Battery research in need of a jolt; Breakthroughs won't happen overnight with complex process of EV technology

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"This could be the beginning of a breakthrough battery technology for electric vehicles."

I see such breathless news releases often enough that I've learned to file them under "How Nice," and move on.

Since I like electric vehicles, I'd be happy if any breakthrough amounts to anything. And I expect it will happen. But not for a while.

Here's why:

The battery is the Achilles heel of electric vehicles.

Although EVs score high for comfort and performance, and sales are improving, they'll remain a niche market until batteries provide much longer range and lifespan, plus faster recharging, at a substantially lower cost.

Experts say range must at least triple, and costs fall two-thirds, before battery power can go mainstream. Most predict that's at least 20 years away.

Some insist lithium-ion batteries will never do the job. They await dazzling alternatives, none of which is remotely ready for prime time.

I learned why development is so slow during a visit to one of North America's leading battery-research centres, the Argonne National Lab, in a leafy suburb west of Chicago.

It's among the institutions and corporations sharing a bonanza of government cash - including $2 billion announced four years ago by U.S. President Barack Obama - to help the United States catch up to Japan, China and South Korea in the global battery race.

Batteries are comprised of cells - 192 in the Nissan Leaf; about 7,000 smaller ones in Tesla's Model S - that, combined, form a pack. For now, EV range varies mainly because some have bigger packs than others.

Each cell contains a stack of components sandwiched together.

The "bread" is the electrodes - a positive cathode on one side; a negative anode on the other. They're made of foil - aluminum for the cathode, copper for the anode - coated with lithium and other chemical compounds.

The "filling" is a separator - a piece of mesh or perforated material that keeps the electrodes from touching and causing a catastrophic short circuit.

An electrolyte, usually a liquid, fills the spaces around these parts.

Lithium ions flow back and forth, through the electrolyte and separator, from one electrode to the other.

When the battery is fully charged, they sit in the anodes.

When the car needs power they move to the cathodes, generating electricity. Recharging returns them to the anodes.

It's a complex process that repeatedly converts chemical energy to electrical, and back again.

In recharging, lithium ions must be pulled from the cathode. But ions don't want to be in the anode, says Daniel Abraham, a materials specialist and 20-year veteran at Argonne.

"It's not their normal state, so energy is required to push them there, like carrying water uphill."

When the battery is asked to produce power, they eagerly rush back to be reunited with their lithium family.

Battery performance depends on:

For range: How many ions the electrodes can store. The more ions, the longer it will function before the anode is empty and recharging is required. This capacity is represented as kilowatt-hours - 24 for the Leaf, 85 for the Model S.

For power: How quickly ions move from the anodes to the cathodes. (Power also impacts range: the faster the ions leave the anode, the sooner it empties.)

For longevity: How well the components resist the decay that afflicts all batteries.

Battery researchers face three main problems.

First, EVs place incredible demands in performance, reliability and safety.

Second, everything happens at a microscopic scale, and even tiny changes impact performance. It's a painstaking job to get the recipe right - both the mix of ingredients and how they're combined and applied - and, equally important, be able to repeat it precisely for commercial production.

"The arrangement of atoms dictates behaviour," Abraham says. "How do you get them to sit in the same place every time?"

"You want every one of your batteries to stay the same," adds Ira Bloom, who heads Argonne's diagnostics and analysis lab. "How do you make it identical? Six manufacturers might claim the same materials, but they could have different three-dimensional structures. So performance changes."

Third, no single recipe is best. Improve one quality and another worsens. Increase capacity, for example, and longevity could fall; boost power and you might lose capacity.

Why do batteries decay over time?

When ions enter and leave the electrode coating, they cause expansion and contraction. This leads to cracks and, eventually, less capacity to hold ions.

As well, ions become trapped in the electrodes and separator, reducing the number available to flow back and forth. And the chemical reactions create contaminants that impede their journey.

Ions travel most easily through water-based electrolytes, but these quickly break down under EV loads. Organic solvents are the current compromise: They slow the ions and are flammable, but they can handle high voltages. Solid electrolytes are in the early research stage.

Most anodes are coated in graphite, which has limited storage capacity but withstands cracking. Silicon holds up to 10 times more ions but falls apart more quickly.

The potential breakthrough mentioned at the top of this story involved a California company, Amprius, trying to boost longevity by forming the silicon into nanowires, far thinner than a human hair.

Cathodes use a wide variety of materials. Recipes are tested and adjusted, over and over. Those that survive laboratory tests move up to larger batches.

Promising batches undergo a year of non-stop cycles of use and recharging - to mimic the 10 to 15 years an EV battery must retain at least 80 per cent of its original capacity.

Then, they're dismantled and viewed through 15 instruments to detect cracks, realignment of atoms, unwanted chemical reactions and other alterations.

"We can see what the materials look like and how they change and whether we like the changes," Abraham says.

"If not, we can go back and alter the chemistry."

This development process can't be hurried. So any breakthroughs will likely be one small step at a time.

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