Development goals and myths of battery technology

Future battery systems: A journey from Li-Ion to myth-busting technologies

Stuttgart. The battery system is perhaps the most critical component of battery electric vehicles. In addition to obtaining the highest possible energy density, aspects such as safety, weight and sustainability play crucial roles. Prof. Dr. Dr. Andreas Hintennach is head of battery cell research at Daimler. In addition to explaining the fundamentals of current lithium-ion cells, he outlines which future technologies actually have a chance.

The battery system is a key element of electric mobility. Every day at Daimler, experts from various disciplines deal with all aspects of this storage technology, from basic research to production maturity. The requirements are complex, and vary depending on the application. This is because 48-volt mild hybrids, plug-in hybrids, and purely electric drivetrains require different development focuses. In order to maintain an overview of this hotly debated topic, Andreas Hintennach gave media representatives an insight into the technical principles as well as Daimler development and research goals during a digital roundtable.

Professor Hintennach, you are working on the research and development of batteries – the current “hot” topic in terms of e-mobility. How is Mercedes-Benz tackling this topic?

Battery technology is a key element of electric mobility and not an off-the-shelf product, but an integral part of the vehicle architecture. Therefore we cover all stages from fundamental research to production maturity. Our activities include the continuous optimization of the current generation of lithium-ion battery systems, the further development of cells available on the world market and research of next-generation battery systems. But of course, there’s more when it comes to batteries for electric vehicles. We are also working on the battery management system, which is a complex computer that you can always improve on. Thermal management is an important topic as well. It is responsible for the life and also the performance of the battery pack. You have to really understand the mechanism of technologies in order to be able to make the right decisions.
What is your current focus?

While our all-new EQC model is being introduced to the markets, we are preparing the way for next generations of powerful battery-electric vehicles. Lithium-ion batteries are the most common type used in electronics and electric vehicles today. In the years ahead, this technology will continue to set the pace – but there is more to come. Regarding research and development, we follow several specific guiding principles. We are consistently working on innovation and alternatives beyond lithium-ion – not least regarding energy density and charging time, but also sustainability. For example, we have agreed on a sustainability partnership with Farasis Energy (Ganzhou) Co., Ltd. to take a holistic approach along the entire value chain: part of the battery cells for the next vehicle generation of our EQ product and technology brand are already to be produced using 100 percent electricity from renewable energies. Our competencies for the technological evaluation of materials and cells as well as research and development activities are being consistently expanded.

So it is more than just about increasing the kWh per battery pack?

Energy capacity is important, of course. But there is more to it: safety is a very decisive factor for us. Material related changes could make it possible to obtain a higher capacity – but with compromises in terms of safety. For us, this is definitely out of the question. A Mercedes-Benz has to be the benchmark when it comes to safety, and this also goes for its battery pack. One of our guiding principles of development is also flexibility: at Daimler, there are a lot of use-cases for battery packs, from the smart to Mercedes-Benz cars and vans – to buses and heavy trucks – and finally from 48-volt mild hybrids to plug-in hybrids and purely electrical cars. And of course, the solutions we come up with must be sustainable.

How important is sustainability in development?

Sustainability has become the overarching principle for any development activity at Daimler. Since the manufacture of vehicles naturally requires a high amount of raw materials, one of our development focuses is on minimizing the need for natural resources, but also to increase transparency at first. During development, we create a concept for each vehicle model in which all components and materials are analyzed for their suitability in the context of a circular economy. Concerning batteries, this concept is already used for fundamental research in which precious materials can be substituted, minimized or used more efficiently. What’s more, recyclability is already taken into account from beginning. So battery production becomes a part of a holistic approach – a closed loop; a so-called circular economy.

What is the environmental impact of electric vehicles? Electric propulsion has a demonstrably worse impact than combustion engines when it comes to production.

