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An open-wheel racecar in the test chamber of Honda's new, $124-million wind tunnel in East Liberty, Ohio. The Honda Automotive Laboratories of Ohio (HALO) facility is the company's first full-scale wind tunnel in North America and is projected to save significant vehicle-development time and money previously spent contracting third-party wind tunnels in the U.S. and abroad. (*Honda*)

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Automotive Engineering®, May 2022, Volume 9, Number 4. *Automotive Engineering* (ISSN 2331-7639) is published in February, March, April, May, June, August, September, October, December by SAE Media Group, 261 Fifth Avenue, Suite 1901, New York, NY 10016 and printed in Mechanicsburg, PA.

Annual print subscription for SAE members: first subscription, $15 included in dues; additional single copies, $30 each North America, $35 each overseas. Prices for nonmember subscriptions are $115.00 North America, $175.00 overseas, $30.00 digital subscription, $30.00 single copies. Periodicals postage paid at New York, and additional mailing offices. POSTMASTER: Please send address changes to *Automotive Engineering*, P. O. Box 3525, Northbrook, IL 60062. SAE International is not responsible for the accuracy of information in the editorial, articles, and advertising sections of this publication. Readers should independently evaluate the accuracy of any statement in the editorial, articles, and advertising sections of this publication that are important to him/her and rely on his/her independent evaluation. For permission to reproduce or use content in other media, contact copyright@sae.org. To purchase reprints, contact advertising@sae.org. Claims for missing issues of the magazine must be submitted within a six-month time frame of the claimed issue's publication date. The *Automotive Engineering* title is registered in the U.S. Patent and Trademark Office. Full issues and feature articles are included in SAE Mobilus®. For additional information, free demos are available at https://saemobilus.sae.org/.
(ISSN 2331-7639 print)
(ISSN 2331-7647 digital)

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SAE INTERNATIONAL®

EDITORIAL

Reconsidering hybrids

After conversations I've had with powertrain engineering executives during the 2022 SAE WCX World Congress, and in reading our reports on the panel discussions, I can conclude two things. First, mobility-industry planning currently faces more uncertainty than at any period in recent memory. It's not a good time to bet on EV sales forecasts and ICE-end dates that seemed unrealistic even before Covid, the chip crisis, and Putin's war of obliteration. Unforeseen externalities have a way of altering outlooks.

Secondly, hybrid-electric propulsion will play a significant role in global vehicle electrification and CO_2 reduction in the next decade. I'm confident of that. And much of the industry seems to agree.

China is having a hybrid-tech revival.

One-quarter of Toyota's vehicle sales in 2021 were electrified vehicles, most of them hybrids. The company that created the modern hybrid and made them aspirational, profitable, and reliable is assembling a pragmatic portfolio—hybrid- and plug-in hybrid vehicles, BEVs, and fuel-cell EVs. "We don't believe a one-size-fits-all approach will work," Dante Boutell, VP of powertrain design for Toyota North America, told the SAE audience.

Honda is expanding standard-hybrid offerings across its lineup as it continues fuel-cell and EV collaborations with GM. Citing these uncertain times, the CEO of BMW and CTO of Mercedes each recently warned that overcommitting on EVs could leave them vulnerable in vehicle sales and in the procurement and cost of strategic raw materials. "When you look at the technology coming out, the EV push, we must be careful because at the same time, you increase dependency on very few countries," asserted BMW boss Oliver Zipse at a media gathering during the New York auto show.

And China? It is experiencing a revival of hybrid technology, according to a recent analysis by engineering consultants FEV. China's best-selling "new energy vehicle" is a series-hybrid SUV with a 40-kWh battery. Admittedly, having both hybrids and BEVs within a single vehicle segment may require OEMs to adopt a two-platform strategy to optimize each powertrain's benefits. That approach is counter to what EV advocates say is a key advantage of battery-electrics: reduced build complexity and bill-of-material. But FEV, with its intimate knowledge of tech trends and developments, anticipates OEMs will need "a significant share" of hybrid-electric vehicles, in addition to BEVs, to comply with 2030 EU CO_2 laws.

Range between fill-ups (or charges) is a major selling point for hybrids. They are vastly superior to even the priciest EVs in this metric. Ford's new $21,000 Maverick hybrid can deliver over 500 miles of driving range, beating Cadillac's $59,000 Lyriq EV and Tesla's $40,000 Model Y each by about 200 miles. There's also the benefit of having a "heat engine" for complete cabin warming, regardless of ambient temperature and duty cycle.

Hybrids ultimately may only be a "bridge" to an all-EV future, but OEMs who have fully committed to EVs in the short term may end up regretting their decisions. While traditional ICEs are heading for a sundown, hybridized combustion engines will power perhaps one third of new vehicles for at least the next decade, and millions beyond it. "Let's just say that by [2030], it's a 50/50 mix of ICE and BEV," Dave Filipe, VP of hardware modules at Ford, postulated to the SAE WCX audience. "But that 50-percent ICE is going to be heavily influenced by the hybrids." And Ford will have more of them, he noted.

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Preparing for a lumpy transition

Recently, I was asked by an OEM to sum up the looming ICE-to-BEV industry transformation. My reply came in a single word: lumpy! And while that description may not be the most finely tailored way to explain the industry's most critical transition since its inception, I think it fits. The changes certainly will not be smooth.

Significant impact already is affecting all facets of the mobility ecosystem — development, system sourcing, production, retail, and aftermarket. The short-to-mid-term future is uncharted territory at virtually every level. There are profound questions and ramifications: transition speed; commitment by all stakeholders (consumers, government, energy utilities, dealers etc.); confidence in upstream inputs and logistic streams; consumer acceptance/education; an all-new service dynamic; and geopolitical conflict swirling around it all. The current ICE infrastructure took more than a century to build and refine, so it's not unrealistic to expect drama and disruption in the next decade. Lumpy, indeed.

We currently are in a 'honeymoon' phase, with significant euphoria about the prospects for the new electrified-propulsion format. Behind the hope and hyperbole, however, are blindingly high levels of capital being diverted towards it. Risk abounds as virtually every OEM attaches its wagon to the BEV train.

OEMs and suppliers across the tiers increasingly realize the transition will be lumpy. It's already well underway in other major global regions. Both China and Western Europe are shifting their propulsion strategies faster than North America. According to S&P Global Mobility's latest Light Vehicle Propulsion Forecast, by 2030 China production is slated to be over 46% BEV, Europe will be at 61% BEV and North America will be more than 30% focused on BEV.

From my conversations across the industry, there already is considerable evidence that suppliers whose business is primarily dependent on ICE propulsion systems are under increasing pressure on volume and resources. The ongoing semiconductor crisis, which may not be alleviated for another year, and other supply chain constraints, including those related to the Russia-Ukraine war, are frustrating the industry's ability to deliver a smooth transition.

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OEM procurement organizations will need to master a balancing act.

Company leaders also are worried about prospects for a steep decline in future vehicle demand spurred by growth of BEV-based product being substituted for ICE versions. Cascading from this is subsequent pressure on capacity utilization and longer sourcing cycles (extended from the classic 5-year all-new/refresh/all-new cycle). OEMs that are increasingly dedicated to BEVs will not require significant ICE system innovation. This has serious potential to hamper their ability to replenish margins with the sourcing of new technology. Several suppliers in the engine, transmission and other areas of the traditional-driveline space may be in the crosshairs.

What are the options for an ICE-focused, component or systems suppliers facing the BEV juggernaut over the next decade? It depends on a myriad of factors. The major variables include ownership structure, financial health, global breadth, affiliations, talent, the ability to shift current processes to BEV-positive technologies and aftermarket exposure. Smooth transition to BEV supply is not an easy task.

OEM procurement organizations will need to master a balancing act of building a supply network for increasing volumes of BEV-focused systems while maintaining their current ICE-focused suppliers as volumes decline or plateau at new lower levels. Ensuring the continuity of supply and the viability of their supply partners over this transition is uncharted territory. Not everyone will win. Yes, the best word to describe the transition is "lumpy." ■

EXPERT Insight

NI Builds on Four Decades of Testing Experience with new Battery Test System

NI accelerates the Future of Transportation by Transforming Test into an Enabler of Product Performance. For SAE's Expert Insight, Felipe Quintana, Systems Engineer at NI, pulls from his experience from working with the Battery Test System, and surfaces the details that are most relevant for engineers to perform at their best when validating EV batteries. SAE's Automotive Engineering *spoke with Quintana about the company's new Battery Test System (BTS) and how this unique fusion of software and hardware can reduce testing times and increase testing efficiency and performance.*

***Automotive Engineering:* Properly testing and validating batteries requires a lot of time. How can NI's new Battery Test System help the testing lab reduce the total amount of time spent in testing and validation?**
Quintana: When designing the NI battery-test platform, we put a lot of effort and thought around lab workflows and lab personas, as well as the responsibilities of these personas. The platform's user experience design allows proper distribution of tasks so that each individual or each team can focus on their area of expertise. Another relevant point: our configuration-based platform allows test engineers to focus on creating test plans and testing the product rather than spending their time on building or sustaining the test infrastructure.

