TECH Trends

TECHNOLOGY CONVERGENCE TO DRIVE AUTOMOTIVE INDUSTRY

Good, better, best. Never let it rest. 'Til your good is better and your better is best – St. Jerome

Mobility technology is becoming better and better on all fronts – better maps for easy navigation even in crowded cities, better batteries with longer range and a much longer life (that can support a million miles!), better motors for powering – we profile a spectrum of such better technologies that hold great promise for enabling future mobility. These ground-breaking technology developments come from researchers across the world who are challenging the limits set by conventional wisdom in fields as diverse as Radar Physics and Battery Chemistry.

Better Maps

Autonomous Vehicles – Partially Coherent Radars – smaller bandwidths

In autonomous vehicle applications based on radars, it was commonly believed that radar resolution was proportional to the bandwidth used. What this means is that a good, accurate radar, required a lot of bandwidth. This dependence forces expensive high-bandwidth implementations in applications where range accuracy and range resolution are crucial. In future, this could be a severe constraint when there are many autonomous vehicles on the road. The cost of high-bandwidth hardware and the regulation of the allowed spectral bands push toward removing this constraint.

Researchers from Tel Aviv University (TAU), Israel have now demonstrated that low-bandwidth radars can achieve similar performance at a lower cost and without broadband signals by exploiting the coherence property of electromagnetic waves. They have experimentally demonstrated a novel type of super-resolution ranging and detection system inspired by Optical Coherence Tomography (OCT), which is not limited by bandwidth, at the expense of longer acquisition time. The new "partially coherent" radar, which uses significantly less bandwidth, is as effective as standard "coherent" radars in experimental situations. Professor Pavel Ginzburg's team published their ground-breaking work in Nature Communications (March 2019) – "Partially coherent radar unties range resolution from bandwidth limitations"

Paper - https://www.nature.com/articles/s41467-019-09380-x

Better Batteries – Better Life

Batteries for EVs – more miles – superionic conducting electrolytes – regeneration of critical materials

To run robotaxis and long-haul electric trucks, Tesla will need a battery that can handle full discharge cycles every day. The problem is that fully discharging and recharging every day puts greater stress on the battery and degrades its components more rapidly. These vehicles will be packing in way more daily miles than your average commuter, which is why Musk wants a battery that can last for one million miles. Jeff Dahn's team - at Dalhousie University, Canada -

was tasked with creating lithium-ion batteries that can store more energy and have a longer lifetime than commercially available batteries. In electric cars, these metrics translate to how far you can drive your car on a single charge and how many charges you can get out of the battery before it stops working. The conventional mindset is that there's a trade-off between energy density and battery lifetime i.e if you want more of one, you get less of the other. Dahn's group was responsible for the seemingly impossible task of overcoming this trade-off.

Dahn's team published a paper in The Journal of the Electrochemical Society "A Wide Range of Testing Results on an Excellent Lithium-Ion Cell Chemistry to be used as Benchmarks for New Battery Technologies" - describing a lithium-ion battery that "should be able to power an electric vehicle for over 1 million miles". They showed that their batteries could be charged and depleted more than 4,000 times while losing only about 10 percent of their energy capacity in its lifetime. These batteries use lithium nickel manganese cobalt oxide, or NMC, for the battery's positive electrode (cathode) and artificial graphite for its negative electrode (anode). The electrolyte consists of a lithium salt blended with other compounds. There is also some discussion of the cathode being nanostructured (and single crystalline) and certain proprietary additives to the electrolyte formulation (ODTO).

Paper - http://jes.ecsdl.org/content/166/13/A3031

Better Electrolyte – Superionic Conductor

Scientists from Japan's Tohoku University and the High Energy Accelerator Research Organization says their research has resulted in a new complex hydride lithium superionic conductor that could result in all-solid-state batteries with the highest energy density to date. All-solid-state batteries, in theory, are expected to cost less, last long, and be capable of more charge/discharge cycles than traditional lithium-ion batteries. In addition, they may have higher energy density, eliminate the need for cobalt, weigh less, and be smaller than traditional lithium-ion batteries. They are also promising candidates for resolving the intrinsic drawbacks of current lithium-ion batteries such as electrolyte leakage, flammability, and limited energy density. Lithium metal is widely believed to be the ultimate anode material for all-solid-state batteries because it has the highest theoretical capacity (3860 mAh g-1) and the lowest potential (-3.04 V vs. standard hydrogen electrode) among known anode materials. Lithium-ion conducting solid electrolytes are a key component of all-solid-state batteries because the ionic conductivity and stability of the solid electrolyte determine battery performance. The problem is that most existing solid electrolytes have chemical/electrochemical instability and/or poor physical contact against lithium metal, inevitably causing unwanted side reactions at the interface. These side reactions result in an increase in interfacial resistance, greatly degrading battery performance during repeated cycling. It is desirable to find a solid electrolyte that is intrinsically stable and compatible with lithium metal to maximize the advantages of the lithium metal anode.

Complex hydrides are a new class of solid electrolytes to address the problems associated with the lithium metal anode owing to their high deformability and outstanding chemical/electrochemical stability against the lithium metal anode, which results from their high reducing ability. Kim et al reported the development of complex hydride solid electrolytes that exhibit high ionic conductivity at room temperature will be a revolutionary breakthrough for all-solid-state batteries employing a lithium metal anode in Nature Communications (March 2019)- "A complex hydride lithium superionic conductor for high-energy-density all-solid-state lithium metal batteries ". The unique properties of the developed complex hydride solid electrolyte will not only inspire future efforts to find lithium superionic conductors based on complex hydrides, but also opens up a new group of solid electrolytes for practical all-solid-state lithium metal batteries that may lead to the development of high-energy-density electrochemical devices.

Paper - https://www.nature.com/articles/s41467-019-09061-9

Better Recycling – regeneration of precious LiCoO2

With the growing applications of lithium-ion batteries (LIBs) in many areas, their recycling becomes a necessary task. Although great effort has been made in LIB recycling, there remains an urgent need for green and energy-efficient approaches. Yang Shi et al, from University of California, San Diego, have reported a non-destructive approach to regenerate cathode materials by hydrothermal treatment of cycled electrode particles followed by short annealing – "Effective regeneration of LiCoO2 from spent lithium-ion batteries: a direct approach towards high-performance active particles" (Green Chemistry, 2018). Unlike the conventional chemical leaching or solid-state synthesis approach, which either requires complicated steps of leaching, precipitation and waste treatment or relies on the chemical analysis of the Li/Co ratio from cell to cell, the proposed non-destructive approach is much simpler and more environmentally friendly and can easily process batteries with different capacity degradation conditions.

In addition, the regenerated LiCoO2 particles can retain their original morphology / structure and provide high specific capacity and cycling stability. Importantly, they show much better rate capability than particles regenerated through the solid-state synthesis approach. Shi's work demonstrates a greener, simpler and more energy-efficient strategy to recycle and regenerate faded LiCoO2 cathode materials with high electrochemical performance. This approach has potential to be widely used to recycle and regenerate LiCoO2 cathodes on a large scale, and can also be potentially applied to other types of cathode materials in LIBs and mixed cathode chemistry.

Paper - https://pubs.rsc.org/en/content/articlelanding/2018/gc/c7gc02831h#!divAbstract

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