, Ankun Yang, Caicai Li, Qingfeng Sun, Yi Cui*c and Huiqiao Li	Zhejiang A&F University, Huazhong University of Science and Technology, Stanford University	Link
Solid state Lithium ion battery	Temperature	A low ride on processing temperature for fast lithium conduction in garnet solid-state battery films	Reto Pfenninger, Michal Struzik, Iñigo Garbayo, Evelyn Stilp & Jennifer L. M. Rupp	Massachusetts Institute of Technology, Swiss Federal Institute of Technology	Link
Lithium ion battery	Fast charging	Asymmetric Temperature Modulation for Extreme Fast Charging of Lithium-Ion Batteries	Xiao-Guang Yang,Teng Liu, Yue Gao, Shanhai Ge, Yongjun Leng, Donghai Wang, Chao-Yang Wang	The Pennsylvania State University	Link
Lithium ion battery	Recycle	Ambient-Pressure Relithiation of Degraded LixNi0.5Co0.2Mn0.3O2 (0 < x < 1) via Eutectic Solutions for Direct Regeneration of Lithium-Ion Battery Cathodes	Yang Shi Minghao Zhang Ying Shirley Meng Zheng Chen	University of California San Diego	Link
Li-S battery	High Performance	A ZIF-67-derived–sulfur sandwich structure for high performance Li–S batteries	Xing Gao, Siwu Li, Ying Du, and Bo Wang	Beijing Institute of Technology, Tsinghua University	Link
All solid state battery	novel Cathode	Taming Active Material-Solid Electrolyte Interfaces with Organic Cathode for All-Solid-State Batteries	Fang Hao, Xiaowei Chi, Yanliang Liang, YeZhang, RongXu, HuaGuo, TanguyTerlier, HuiDong, KejieZhao, JunLou, YanYao	University of Houston, Purdue University, Rice University	Link
Li-S battery	novel Cathode	A linear molecule sulfur-rich organic cathode material for high performance lithium–sulfur batteries	HongfeiXu, YongzhengShi, ShubinYang, BinLi	Beihang University	Link
Lithium ion battery	Novel Anode	A Semiliquid Lithium Metal Anode	SipeiLi, HanWang, JuliaCuthbert, TongLiu, Jay F.Whitacre, KrzysztofMatyjaszewski	Carnegie Mellon University	Link

MOBILITY INDUSTRY INSIDER

Academic paper: Appendix (4/5)

Lithium ion battery	Electrolyte	Constructing Robust Electrode/Electrolyte Interphases to Enable Wide Temperature Applications of Lithium-Ion Batteries	Bin Liu, Qiuyan Li, Mark H. Engelhard, Yang He, Xianhui Zhang, Donghai Mei, Chongmin Wang, Ji-Guang Zhang, Wu Xu	Pacific Northwest National Laboratory	Link
Lithium ion battery	Electrolyte	High-Efficiency Lithium-Metal Anode Enabled by Liquefied Gas Electrolytes	YangyuchenYang, Daniel M.Davies, YijieYin, OlegBorodin, Jungwoo Z.Lee, ChengchengFang, MarcoOlguin, YihuiZhang, Ekaterina S.Sablina, XuefengWang, Cyrus S.Rustomji, Y. ShirleyMeng	University of California San Diego, U.S. Army Research Laboratory	Link
Li-S battery	novel Cathode	Sulfur-anchored azulene as a cathode material for Li–S batteries	Zhenying Chen, Jörn Droste, Guangqun Zhai, Jinhui Zhu, Jun Yang, Michael Ryan Hansen and Xiaodong Zhuang	Shanghai Jiao Tong University, Institute for Physical Chemistry, Changzhou University	Link
Lithium ion battery	Novel Anode	An air-stable and waterproof lithium metal anode enabled by wax composite packaging	YunboZhang, WeiLv, ZhijiaHuang, GuangminZhou, YaqianDeng, JunZhangaChenZhang, BoyuHao, QiQi, Yan-BingHe, FeiyuKang, Quan-HongYangd	Tsinghua University, Stanford University, Tianjin University	Link
Lithium ion battery	Cobalt free electrode	A path toward cobalt-free lithium-ion cathodes	Jason R.Croy, Brandon R.Long, Mahalingam Balasubramanian	Argonne National Laboratory	Link
Al battery	novel Cathode	Concept and electrochemical mechanism of an Al metal anode – organic cathode battery	JanBitenc, NiklasLindahl, AlenVizintin, Muhammad E.Abdelhamid, RobertDominko, PatrikJohansson	National Institute of Chemistry, Chalmers University of Technology, University of Ljubljana	Link
Lithium ion battery	Electrolyte	Using Mixed Salt Electrolytes to Stabilize Silicon Anodes for Lithium-Ion Batteries via in Situ Formation of Li–M–Si Ternaries (M = Mg, Zn, Al, Ca)	Binghong Han, Chen Liao, Fulya Dogan, Stephen E. Trask, Saul H. Lapidus, John T. Vaughey, Baris Key	Argonne National Laboratory	Link
Lithium ion battery	Electrolyte	UV-cured gel polymer electrolytes with improved stability for advanced aqueous Li-ion batteries	Spencer A. Langevin, Bing Tan, Adam W. Freeman, Jarod C. Gagnon, Christopher M. Hoffman, Jr., Matthew W. Logan, Jeffrey P. Maranchia and Konstantinos Gerasopoulos Johns Hopkins University Applied Physics Laboratory	Johns Hopkins University Applied Physics Laboratory	Link