Additionally, our platform is IoT centric, and it lets the user manage systems and monitor tests remotely, while also having access to all the data being collected at the lab in the form of data logs that you can review after the fact or after testing, but also in the form of real-time dashboards. So, the days when engineers walked around the lab grabbing data computer by computer with a USB flash drive is something we've put an end to with this platform.


Felipe Quintana

***Automotive Engineering:* The Battery Test System merges software and hardware functions. Does NI develop its own software – and is software a key factor in the system's flexibility and customization?**
Quintana: Yes, NI has developed its battery test platform hardware and software building on over 45 years of test and measurement experience and it is an expandable and customizable platform. The platform leverages NI software such as VeriStand, which is our real-time test engine, as well as TestStand, our industry leading test executive, and SystemLink. SystemLink is a powerful tool that allows test-site management, automated software deployment, centralized result collection, test-data management, and data analysis, in addition to other tasks that we have identified as relevant to the future of battery testing. With regards to flexibility and customization, NI products are all modular and flexible, customizable by design.

***Automotive Engineering:* Management of testing data is increasingly vital. What specific features in the Battery Test System optimize data efficiency and archiving?**
Quintana: Data collection and data analysis have been historically, I would say, neglected by test systems and test engineers. Our IoT-centric infrastructure allows the test systems on the floor to report results, status, and raw data to a SystemLink server. In the SystemLink server, the data is safely stored and managed. Engineers no longer need to be on site to be efficient because they have access to all this data remotely. The platform also makes it easy to automate and perform data analytics on the data sets and get actionable data insights. Once in the server, the data is easy to query, categorize and search. You can create automated Python scripts or Jupyter-based data analysis – and we even offer integration with Grafana to help you visualize your data through interactive dashboards.

***Automotive Engineering:* NI's Battery Test System incorporates a hardware abstraction layer. How vital is that and how is hardware abstraction different from simulation?**
Quintana: The capital investment needed for battery testing is high. In practice, this means that even when a customer might want to change their battery-test solution, they are forced to keep existing hardware, and they might only have the flexibility of changing software due to budget constraints. We frequently see customers with a variety of hardware – new and old from different brands, different models – and they want to keep it. The hardware abstraction layer decouples the software from hardware and makes the overall software agnostic of the brand or model of the hardware being used, so you don't have to completely re-work the software just because you changed hardware.

Simulation is the idea of replacing real hardware with simulated virtual hardware. Hardware abstraction layers and simulated hardware are correlated in the sense that once a hardware abstraction layer has been established, the physical hardware can be replaced with simulated hardware; the software, again, is agnostic. This is obviously a great flexibility that lets you accelerate the time to market and lets you keep up with the current trends, such as working from home. ■

Watch the full interview with Felipe.

PROPULSION

SAE WCX 2022: ICE won't melt amid shift to EVs

Top powertrain experts discuss the ICE + electrifed future at SAE WCX 2022. From left: Moderator and veteran AVL exec Ray Corbin at podium; GM's Dan Nicholson; Dante Boutell with Toyota; Denso's Andrew Clemence, and Dave Filipe with Ford.

The transition to electrified vehicles in OEM portfolios is progressing, but internal combustion engines (ICE) will continue to power millions of new vehicles for a still undetermined period, according to top powertrain executives. "Let's just say that by the end of the decade, it's a 50/50 mix of ICE and BEV [battery electric vehicles]. But that 50 percent ICE is going to be heavily influenced by the hybrids," David Filipe, VP of vehicle hardware modules at **Ford Motor Co.**, said during the April 7 "The Future Powertrain-Propulsion Portfolio Challenge" panel session at April's **SAE** WCX 2022 conference in Detroit.

Filipe offered this statistic: Of the orders taken to date for the 2022 Ford Maverick, 67% are for the compact pickup's standard hybrid powertrain, a 2.5-L Atkinson-cycle 4-cylinder SAE-rated at 191 hp (142 kW) when combined with the electric motor. Maverick's optional engine is a 2.0-L EcoBoost 250-hp (186-kW) gasoline engine. Ford will launch more hybrids in the future, Filipe confirmed.

One-quarter of vehicle sales last year for **Toyota** were electrified vehicles, the vast majority hybrids. The automaker's future includes BEVs, hybrid- and plug-in hybrid vehicles and fuel cell EVs. "We don't believe a one-size-fits-all approach will work," Dante Boutell, VP of powertrain design for Toyota North America, told the SAE audience. "There are customers out there that have specific needs that require multiple technologies and systems."

General Motors' road to zero emissions includes 30 new EVs by 2025. The automaker is investing $35 billion through 2025 for its EV and autonomous-vehicle portfolios. "We intend to be the electric-vehicle market leader in the U.S. market by the end of decade," asserted Dan Nicholson, GM's VP of global electrification, controls, software and electronics. Even though electrified vehicles are making significant inroads, Ford's Filipe predicts that ICEs will be in-play for another 10, 15, possibly 20 years. Said GM's Nicholson, "I don't know of any OEM that has made its last [IC] engine or is done with [ICE]."

Supporting ICEs

The protracted shift from ICE-powered to electrified vehicles is keeping the supply chain very busy. "There's going to remain a market for ICE, and the supply base is going to be challenged with the diversity of technologies required," said Andrew Clemence, senior VP of green technology and the electrification business unit leader at **Denso North America**.

The progression to electrified vehicles requires a balance with ICE. Ford's Filipe noted that in the past decade, conventional powertrains were typically upgraded every three to five years – "a very quick rate of updates in technology," Filipe said. "We're going to slow that down. But we still need to make the updates" to meet ongoing emission requirements.

According to Toyota's Boutell, whether ICE technology updates are compliance-related,

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ADAM ISOVITSCH/SAE

performance-related or cost-related, there likely will be opportunities to commoditize and simplify things. "Although a lot of money and a lot of manpower are going to be funneled toward electrification, we still have to pay attention to the engines we have in the market and will have in the market for many years," he said.

Denso's Clemence said that while suppliers follow the lead of their OEM customers, "we do have to choose and focus where we think we can bring the most value to our customers," he said. Denso is "very focused" on electrification technology, but "we're not going to leave our customers without a choice in the ICE area, so we'll continue to support that," Clemence declared.

According to Ford, 67% of the orders taken for the 2022 Maverick are for the standard hybrid powertrain.

FORD

Workforce impact

Providing technology for ICE-powered vehicles and electrified vehicles has prompted Denso to prepare its workforce and share resources across different product groups. "So that we don't get stuck in silos, we allow the opportunity for associates to rotate, up-skill, re-skill, so we can repurpose them in these new areas that are going to be important for our success in the future," he explained.

On the EV front, grabbing buyers beyond the early adopters means the industry must find ways to alleviate concerns over range anxiety and other so-called grief points. EV drivers need to find reliable, ready-to-use fast charging en route. "Our development fleets feel the pain that customers feel," said GM's Nicholson. Added Toyota's Boutell, "To get to mass adoption of BEVs, we need to address the values to the customer, and one of the values is convenience."

Kami Buchholz

PROPULSION

ICE life extension: searching for more solutions

Whichever way you "slice" it, the future of the 150-year-old internal combustion engine is moving steadily into the hands of global emissions-policy regulators. New ICE programs are dwindling amid the electrification juggernaut. Fuels chemists and combustion scientists are fighting a rear-guard action to keep the "heat engine" viable in the face of ever-tighter tailpipe standards for both light-duty vehicles and commercial trucks and equipment. For many emission-control system suppliers, the sunset is already beginning. The key question is, how quickly will it arrive?

"The continued development of ICEs must support de-carbonization," asserted Jim Szybist, senior research staff scientist at **Oak Ridge National Laboratory**, who kicked off the 2022 SLICE (Sustainable Low-Impact Combustion Engine) Symposium, held during the first day of SAE International's annual WCX World Congress in Detroit. Reducing greenhouse-gas (GHG) emissions is now the dominant driver in ongoing ICE planning and fuels/technology development, Szybist noted, particularly for the light-duty vehicle sector responsible for 57% of transport-generated GHGs.

The sharpened focus on GHG emissions, amid industry's shift to EV development, prompted SAE advanced-powertrain committees to pivot their annual High-Efficiency IC Engines meeting toward one incorporating sustainable/renewable-fuels research discussions. Hence the creation of SLICE. The symposium's main audience – fuels experts, commercial-diesel engineers, combustion- and aftertreatment-systems engineers, and scientists from research universities and the U.S. national laboratories – was reflected in the packed meeting room on April 4.