The production of the combustion engine has been steadily improved over the past 133 years. The battery and the fuel cell, on the other hand, currently start life with more emissions due to the increased energy requirement. However, in terms of operation they are both much more efficient. And that pays off in the long run. Even if we do not charge them using CO₂-neutral electricity, battery-powered vehicles generate around 40 percent fewer emissions over their life cycle than vehicles with gasoline engines, and 30 percent less than diesel-powered vehicles. And in this calculation, our target CO₂ reductions for production by 2039 and the recycling of raw materials that will be incorporated into the production cycle in the future are not even taken into consideration. Both will further improve the sustainability of our vehicles holistically, and in so doing contribute to our “Ambition2039”. Today, our vehicles are already 95 percent recoverable.
How long will it be until a market for secondary raw materials is in place?

In eight to ten years there will be a significant number of vehicle batteries available for recycling. Then in particular cobalt, nickel, copper, and later also silicon will be recycled. We are already very well prepared and the processes are in place, as are the opportunities for returning secondary raw materials into the production cycle. We currently do this with our test batteries. The establishment of a functioning market for secondary raw materials for Europe is of great political importance, because Europe barely has any primary sources. But we are of course doing everything we can to ensure that batteries last as long as possible.

What materials are used in the battery?

With lithium ion technology the cell structure is always similar, regardless of whether it is a cell phone or an EV battery. There are always two metal sheets, such as copper and aluminum. Between the metal sheets are the two poles with the cathode and anode, among which the electric reaction takes place. For the reaction a reactive metal such as lithium is required. The biggest cost factor is the composition of the cathode, meaning the positive pole of the battery. It consists of a mixture of nickel, manganese and cobalt. The anode is made from graphite powder, lithium, electrolytes and a separator.

And where does the aforementioned silicon come into play?

Silicon will largely replace graphite powder in the future. This will enable us to increase the energy density of batteries up to about 20 to 25 percent. Silicon allows us to use materials on the cathode side that are not compatible with the graphite that is currently used. Imagine two glasses. If you want to pour water from one into the other, the second should at least be the same size so that it does not overflow. Similarly, the anode and the cathode should harmonize, which we call ‘balancing’. Silicon is also used, however, to improve the speed of charging.

An important cue: Cobalt is frequently associated with violations of human rights and damage to the environment in connection with its extraction, particularly when it stems from the Democratic Republic of Congo. What is Daimler doing about this?

We have developed an approach that is aimed at making sure that our suppliers meet our requirements with respect to sustainability, and in doing so aim to achieve greater transparency in the supply chain. To this end, we have engaged an audit company to clarify and monitor every stage of the cobalt supply chain in accordance with OECD standards. After all, electromobility is only truly sustainable if the raw materials are extracted under sustainable conditions.

Another strategy is to replace cobalt with other, less critical materials ...

We are doing research on that. With the current generation of battery cells, we have already been able to reduce the proportion of cobalt in the active material (nickel, manganese, cobalt, lithium) from around a third to less than 20 percent. In the laboratory we are currently working with less than ten percent and the share is set to fall even more in the future. From a chemical perspective there are a lot of arguments for abstaining cobalt entirely. The more the mixture of materials is reduced, the easier and more efficient it is to recycle. The energy required for chemical production is also reduced because the mixture is easier to produce.
What will replace cobalt and other materials like Lithium?

They are materials that are mainly based on manganese - a raw material that is less troublesome from an ecological perspective and easier to work with. Excellent recycling facilities are already in place for manganese because it has been used for decades in the form of alkali batteries (non-rechargeable batteries). The task for researchers is to make this type of battery chargeable. We expect the technology to be ready for market by the second half of the 2020s. Another alternative is the lithium/sulfur battery. Sulfur is an industrial waste product with almost no costs that is very pure and can easily be recycled. It poses significant challenges with respect to energy density, but also has an unbeatable ecobalance. However, it may take years until this technology is available for passenger cars.

Lithium is also the subject of criticism. Can this raw material also be replaced?

It can. The magnesium-sulfur battery, for example, contains no lithium. We are familiar with magnesium from our everyday lives in the form of chalk. The big advantage is that it is freely available. The Swabian Alb consists entirely of chalk, for example. However, our research is currently at a laboratory stage.