Academic paper: Appendix (5/5)

Lithium ion battery	Fast charging	Photo-accelerated fast charging of lithium-ion batteries	Anna Lee, Márton Vörös, Wesley M. Dose, Jens Niklas, Oleg Poluektov, Richard D. Schaller, Hakim Iddir, Victor A. Maroni, Eungje Lee, Brian Ingram, Larry A. Curtiss & Christopher S. Johnson	Argonne National Laboratory	Link
Supercapacitors	High Performance	Highly Multifunctional Dopamine-Functionalized Reduced Graphene Oxide Supercapacitors	ParaskeviFlouda, Smit A.Shah, Dimitris C.Lagoudas, Micah J.Green, Jodie L.Lutkenhaus	Texas A&M University	Link
Lithium ion battery	Fast charging	A mechanism of defect-enhanced phase transformation kinetics in lithium iron phosphate olivine	Liang Hong, Kaiqi Yang & Ming Tang	Rice University	Link
Li-S battery	novel Cathode	Laser induced molybdenum sulphide loading on doped graphene cathode for highly stable lithium sulphur battery	Yihe Huang, Richard Field, Qian Chen, Yudong Peng, Monika S. Walczak, Hu Zhao, Guangyu Zhu, Zhu Liu & Lin Li	The University of Manchester	Link
Lithium ion battery	Electrolyte	Catalyst-Free Dynamic Networks for Recyclable, Self-Healing Solid Polymer Electrolytes	Christopher M. Evans, Brian B. Jing	University of Illinois	Link
Lithium ion battery	Recycle	Cathode healing methods for recycling of lithium-ion batteries	Steve E.Sloop, LaurenCrandon, MarshallAllen, Michael M.Lerner, HanyangZhang, WeekitSiris ksoontorn, LindaGaines, JoonKim, MyongjaiLee	Oregon State University, Argonne National Laboratory, OnTo Technology LLC	Link
Lithium ion battery	Recycle	Recycling $LiCoO_2$ with methanesulfonic acid for regeneration of lithium-ion battery electrode materials	BinWang, Xin-YeLin, YuanyuanTang, QiangWang, Michael K.H.Leung, Xiao-YingLu	Technological and Higher Education Institute of Hong Kong, Hong Kong Applied Science and Technology Research Institute, Southern University of Science and Technology, Beijing Forestry University, City University of Hong Kong	Link
Lithium ion battery	Recycle	A green and effective room-temperature recycling process of $LiFePO_4$ cathode materials for lithium-ion batteries	LiLi, YifanBian, XiaoxiaoZhang, YingYao, QingXue, ErshaFan, FengWu, RenjieChen	Beijing Institute of Technology	Link
Lithium ion battery	Recycle	Recycling of Ni-rich $Li(Ni_{0.8}Co_{0.1}Mn_{0.1})O_2$ cathode materials by a thermomechanical method	Seung-HwanLee, Hyun-SooKim, Bong-SooJin	Korea Electrotechnology Research Institute	Link
Lithium ion battery	Recycle	Novel efficient and environmentally friendly recovering of high performance nano-$LiMnPO_4$/C cathode powders from spent $LiMn_2O_4$ batteries	QiMeng, JianguoDuan, YingjieZhang, PengDong	Kunming University of Science and Technology	Link
Lithium ion battery	Fast charging	Fast charging of an electric vehicle lithium-ion battery at the limit of the lithium deposition process	JohannesSiega, JochenBandlow, TimMitsch, DanielDragicevic, TorbenMaterna, BerndSpier, HeikoWitzenhausen, Madeleine Ecker, Dirk UweSauer	RWTH Aachen University	Link
Lithium ion battery	Temperature	Effect of temperature on silicon-based anodes for lithium-ion batteries	M.J.Piernas-Muñoz, S.E.Trask, A.R.Dunlop, E.Leel.Bloom	Argonne National Laboratory	Link

Global funding report – Appendix (1/2)