Life-cycle analysis (LCA) is playing a significant role in both product and policy planning, explained Dr. Michael Geller, deputy director of the **Manufacturers of Emission Controls Association** (MECA). His SLICE keynote presentation, "Integrated Approach to Mobile-Source GHG Reductions," highlighted the industry's collective progress toward meeting the Biden administration's GHG reduction goals for 2030 (50-52% lower than in 2005). "We're almost there," he observed.

GHG emissions reduction is the focus for all ICE developments going forward, said ORNL's Jim Szybist.

Geller also clearly noted the challenges and uncertainties facing the industry, including the significant impact of grid-CO2 intensity on upstream GHG emissions, the pace of renewable-energy power, and EV battery development and cost. While bullish on the influence of increased penetration of hybrids and EVs on overall GHG reduction, Geller, an environmental engineer and former **EPA** official with deep experience in GHG and particulate emissions, stressed the challenge of electrifying transport sectors beyond LDVs, particularly aircraft. Biofuels from renewables, he said, "are at the forefront" of GHG mitigation in aviation.

Subsequent presenters at the 2022 SLICE detailed developments in hydrogen, methanol, ammonia, synthetics and other potential fuel solutions for large-displacement commercial ICEs, as the drive to promote a lower carbon footprint and lower emissions across all transportation sectors gains steam.

Lindsay Brooke

PROPULSION

Stellantis' Hurricane is coming

Although **Stellantis** has announced its intent to have EVs account for at least 50% of its sales mix by 2030, this week Micky Bly, the company's Head of Propulsion Systems, revealed an all-new 3.0L inline six-cylinder engine dubbed Hurricane. "Internal-combustion engines will play a key role in our portfolio for years to come," Bly declared, "and we owe it to our customers and the environment to provide the cleanest, most-efficient propulsion possible."

He said the twin-turbocharged Hurricane I-6 is a "clean-sheet" design that at once will outperform larger-displacement engines (read: the V8s American customers revere in pickup trucks and SUVs) while offering better fuel economy and reduced emissions. The inline 6-cylinder layout has long been a favorite of engine developers because of its inherent balance and superior NVH qualities, but Bly noted another factor: "It sounds wonderful."

Initially, the 3.0L Hurricane, developed in SO (standard output) and HO (high-output) variants, will be built at Stellantis' engine plant in Saltillo, Mexico. Bly confirmed there is potential to add Hurricane production at a company engine-building site in the U.S. Currently installed capacity at the Saltillo plant is approximately 250,000 units.

Bly said the Hurricane will be available in some Stellantis models this year. Although he would not be specific about vehicle applications, he noted that the new inline six is intended only for vehicles with longitudinal engine placement. "It fits in any [longitudinal-engine] vehicle that has a V6 or V8 today," he said. More specifically, "The Hurricane twin-turbo I-6 is the primary internal combustion powerplant of the future in North America for vehicles using the STLA Large and STLA Frame platforms," said the company in a release.

Although Bly would not confirm it, the Hurricane engines likely will immediately displace at least some volume of

LINDSAY BROOKE

the company's celebrated "Hemi" V8 – not to mention the 3.6L V6 also used in many truck, SUV and passenger-car models – as the company seeks to address increasing regulatory pressure to reduce greenhouse-gas emissions. Stellantis recently seems to have been deemphasizing Hemi branding in vehicle engine bays and the Hurricane SO outpowers the Hemi 5.7L V8, which currently generates 395 hp and 410 lb-ft (556 Nm) in the Ram 1500, for example.

The Hurricane moniker is not new for the company. Its Willys and AMC predecessors used the name in the 1950s through the early 1970s for a 4-cyl. engine used in various Jeep CJs and trucks and Willys-brand sedans.

"[ICEs] will play a key role in our portfolio for years to come, and we owe it to our customers and the environment to provide the cleanest, most-efficient propulsion possible."

Note side-mounted intercooler on the High-Output variant of Stellantis' new I-6.

STELLANTIS

Power or efficiency paths

The company said that the SO variant of the Hurricane I-6 is "optimized for efficiency," but at an SAE-certified estimated 400-plus hp (Stellantis said final horsepower and torque figures will vary based on model application), it generates a minimum of 133 hp/L, a power density that Bly said places the engine "at the leading edge of horsepower per liter." The Hurricane SO will be rated for a minimum of 450 lb-ft (610 Nm).

Bly said 90% of peak torque is available over a 4000-rpm range. The engine's redline is a comparatively unstressed 5800 rpm and the company said the engine is up to 15% more efficient than larger engines. The Hurricane HO 3.0L is SAE-rated at a minimum of 500 hp and 475 lb-ft (644 Nm). Its redline is 6100 rpm. Total engine weight is about 441 lb. (220 kg), or around 11 lb. (5 kg) more than the Hurricane SO.

Some 3 lb. (1.4 kg) per engine is saved via the use of plasma transfer-wire arc (PTWA) coating of the cylinder bores instead of fitting iron liners. The low-friction coating, used by Ford, Porsche and other automakers, also is 10 times more wear-resistant than an iron liner, Bly said. The Hurricane uses a deep-skirt aluminum block and structural aluminum oil pan topped by DOHC cylinder head. Variable valve timing imparts 60 deg. of crankshaft authority on the intake valves and 55 deg. on the exhaust side. The Hurricane is fitted with a forged-steel crankshaft and connecting rods.

The new Hurricane design shares its 84 x 90-mm bore and stroke (3.31 x 3.54-in.) dimensions – as well as bore spacing – with Stellantis' global 4-cyl. engine family. The "common-cylinder" format – also used by other global automakers – could "maybe lead to other future spinoffs," Bly allowed. He suggested a 3-cyl. variant is unlikely, given the existing strength of the 3-cyl. family from the PSA Peugeot-Citroen side of the Stellantis propulsion portfolio.

Bly said the two Hurricane variants share about 96 common parts. The differences in output between the SO and HO effectively define the variant-specific components.

The twin turbochargers of the Hurricane SO operate at a peak 22.4 psi (1.5 bar) versus the 26 psi (1.8 bar) of the HO. The Hurricane SO operates at a 10.4:1 compression ratio compared to the 9.5:1 compression ratio for the HO variant. At a sensitive time for gasoline prices, Bly confirmed that for the Hurricane SO, premium unleaded gasoline is recommended but not required – for the HO, premium unleaded is a requirement.

The two engines also have different thermal-management and fuel-injection systems. The engine-mounted water-to-air intake-charge cooler has a single inlet for Hurricane SO and dual inlets for the HO variant.

Meanwhile, the 350-bar (5075-psi) direct-injection system has a single pump for the SO and dual pumps for the HO; a separate chain-driven shaft energizes the pumps.

For now, the new engine is fitted with a stop-start system, but Bly said the new Hurricane is capable for future hybridization.

Bill Visnic

Bringing back the hot hatch: 2023 Toyota GR Corolla

Fulfilling a commitment to offer more thrilling rolling stock, Toyota recently revealed its new 2023 GR Corolla, a turbocharged, all-wheel-drive (AWD) 5-door C-class hot hatchback developed by its Gazoo Racing (GR) performance division. Sharing drivetrain components with the smaller and not-for-U.S.-sale GR Yaris, the sinister-looking compact's sole transmission offering will be a rev-matching 6-speed manual. With only a few front-wheel-drive competitors remaining in the segment, including **Honda**'s Civic Type-R and **Hyundai**'s Veloster N, Toyota provided no pricing, but confirmed the AWD GR Corolla will go on sale in the U.S. later this year.

Things are getting serious: Toyota's all-new all-wheel-drive 2023 GR Corolla.

As Toyota Gazoo Racing's first wholly developed and manufactured model for the North American market, the GR Corolla is propelled by a more-powerful version of the G16E-GTS turbocharged, direct-and-port injected 3-cyl. used in the GR Yaris. In the GR Corolla, the 1.6L delivers 300 hp (224 kW) and 273 lb-ft (370 Nm) – a 32 hp/24 kW gain compared to the GR Yaris. The 12-valve, DOHC engine features a single-scroll, ball-bearing turbo integrated into the exhaust manifold. It delivers peak torque from 3000-5500 rpm and max hp at 6500 rpm.

The GR Corolla features the same GR-Four AWD system from the GR Yaris. The system provides selectable power-distribution settings, giving drivers a choice of 60/40, 50/50 or 30/70 front/rear power splits. Open front and rear differentials are standard, with optional Torsen limited-slip differentials available at both axles.

Dedicated GR production

Toyota has established a dedicated GR production center at its factory in Motomachi, Japan (previously home to Lexus LFA supercar production), which will manage assembly of both the GR Corolla and Yaris. The GR Corolla is built on Toyota's GA-C platform, with frame reinforcements developed at the Motomachi plant. The additional rigidity comes from "significantly more" frame-weld points to strengthen joints, and extensive use of structural adhesives to increase joint rigidity between components.