So there are no alternatives to the lithium-ion battery at present?

There are, in some applications. There are even technologies that are superior to the lithium-ion battery. These include the solid-state battery, which we will be using in our Mercedes-Benz eCitaro urban bus within the second half of the 2020's. The technology has a very long life cycle, and also does not include any cobalt, nickel or manganese. However, its energy density is lower, which makes it relatively large and slow to charge. That is why it is good for commercial vehicles but not for passenger cars. The lithium-ion battery will be with us for years to come.

What will be the next “holy grail”? Are solid-state batteries the future?

There is not one single post-lithium-ion technology. Be it cells with solid-state electrolytes, lithium metal anodes, or lithium sulfur systems - all technologies differ in their specific material requirements, their applications and not least their level of maturity. Each technology has its specific pros and cons. The good news is that there are multiple paths which lower the risk of a potential dead-end road in development. Not yet around the corner – but also not very far down the road – are batteries in which the graphite coating of the anode can be replaced with novel materials such as lithium-metal foil or silicon powder. Both increase energy density by far. This leads to higher range and could even support fast charging. All solid-state batteries have great advantages when it comes to safety, but we are still working on fast charging and a longer lifespan before we can say “this is the technology we should bring to the road now” regarding our passenger cars.

And what will happen further down the road?

Lithium-sulfur is one possible alternative. Replacing the nickel and cobalt of today’s batteries with sulfur would significantly increase sustainability. The energy density also has a lot of potential, but the lifespan is not yet long enough and it will take a while until there is a breakthrough in this area. In lithium-air batteries, there is really only lithium. The rest – the oxygen – simply comes from the air. Chemically, it’s a concept similar to what you have in a fuel cell, where we are using hydrogen. The energy density would be outstanding – but this technology is still quite far down the road.
With your research car VISION AVTR you went one step further, far beyond tomorrow. Is organic battery technology really an option?

With the VISION AVTR, Mercedes-Benz is presenting a sustainable vision of emission-free mobility - also when it comes to drive technology. For the first time, its revolutionary battery technology consists of organic-cell chemistry based on graphene and thus does not use any rare, toxic or expensive materials such as metals. This makes e-mobility independent of fossil resources. An absolute revolution is the 100 percent recyclability through composting due to the materiality - a prime example of a future circular economy in the raw materials sector. In addition to an exponentially high energy density, the technology also impresses with its exceptional quick charging capability. Organic batteries are currently part of our fundamental research. It will still take several years until it can be established in Mercedes-Benz vehicles - but the potential is there!

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Mercedes-Benz AG at a glance
Mercedes-Benz AG is responsible for the global business of Mercedes-Benz Cars and Mercedes-Benz Vans with over 173,000 employees worldwide. Ola Källenius is Chairman of the Board of Management of Mercedes-Benz AG. The company focuses on the development, production and sales of passenger cars, vans and services. Furthermore, with its pioneering innovations, the company aspires to be a leader in the fields of connectivity, automated driving and alternative powertrains. The product portfolio comprises the Mercedes-Benz brand with the sub-brands Mercedes-AMG, Mercedes-Maybach and Mercedes me, as well as the smart brand and the EQ product and technology brand for electric mobility. Mercedes-Benz AG is one of the largest manufacturers of premium passenger cars. In 2019, it sold nearly 2.4 million passenger cars and more than 438,000 vans. In its two business segments, Mercedes-Benz AG is continually expanding its worldwide production network with over 40 production sites on four continents, while gearing itself to meet the requirements of electric mobility. At the same time, the company is constructing its global battery production network on three continents. Sustainable actions play a decisive role in both business segments. To the company, sustainability means creating lasting value for all stakeholders: customers, employees, investors, business partners and society as a whole. The basis for this is Daimler's sustainable business strategy. In it, the company takes responsibility for the economic, ecological and social effects of its business activities and looks at the entire value chain.