Industry	Company	Country	Round/Type	Amount (M$)	Investors	Quarter
Batteries	Saratoga Energy Corporation	USA	Seed	0.15	US Department of Energy, Y Combinator	Q1
Batteries	Tiamat	France	Grant	0.77	Unknown	Q1
Batteries	ION Energy	India	Venture	Unknown	Unknown	Q1
Batteries	LeydenJar Technologies	Netherlands	Seed	3.3	Unknown	Q1
Batteries	Batron Arge	Turkey	Seed	0.092	Unknown	Q1
Batteries	Northvolt	Sweden	Venture	13.7	European Investment bank (EIB), Siemens AG, Vattenfall	Q1
Batteries	Natron Energy	USA	Corporate Round	Unknown	Chevron Technology Ventures, Fluxus Ventures	Q1
Batteries	Phylion Battery	China	Private Equity	136.8	Boxin Capital, CCB Int., Legend Holdings, PCCW, Yingke	Q2
Batteries	Nano One	Canada	Grant	5	Unknown	Q2
Batteries	Romeo Power	USA	Venture	88.5	BorgWarner, OpenDoor Venture Capital	Q2
Batteries	Nawa Technologies	France	Venture	9.7	Unknown	Q2
Batteries	Ion Storage Systems	USA	Venture	8	Unknown	Q2
Batteries	Clean Energy Global	Germany	Seed	0.33	Unknown	Q2
Batteries	Enevate	USA	Corporate Round	Unknown	Alliance Ventures, Lenovo, LG Chem, Presidio Ventures, Samsung	Q2
Batteries	Nanoramic Laboratories	USA	Funding Round	8.5	Unknown	Q2
Batteries	Sila Nanotechnologies	USA	Series E	170	Daimler	Q2
Batteries	Zenlabs Energy	USA	Grant	4.8	United States Advanced Battery consortium (USABC)	Q2
Batteries	TWAICE	Germany	Seed	2	Unknown	Q2
Batteries	Northvolt	Sweden	Corporate Round	400	BMW, Volkswagen Group, Goldman Sachs, IKEA, Siemens	Q2
Batteries	Northvolt	Sweden	Corporate Round	600	BMW, Volkswagen Group, Goldman Sachs, IKEA, Siemens	Q2
Batteries	Mandian Future	China	Angel	Unknown	Zhonglu Capital	Q2
Batteries	Forge Nano	USA	Unknown	Unknown	Unknown	Q3
Batteries	Titan Advanced Energy Solutions	USA	Series A	10	Energy innovation, Massachusetts Clean Energy, Schneider Electric Ventures	Q3
Batteries	Pure EV	India	Venture	35	Unknown	Q3

Global funding report – Appendix (2/2)

Batteries	Motiv Power Systems	USA	Series A	9.1	Unknown	Q3
Batteries	Motiv Power Systems	USA	Series A	37.4	Unknown	Q3
Batteries	Solid Power	USA	Series A	20	A123 Systems, Samsung Venture IM, Solvay, Volta Energy	Q3
Batteries	Romeo Power	USA	Venture	4	HG Ventures	Q3
Batteries	Pushme	UK	Series A	0.6	HAX, SOSV	Q3
Batteries	Rovilus	Taiwan	Seed	0.15	500 startups	Q3
Batteries	Volt14	Hong Kong	Seed	0.95	500 Durians	Q3
Batteries	Loop Energy	Canada	Corporate	Unknown	Canadian T.A, Cummins, Innovation, Science& Economic Dev Canada	Q3
Batteries	Sila Nanotechnologies	USA	Series E	45	Daimler	Q4
Batteries	Group 14 Technologies	USA	Venture	18	Amperex Technologies, BASF VC	Q4
Batteries	Wildcat Discovery Technologies	USA	Series C	20	Flint Hills Resources	Q4
Batteries	NOHMs Technologies	USA	Debt Financing	1.8	Unknown	Q4
Batteries	AllCell	USA	Convertible Note	0.23	Shell	Q4
Batteries	Batron Arge	Turkey	Seed	0.067	Trangels, Erban	Q4
Batteries	Greenvolt Nano	USA	Unknown	0.05	Horizon 2020	Q4
Batteries	Futavis	Germany	Unknown	Unknown	Deutz	Q4
Batteries	Dukosi	UK	Unknown	Unknown	KCK-US	Q4
Batteries	Motiv Power Systems	USA	Series B	13	Unknown	Q4
Batteries	Amprius	USA	Unknown	Unknown	Airbus Ventures	Q4
Batteries	Log 9 Materials	India	Series A	3.5	Unknown	Q4
Batteries	Chengdu OK New Energy	China	Unknown	Unknown	AVX	Q4
Batteries	Pivot Power (Energy Storage)	UK	Unknown	Unknown	EDF Energy	Q4
Batteries	GamY	Germany	Seed	0.12	TechStars	Q4
Batteries	Addionics	UK	Venture	3.5	Intel	Q2 2020
Batteries	Addionics	UK	Grant	2.5	Intel	Q2 2020
Batteries	TWAICE	Germany	Series A	11	Unknown	Q1 2020
Batteries	Nawa Technologies	France	Venture	14	Unknown	Q1 2020
Batteries	ZincFive	USA	Series C	13.1	Unknown	Q1 2020
Batteries	Phinergy	Israel	Corporate Round	Unknown	Unknown	Q1 2020

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