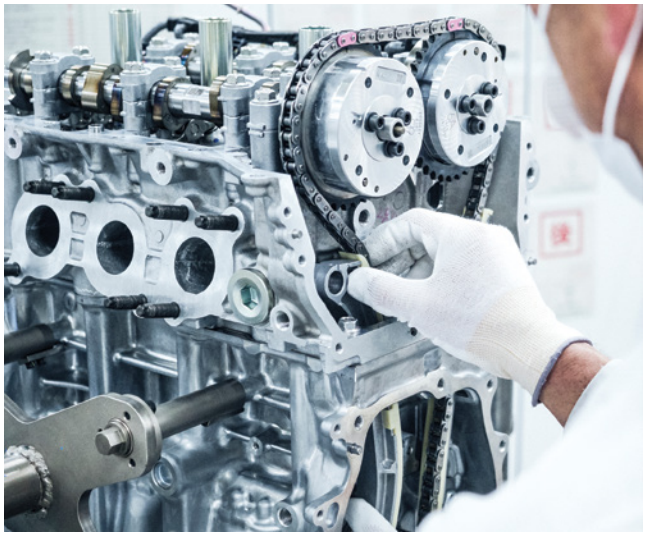
Eschewing a traditional conveyor system, the GR Corolla's body and assembly lines consist of multiple stations serviced by automatic guided vehicles (AGVs). Toyota claims that although this setup takes longer than a conventional mass-produced car, the fully flexible method enables many manual-assembly techniques to ensure precise body and suspension alignment, while reducing dimensional variation and keeping additional weight to a minimum.

With a 103.9-in. (2,639 mm) wheelbase, the GA Corolla's front suspension is by specially tuned MacPherson struts with stabilizer bars. The rear suspension uses a double-wishbone type multilink system. The car's serious intent is highlighted by its upsized brakes and sticky **Michelin** Pilot Sport 4 tires (235/40R18) at each corner.

The GR Corolla will come in two grades, Core and Circuit Edition. The Core trim will be available first in late 2022. The limited-run (1,500 units for the U.S.) Circuit Edition will arrive in 2023, equipped with most of the Core-grade options, including the Torsen differentials, a technology package with premium **JBL** audio and Qi-compatible wireless charging and a cold-weather package sporting heated front seats and steering wheel.

Toyota will also provide new GR Corolla owners with a complimentary 1-year membership in the **National Auto Sport Association**.

Paul Seredynski



The new GR Corolla is powered by a higher-output version of the G16E-GTS turbocharged, direct-and-port injected 3-cyl. used in the GR Yaris.

BOTH IMAGES: TOYOTA

2022 Grand Cherokee plugs in

Water's no worry for the first-ever hybrid variant of Jeep's Grand Cherokee.

Plug-in hybrids are a controversial subject in engineering and product-planning circles. With a modicum of electric-only capability and superior driving range but retaining the tailpipe emissions and cost/complexity burden of two powertrains, PHEVs are a polarizing yet ideal product for certain applications.

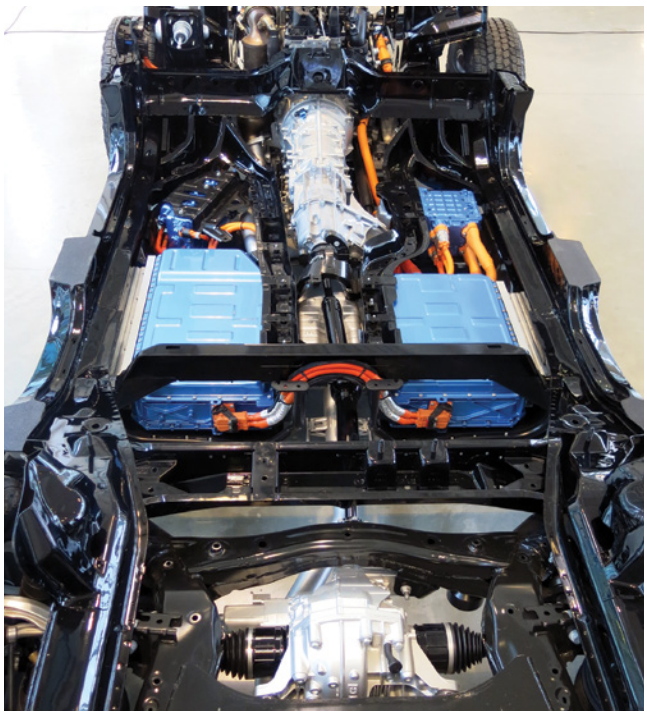
Clawing confidently across Texas slickrock, with only its batteries providing drive torque to all four wheels, the all-new 2022 **Jeep** Grand Cherokee 4xe makes a strong case for PHEV in the SUV segment. Off road operation is as quiet as a mountain bike to other trail users, and in moderate thermal conditions the "4-by-e" Grand Cherokee can travel up to 25 miles (40 km) before the long-stroke 2.0-L turbocharged Otto-cycle engine (part of Stellantis' GMET family, made in Italy) engages. When it does, as SAE Media experienced during the 4xe's recent launch event, the transition is smooth and nearly seamless. And in very cold ambient temperatures, the hybrid system defaults to combustion-engine power, based on coolant temperature, a feature that customers in four-season markets will appreciate. With 470 lb-ft (637 Nm) of total system torque on tap, there is a lot to like about the fifth-generation Grand Cherokee configured for plug-in duty.

Jeep planners and many customers agree. The Wrangler 4xe, with essentially the same hybrid-electric system as the Grand Cherokee, is the top-selling PHEV in North America. Jeep brand CEO Christian Meunier says "4-by-e is the new 4-by-4," whether serving as a pathway to battery-electric Jeeps in 2025 or filling a longer role in the Jeep portfolio. The plug-in powertrain is available on the standard Grand Cherokee as well as Trailhawk, Overland, and Summit trims.

Simulation sped development

"We knew electrification was a requirement" for the 2022 model, explained Grand Cherokee vehicle line executive Tom Seel, "but it was also a requirement to not compromise the customer package or comfort." The development team packaged the twin lithium-ion NMC battery packs as low as possible in the unibody structure, ahead of the second-row seat crossmember, to maintain a center of gravity conducive to good vehicle dynamics. Each of the batteries, supplied by Stellantis partner **Samsung SDI**, contain 48 nickel manganese cobalt (NMC) cells, same as the Jeep Wrangler 4xe. The 400-volt system incorporates a dedicated thermal management system with coolant heater. It delivers a total of 17 kWh without reducing the non-hybrid model's rear occupant leg room (38.2 in./971 mm) and knee room 4.1 in./103 mm).

Seel described engineering the vehicle's high-voltage cable routing as a balancing act between product and process. "All the routings had to be engineered for the [in-plant assembly] process," he explained. "We completed, with manufacturing engineering, numerous virtual simulations of the process of connecting all the high-voltage cables prior to any hardware being built. This ensured that we'd have quality connections to support the electrified vehicle."



Naked display chassis shows packaging for the Grand Cherokee 4xe's twin battery packs, hybrid transmission, electronic power control modules and ZF rear diff module.

FROM TOP: STELLANTIS; LINDSAY BROOKE

The 2022 Grand Cherokee 4xe's all-electric drive mode has no compromises in extreme off-road driving.

Maximum battery charge rate with an SAE J1772 connector is 7.2 kW. According to vehicle synthesis manager Eunjoo Hopkins, charging the 4xe on Level 1 requires 12-14 hours; Level 2 charging takes 3-4 hours.

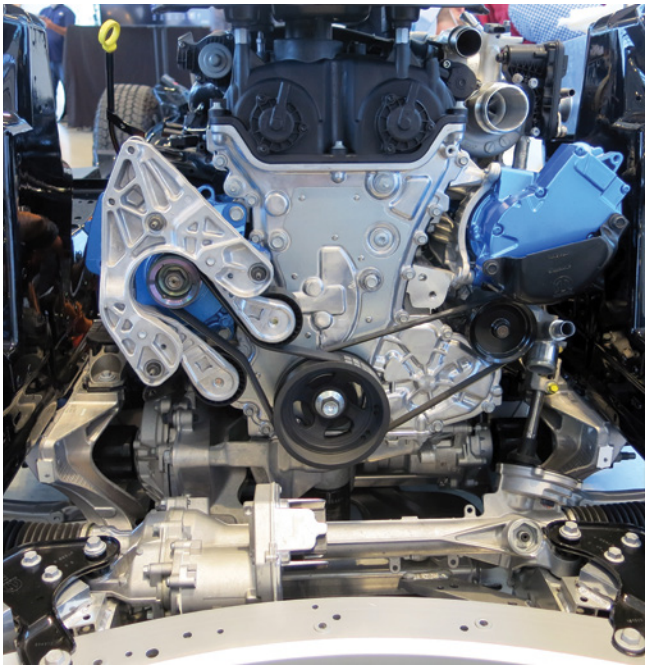
A naked Grand Cherokee 4xe chassis on display at the media launch event showed a very robust, almost military-grade-looking high-voltage electrical network. All connectors are sealed—a requirement for Jeep's 24 in./609 mm water fording specification. Across the underbody, 3.5-mm (.137-in.) steel skidplates shield the batteries and electronic components.

With the battery packs positioned, Seel's team turned to reengineering the exhaust system, incorporating an active noise cancellation package with center sound resonator and a transverse muffler in the rear. Positioning the inverter and other key PHEV electronic modules, including a new electronic brake module (it allows for increased rate of hydraulic pressure build to facilitate torque transfer) required unique structures to be added, Seel noted. The changes include a floorpan stamping that is unique to the 4xe model. The plug-in, rated at 57 mpg-e, uses a 19-gal. (72-L) fuel tank, versus the 23-gal. (87-L) vessel used by the 3.6-L V6 and 5.7-L V8 models.

Close inspection of the 4xe chassis reveals how smart component design helped solve various packaging challenges. The densely-packed space around and under the ICE and **ZF**-licensed 8P75PH hybrid transmission include active engine mounts, an electric power steering system (EPAS), an electrically-disconnecting front sway bar, and a front drive module directly mounted to the engine with half shafts that extend through the oil pan. The sway bar system helps deliver a 455 ramp-travel index (a key axle-articulation metric) that is a 20% improvement over the previous-gen vehicle. Engineers also increased the OR2 (off-road) suspension travel by 15 mm (.59 in.), enabling a total ground clearance of 10.9 in. (254 mm) at full extension.

Useful drive modes

As on the Wrangler 4xe, the "e-Torque" hybrid system combines a 44-hp (33-kW) engine-mounted (P1) belt-starter generator delivering torque to the crankshaft and start-stop functionality, with a 134 hp (100 kW) AC traction motor mounted in the P2 position between the engine and 8-speed transmission, replacing the torque converter. A clutch manages the torque input from the 2.0-L engine; when the clutch is open, the motor-generator drives the transmission for full-electric operation. The system also manages the re-gen braking.



P1-hybridized engine, EPAS, electronic sway bar and front axle disconnects, active engine mounts and direct-to-engine axle mounting make the Jeep WL's front end a tight space.

The 4xe uses a unique MP3028C active transfer case supplied by **Magna Powertrain**, featuring a 2-High selection for improved fuel economy. On Trailhawk models the T-case works with a ZF rear electronic limited-slip differential to improve traction by vectoring torque to the wheel with the most grip. When not in all-electric mode, the 4xe operates as a hybrid, providing greater range extension. The 4xe has a 3.70:1 rear-axle ratio, versus 3.45:1 for V6 and V8 models. The Trailhawk model's crawl ratio is 47.4:1, compared with 44:1 for the ICE-powered Trailhawk.

Three drive mode buttons on the IP allow driver selection of different driving modes. 'Hybrid' is the default. There's also Electric Only and E-Save, which charges the battery and conserves it for later use. In the E-Save mode, the driver can choose between two sub-options: Battery Save, where the vehicle uses all the available torque capacity while driving to maintain battery charge at a pre-set limit; or Battery Charge, which enables the 2.0-L engine to actively recharge the battery while driving.The 4xe can also optimize regenerative energy capture, via a driver-selectable Regen mode. The Max Regen function allows for maximum regen capture.

Both the PHEV and conventional Grand Cherokees are built on the same body line at Stellantis' Detroit Assembly-Mack complex.

Lindsay Brooke

FROM LEFT: MARK RICHARDSON; LINDSAY BROOKE

HONDA AIRS IT OUT

Aeroacoustic NVH testing is readily accommodated in Honda's all-new wind tunnel.

HONDA

Honda's aerodynamic and NVH development gets a breath of fresh air from its first full-scale wind tunnel in North America.

by Bill Visnic

Acknowledging the twin priorities of aerodynamic and NVH optimization in the increasingly electrified passenger-vehicle future, **Honda** in late March inaugurated its first full-scale wind tunnel in North America. The $124-million Honda Automotive Laboratories of Ohio (HALSO) facility, built on the grounds of Ohio's sprawling Transportation Research Center is conveniently adjacent to Honda's longstanding product-development and manufacturing hub that spans the East Liberty and Marysville areas.

"Conveniently located," isn't the half of it. Prior to the opening of the HALO wind tunnel – which currently is running a single shift but will be "fully operational" by fall 2022 – Honda's U.S. operations rented wind-tunnel time in a variety of locations because the company's only full-scale tunnels are in Japan and Europe. Shipping prototype vehicles and accompanying engineers and technicians to rented tunnels is an enormous direct cost, said Mike Unger, lead manager for the new facility. But maybe worse is the detrimental impact on ever-tightening vehicle-development timelines. It all can be a huge hassle, leading Honda some years ago to begin planning HALO's wind tunnel in Ohio.

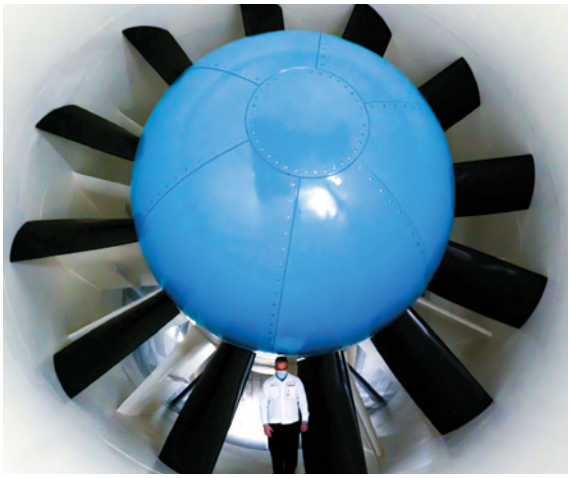
It is "the world's most-advanced wind tunnel," Unger flatly claimed during a media walkthrough of the 110,000-sq.ft. (33,528-sq.m) facility that houses the one-eighth-mile tunnel itself as well as a variety of no-prying-eyes "customer" workbays to serve the third-party entities envisioned to lease the facility as Honda reverses the renter-landlord relationship. Then again, Unger concedes, given the relative global scarcity of full-scale automotive wind tunnels, just about every totally new tunnel becomes the de facto world's best.

In the roughly two-year project, the designer and general contractor for HALO's wind tunnel was Dallas, Texas-based **Jacobs Technology**. The College of Engineering at **The Ohio State University** reported last year that as Honda was evaluating the wind tunnel project, company personnel visited **Pininfarina** in Italy and met Antonello Bianco, a wind-tunnel expert and currently senior researcher at OSU's Center for Automotive Research, who also advised Honda on the project.

Rolling-road modularity

A central feature of Honda's new wind tunnel is the novel "modular" moving ground plane ("rolling road") system that allows for quick, four-hour changes between the five-belt rolling-road dynamometer and a wide-belt rolling road. The belts, used to mimic the action of the vehicle in motion, are sheets of stainless-steel composite less than 1mm thick. Vehicles that are more or less conventional (i.e. crossovers, SUVs and other vehicles with everyday ground clearance) are tested on the five-belt module, one at each wheel and a wider belt running down the underbody of the vehicle. Special vents assure the flowing air isn't collecting in unwanted areas, particularly in front of the moving wheels. And to also ensure the least amount of rolling resistance, the vehicle's axles are disconnected

Forty-ton rolling-road modules can be relatively easily swapped in the wind-tunnel test chamber.



The heart of the wind tunnel's operation is the 6700-hp fan that can create up to 192-mph wind speed.

HALO wind tunnel control room during aeroacoustic testing.

and brake pads are removed.

For low-riding racecars and sportscars, the wide-belt ground plane – which can run at up to 193 mph (311 km/h) is more desirable because of the crucial nature of the air boundary layer at the front of the car. This is where the modular system – supplied by Minnesota-based **MTS** – comes into play. A crane positioned outside the testing area slides over to remove the rolling road as a self-contained, 40-ton cassette. Then the desired ground-plane dyno is inserted into its place. Although the four-hour time to swap between rolling-road modules is a boon, Unger concedes ideal test planning wouldn't rely on such hot swaps. Vehicles, meanwhile, can be changed in 60 minutes or less, Unger claimed.

Atop each rolling-road module is a 12-m. (39.4-foot) turntable to which the vehicle is secured. The turntable can be rotated to any position up to 180 degrees relative to the airflow. Underneath is an ultra-precise three-axis balance system that serves several purposes, one of the most important being to measure aerodynamic drag force. Honda said its sensitivity is plus-or-minus about 2.5 Newtons, or the weight of a D-size battery. The entire setup can assess some 2,700 channels measuring load, force and balance.

Aeroacoustic measures

To ascertain precise readings of general noise, flutter, frequency and other wind-generated effects, the new wind tunnel is designed to quickly and easily enable the setup of comprehensive acoustic arrays supplied by **Siemens**. The top, front, side and interior arrays can deploy up to 502 external microphones (as well as cameras) and 54 in-cabin microphones.

When the test chamber is set up for aeroacoustic NVH measurements, a special acoustic cover is placed on the turntable because the rolling road is not required when the only concern is the noise and other effects created by the wind. The chamber itself is painstakingly sound-deadened: at a wind force of 87 mph, there is just 56.5 dBA of

ALL IMAGES: HONDA

ambient noise, helping the microphones to pick up the most subtle of noises from airflow over the vehicle.

The wind-related NVH metrics don't stop with the microphone arrays. Interior noise testing also can encompass the use of the distinctive "Aachen head" acoustic test devices, which can perceive and record noise in the same fashion it would affect a human occupant.

Gale force – and then some

The wind tunnel's test chamber is set up as a "variable-nozzle" layout in that if the widest configuration of 25 sq. m (269 sq-ft) is used, the maximum air velocity equates to 155 mph (250 km/h). The tighter 18 sq-m (194 sq-ft) setup can deliver the tunnel's maximum 192 mph (310 km/h) wind speed. The airflow is generated by a **GE**-made fan that's 8m (26.3 ft) in diameter and is propelled by a 5-mW, 6,700-hp electric motor. The fan requires just 250 rpm to generate the facility's 192-mph maximum wind speed.

The wind tunnel's fan sits aft of the test chamber in terms of the airflow circuit. Just downstream of the fan is a 2-story-high wall that forms a hulking heat exchanger to deliver air to the test chamber at precisely the required temperate. The heat-exchanger wall circulates 16,000 gallons of propylene glycol to deliver constant air temperatures ranging from 50 deg. F (10 deg. C) to 122 deg. F (50 deg. C). Any temperature in that range can be achieved in a maximum of 30 minutes.

HONDA

Hulking heat-exchanger wall controls wind-tunnel air temperature.

Unger conceded that the industry's newest wind tunnel typically is judged "the best" given the roughly decade or more between new tunnel constructions. Some existing wind tunnels may be marginally better at some practice or another than Honda's new facility, he allowed, but in terms of breadth of capability, "this tunnel is unmatched," he said. ■

Two-wheeled tech:
The latest in motorcycle applications

Drawing heavily from automotive advances, the latest in connectivity, safety and convenience are infiltrating the moto world.

by Paul Seredynski

With summer looming in the northern hemisphere and the global COVID pandemic slowly abating, it's natural for enthusiast-engineers to shift focus towards two-wheeled pursuits, including the year's latest technologies. Trends that are altering the automotive landscape are making similar inroads on the motorcycle front, with the SUV-equivalent "adventure bike" morphing the sales landscape, and digital connectivity features supplanting horsepower in the eyes of many enthusiasts as must-have features.

With electrification making scarce OEM inroads [https://www.sae.org/news/2018/10/harley-davidson-electrics-up], and hydrogen [https://www.sae.org/news/2022/03/keeping-combustion-in-the-conversation] offering a scant lifeline for combustion fans, the largest trend in bikes is connectivity and its associated safety benefits. According to a 2021 survey available from **Research & Markets**, the motorcycle industry's connected- technology investment between 2021 and 2027 is expected to see a compound annual growth rate of 54.7% (from $55M to $757M). Embedded connectivity hardware is expected to constitute the majority of that investment, a trend already keenly visible in the market. We've curated some of latest technology applications, while many remain hopeful the sport retains its ability to help riders occasionally disconnect.

2022 KTM RC wheel/brake tech

KTM has updated its 2022 range of small-displacement RC sportbikes with new, lighter brake components and a lighter-but-stronger wheel design. This combination removed 7.5 lb (3.4 kg) of unsprung mass from the already lightweight RC 125 and RC 390 sportbikes. The all-new braking components comprise a radially mounted front 4-piston ByBre (the "by **Brembo**" subsidiary) caliper combined with a 320-mm brake rotor. The front setup is reminiscent of engineer Erik Buell's rim-mounted perimeter disc-brake system first used on the 2007 XBRR race bike. The KTM's single-piston rear caliper is paired with a 230-mm rotor, saving 2.2 lb (960g) over the previous design. The new wheel design with fewer spokes and open hubs saved 5.3 lb. (2.4 kg).

BMW smartphone cradle

Many bikes seen on the road today are sprouting aftermarket cellphone mounts; leave it to **BMW Motorrad** to intelligently integrate the nigh ubiquitous device. The ConnectedRide Cradle lets BMW motorcycle owners secure their smartphones for navigation or other functions high in the pilot's line of sight — and on compatible BMW models, employ the grip-mounted Multi-Controller and BMW Motorrad Connected App to control certain phone functions.

The cradle provides both Qi wireless charging or wired voltage via a USB-C connection and there is a locking mechanism for security. The cradle is compatible with most BMW models with "navigation prep" and equipped with Multi Controllers. Eligible smartphones must feature Bluetooth Low Energy version 4.2 and reside in a dimensional (height/width/depth) window between 130.1 x 65.5 x 6.9mm (5.1 x 2.3 x 0.27 in.) and 162.5 x 78.1 x 8.8mm (6.4 x 3.1 x 0.35 in.).

Bosch Help Connect

Taking advantage of smartphone ubiquity, **Bosch**'s new Help Connect system can use a phone to automatically summon help in case of an accident. Combining a smartphone app that leverages the device's built-in sensors, it uses an algorithm that evaluates speed, acceleration, and rotation to automatically detect a crash. If an incident is detected, the app can alert emergency services via the Bosch Help Connect emergency call center and direct services to the scene, transmitting current location, severity of the impact and optionally stored health data. The service currently is available in 11 European countries when using a German SIM card, and Help Connect also is being integrated into Bosch's IMU (inertial measurement unit) as part of its motorcycle stability control (MSC) setup. Via Bluetooth, it can connect to a corresponding smartphone app to transmit data to an emergency call center.

Continental MultiViu Sports display

With a 7-inch version appearing on the 2022 KTM 1290 Super Adventure S, **Continental**'s new MultiViu Sports display platform is a highly adaptable motorcycle instrument cluster based on a scalable development platform easily adapted to diverse applications. The automotive-grade display uses optical bonding technology to provide sharp images, and it will be offered in various sizes and aspect ratios in both portrait and landscape format. The TFT display features anti-glare and anti-reflection coatings, an 800x480-pixel resolution (for 5- and 7-inch sizes), a brightness value of 1,000 cd/m^2 and a contrast of 1,000:1. The Continental developer platform permits customized image content and simplified integration of external services such as weather info or music streaming, with future versions offering touchscreen functionality.

Two-wheeled tech:

The latest in motorcycle applications

Ducati Futa ebike

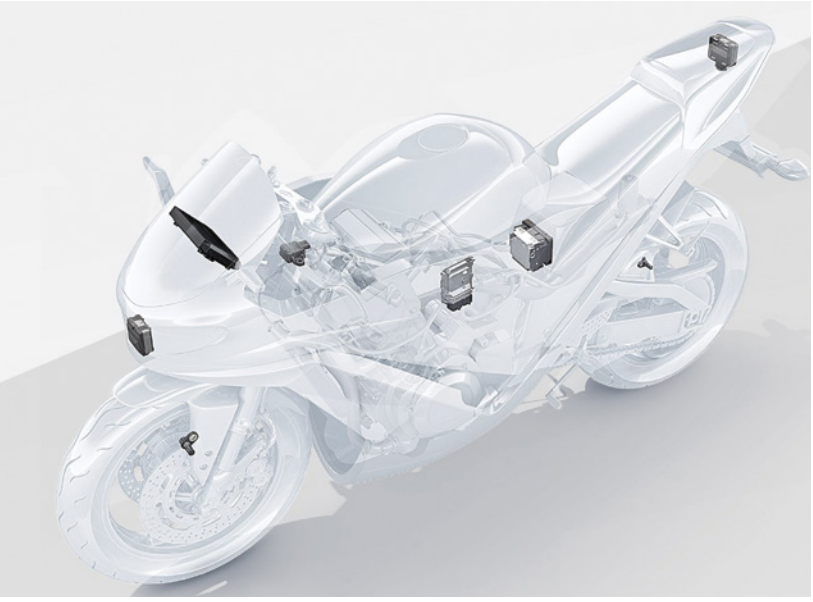
What moto-tech roundup is complete without a blood-red **Ducati** — even one with pedals? The new-for-2022 Ducati Futa electric-assist road bicycle is part of Ducati's partnership with Italian e-bike manufacturer Thok Bicycles and named for the famous Apennine pass. The Futa features a carbon-fiber monocoque frame housing a 250-Wh **FSA** battery and is electrically assisted by a rear-hub-mounted FSA System HM 1.0 motor; the 250-W electric machine can provide 42 Nm (31 lb-ft) up to the Euro assist limit of 25 km/h (15.5 mph). A **Garmin** controller on the handlebar manages the five levels of assist and an FSA smartphone app lets riders view system status and battery state-of-charge. Currently the lightest production Ducati at 12.4 kg (27.3 lb), Futa features wireless 2x12 electronic shifting, 160-mm brake rotors and carbon rims fitted with **Pirelli** Cinturato Velo TLR tires. An optional 250-Wh "water bottle" range extender also is available.

Harley-Davidson Adaptive Ride Height

One of the cleverest innovations in recent memory, **Harley-Davidson**'s optional Adaptive Ride Height (ARH) feature for the all-new Pan America 1250 Special can automatically transition the motorcycle between a lowered stopped position and a pre-set rolling ride height, reducing the seat height when stationary from 1 to 2 in. (24.5-49 mm). The lowering maximum is determined by the **Showa** rear shock's automatically selectable pre-load, which alters ride height when underway. ARH does not affect suspension travel or ride quality, and provides selectable sub-modes to tailor how quickly the linkage-based rear suspension lowers, the delay to when the lowering begins, or a locked mode for off-road riding.

Honda Africa Twin smartphone compatibility

Making it easier to get away but harder to escape, the 2022 **Honda** Africa Twin will feature compatibility with both **Apple** CarPlay and Android Auto via its 6.5-inch TFT display, matching the full integration that first debuted for the brand on the 2021 Gold Wing. New Africa Twin owners will be able to seamlessly integrate applications and services including music, phone calls and messaging when paired with a required Bluetooth headset.



Kawasaki adds Bosch ARAS safety suite

Joining BMW, KTM and Ducati [https://www.sae.org/news/2021/02/motorcycles-enter-the-adas-age], **Kawasaki** has integrated the latest radar-based Bosch advanced rider assist system (ARAS) to a top-tier model, the Ninja H2 SX SE. The plushest of Kawasaki's supercharged machines, the sport-touring H2 SX SE features radar-based adaptive cruise control (ACC), forward-collision warning (FCW) and blind-spot detection (BSD). Both ACC and FCW use a forward-facing radar sensor, while the BSD function uses a rear-facing radar sensor to register objects in harder-to-see areas on each side of the motorcycle, illuminating a built-in LED warning light in the associated rearview mirror. The system also will alert if a lane change is indicated by the turn signal while a vehicle is detected in the blind spot, flashing the mirror LED.

Marelli scooter inverter

Marelli will be supplying the inverter for the sleek new BMW CE 04 electric scooter. Developed and produced in-house by Marelli, the supplier also will provide the component's related software. An inverter enables conversion of the scooter's battery's DC power to the three-phase AC required by the electric propulsion motor. A two-wheeler's stringent dimensional limits, external environment and required high power density increased design challenges, the company said. On the CE 04, the inverter delivers 43.5 kW peak at nominal voltage of 145V, with full performance (300 ampere rms) in the 115- to 175-Volt range. Marelli's scalable architecture can produce more-powerful versions (up to 450 ampere rms/348 volt) within similar dimensions.

Two-wheeled tech:

The latest in motorcycle applications

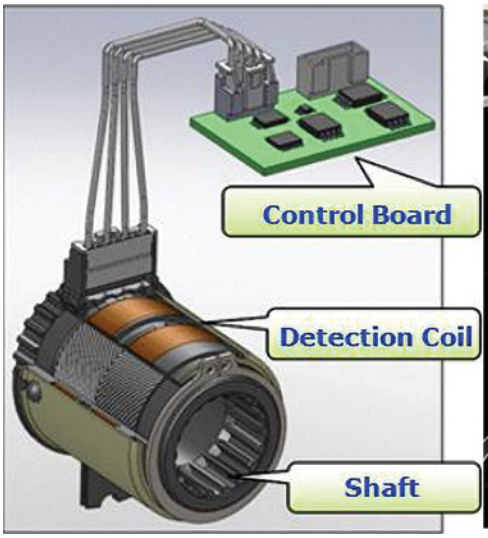
"Making it easier to get away but harder to escape, the 2022 Honda Africa Twin will feature compatibility with both Apple CarPlay and Android Auto."

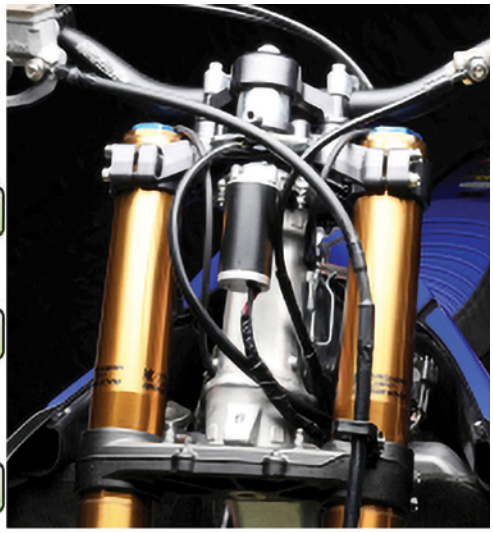
Triumph EV prototype progressing

Triumph announced in February that it had completed the collaboration stage of its TE-1 EV prototype project [https://www.sae.org/news/2021/04/toward-an-electric-two-wheeled-triumph] and would begin the electric motorcycle's testing program. Triumph has been working with **Williams Advanced Engineering**, **Integral Powertrain Ltd.** and the **University of Warwick** on the development of the naked performance machine. The prototype demonstrator is outfitted with a **Gates** Carbon belt drive, Öhlins suspension including a prototype rear shock and Brembo M50 monobloc calipers. It will undergo six months of rolling-road and track testing in preparation for active demonstrations and media engagement this summer.

Yamaha power steering

Yamaha Motor announced in March that it is developing an electric power steering (EPS) system for a "wide range" of motorcycles. Two Yamaha Factory Racing Team machines (a YZ450FM and a YZ250F) will be fitted with the systems and compete in the 2022 All Japan Motocross Championship to gather data. The EPS system employs a magnetostrictive torque sensor (derived from Yamaha's e-bicycle motors) that enables it to function as a steering damper and provide assist, improving stability and agility while reducing rider fatigue, the company claims. ■





Niobium oxide research at the CBMM laboratory in Araxa, Brazil.

CBMM

NIOBIUM: magic metal for battery anodes?

Increased cell capacity and rapid recharging in thermal extremes are potential benefits of electrode chemistries fortified by the humble element Nb.

by Kevin Cameron

The element niobium (Nb), a transition metal, stands ready to improve the performance of one of the lithium-ion battery's confusing array of possible electrode chemistries — the LTO (lithium titanium oxide) anode, which after graphite is the second most-produced.

During battery charging, lithium ions leave the positive cathode and move through the battery's electrolyte to take up positions of higher energy in the anode. During discharge, this process reverses and drives electrons through an external circuit to power the load. Most desired in an anode is large surface area in which a great number of lithium ions can take positions, giving potential for high energy storage. Also desirable is an open structure offering little resistance to the movement of ions, to allow rapid charge/discharge without excess heating.

The warm undersides of laptops remind us that this resistance is real. This is analogous to the loading and unloading of airliners. For maximum capacity we must put seats everywhere, but "resistance" — the difficulty of reaching your seat — is extreme. Seating area is sacrificed to provide one or more aisles to speed passenger movement.

Carbon as a Li-ion battery anode offers tremendous surface area but its volume increases and decreases as lithium ions enter and depart, producing cyclic strain that in time detaches carbon particles that may lead to battery self-discharge. Carbon anodes are potentially subject to "lithiation" — the deposition of metallic lithium, a possible consequence of which is the growth of dendrites (like the growth of "whiskers" sometimes seen protruding from tin plating). Dendrite growth can perforate the membrane separating anode and cathode, allowing self-discharge and runaway heating that can burst containment and ignite the organic electrolyte.

All this quickly becomes too complicated to hold the interest of non-specialists. Yet research in countless corporate and university laboratories produces steady reporting of "breakthroughs" by tech websites, each maximizing "clicks" by giving the impression that the long-hoped-for Super Battery will hit the market by Friday at the latest. When you puzzle through these announcements, you find most relate to small refinements — a new fire-retardant for the electrolyte or means of enhancing electrode conductivity with finely-divided graphite. Incremental improvements are important but seldom revolutionary.

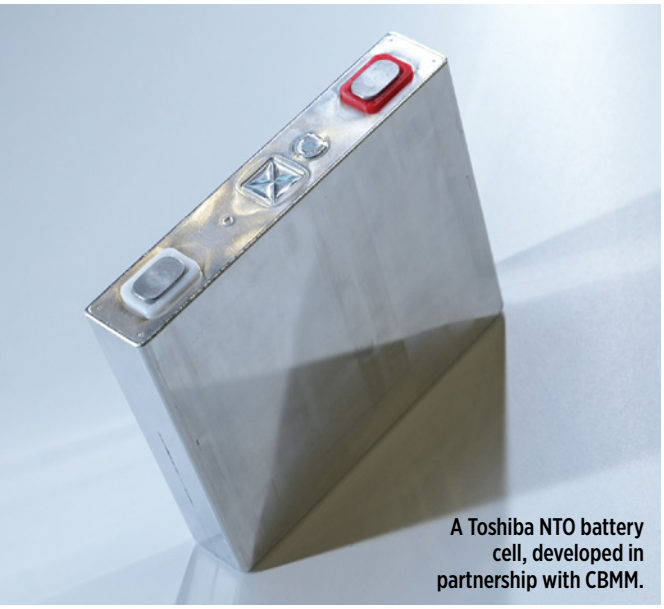
Chemistry trade-offs

There are also the enduring holy grails of battery technology, offering promise of revolutionary energy density, such as the lithium-air cell, offering ten times the theoretical energy density of the best on today's market, and on which **IBM** expended three years' research. Or the theoretical potential of a nanosilicon anode. Their promise remains to be realized. There is a romantic urge to believe that someone (possibly resembling the comic character Gyro Gearloose), working in a basement, will stumble upon something that works.

The properties of Li-ion batteries are pictured as wheels, the length of each "spoke" corresponding to one aspect of performance: cost, safety, life, specific energy storage, speed of charge and discharge. No truly well-rounded electrode chemistry has appeared, so the business pursues several chemistries, each specialized for particular applications. **Tesla** has focused until recently on cathodes of NCA (nickel cobalt aluminum oxide) for their high specific energy. Along with **VW**, **Rivian** and **Ford**, Tesla has shifted to the high-current LFP (lithium iron phosphate) cathode long favored by power tool manufacturers and Chinese battery-and-vehicle maker, **BYD**. LFP cells offer lower specific energy

NIOBIUM: magic metal for battery anodes?

"Niobium's ability to assume multiple oxidative states is basic to the expanded capabilities."



A Toshiba NTO battery cell, developed in partnership with CBMM.

Niobium-based anodes are also gaining favor among electric motorcycle OEMs. U.S.-based Lightning Motorcycles, maker of the Strike Carbon superbike shown, partnered with CBMM on NTO cells it used to set the world speed record (215.907 mph) for electric two-wheelers. Another electric-bike maker, Brazil-based Horwin, is working with CBMM and expects to launch its first NTO-battery-powered bike by 2024.

and are more thermally stable. Another strategy is the hybrid battery, which seeks a "rounder wheel" by combining one battery of high specific energy chemistry with another having high current chemistry, with the latter being recharged by the former.

Anodes such as LTO (lithium titanium oxide), with an open-spinel chemical structure, allow high current and rapid charging with good safety and outstanding cycle life (thousands, not hundreds of cycles). But their specific energy storage capability is much inferior to that of batteries favored for camera/laptop/phone or EV applications. These qualities have given it a place in powering electric city buses on short, repetitive routes. High charge/discharge current and very high cycle life allow a 6-minute charge at either end of a route to provide adequate power and longevity.

Curb your enthusiasm

And what of niobium? **Toshiba** in Japan has marketed its LTO battery since 2008, while research into open-structured anodes has continued in many places. It has been discovered that a niobium titanium oxide (NTO) structure has a theoretical volume capacity (mAh/cm^3) three times that of LTO, making NTO a potential competitor in the EV market. It is claimed that the resulting battery maintains 90% of its initial capacity after 5,000 charge/discharge cycles, retaining LTO's ability to be rapidly recharged in temperature as low as 14°F (-10°C).

These new anode materials are described as Wadsley-Roth crystallographic shear structures, open enough to offer rapid, low resistance charge/discharge, containing many lattice vacancies for lithium ions, yet not changing volume during charge/discharge as carbon does. Niobium's ability to assume multiple oxidative states is basic to the expanded capabilities. The intensive and detailed study that has gone into such development gives hope that increasingly, improved battery electrode capabilities can be actively engineered — perhaps even by computational methods — rather than passively discovered by that old stand-by of research, trying everything.

Rapid charging capability sounds good but restrain enthusiasm until you calculate the amperage required. Can foreseeable charging stations deliver it — even with the liquid-cooled cables now being discussed? Creating a new anode composition such as NTO is only a beginning. A whole range of existing and possible future techniques must be applied to optimize the performance of its chemistry. As noted in one paper, such work "requires deep understanding of crystal and electronic structure."

A primary supplier of ferroniobium (used in tiny amounts as a grain refining agent in HSLA [high-strength low-alloy] steels) and niobium oxide is **CBMM** (Companhia Brasiliera Metalugia e Mineracao) in Araxa, Brazil. On Sept. 24, 2021, CBMM signed an agreement with Toshiba and **Sojitz** Corp., a Japanese trading company, to develop a Li-ion battery with NTO anode having higher specific energy yet retaining the rapid charging and long life of its LTO predecessor. ■

FROM LEFT: CBMM; LIGHTNING MOTORCYCLES

UPCOMING WEBINARS

UTILIZING MODEL-BASED SYSTEMS ENGINEERING APPROACH FOR VEHICLE DEVELOPMENT

Thursday, May 12, 2022 at 2:00 pm U.S. EDT

Global innovators within the transportation and mobility industry must manage complexity, optimize performance, and ensure vehicle safety. An integrated platform for model-based systems engineering (MBSE) fortifies your ability to manage embedded systems and electronics. This 60-minute Webinar examines the benefits of implementing MBSE, including:

- Increased user satisfaction and decreased vehicle recalls
- Compliance with safety standards and emissions, economy, and crash regulations
- Examination of high-level design alternatives and optimization of new, fast-changing technology through simulation and automation rather than costly physical tests
- Traceability from initial requirements through final testing

Speakers:

Sanjay Khurana
Director of Technical Sales, Cyber/Electrical/ Fluidic Systems, Dassault Systèmes

Rosa Gragossian
Senior Industry Process Consultant, Dassault Systèmes

Sponsored by: DASSAULT SYSTEMES

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For additional details and to register visit: www.sae.org/webcasts

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DATA ORCHESTRATION AND SMART INGEST FOR AUTONOMOUS DEVELOPMENT: AN OVERVIEW AND DEMO

Thursday, May 26, 2022 at 11:00 am U.S. EDT

With ADAS/AD sensor data collection already measured in petabytes and growing exponentially, sensor data management is an obvious strain on budgets. To reduce complexity and costs, two critical improvements are needed. The first is to fast-track development teams' important topical data. The second is to remove corrupt or unusable data before it incurs further downstream costs. This 30-minute Webinar provides an overview and demo of a scalable data management and storage solution jointly developed by Elektrobit and Dell Technologies.

Speakers:

Lawrence Vivolo
Senior Business Development Director, Dell Technologies

Dylan Dawson
Business Development Manager, Elektrobit

Sponsored by: DELL Technologies Elektrobit

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For additional details and to register visit: www.sae.org/webcasts

UPCOMING WEBINARS

PREPARING FOR THE CABIN COOLING TRANSITION: R-134A TO R-1234YF

Tuesday, May 31, 2022 at 2:00 pm U.S. EDT

R-1234yf refrigerants for mobile air-conditioning systems have been widely used in passenger vehicles for several years, but they are just now gaining traction in medium- and heavy-duty commercial vehicles. This 30-minute Webinar reviews the rationale for refrigerant transition, key regulatory drivers, and differences in the materials.

Topics include:

- Why heavy-duty cabin-cooling refrigerants are transitioning to YF
- The current regulatory landscape (Light Duty YF, AIM Act, SNAP for Off-Road Heavy Duty)
- The difference between R-1234YF and R-134a (Flammability, Performance, GWP)

Speakers:

Adam Kimmel
Senior Principal Consultant – Technical Service, Chemours

Jess Greer
Business Consulting Senior Analyst, Chemours

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HOW TO ACHIEVE POWER GRID SEPARATION IN AUTONOMOUS VEHICLE TOPOLOGIES

Thursday, June 2, 2022 at 11:00 am U.S. EDT

As autonomous functionality grows within the automotive industry, vehicle architectures are becoming increasingly more complex. It is essential to have redundant and safe power management to ensure all critical devices are operational. During this 30-minute Webinar, two experts in automotive controls technology discuss an approach to achieving power grid separation safely and reliably for autonomous vehicles.

Speakers:

Joe Vollmer
Sales Director, Eberspaecher Automotive Controls, North America

Patrick Fritz
Systems Engineer, Eberspaecher Automotive Controls, Germany

Sponsored by: Eberspächer

Hosted by: SAE INTERNATIONAL

For additional details and to register visit: www.sae.org/webcasts

SPOTLIGHT: 3D PRINTING

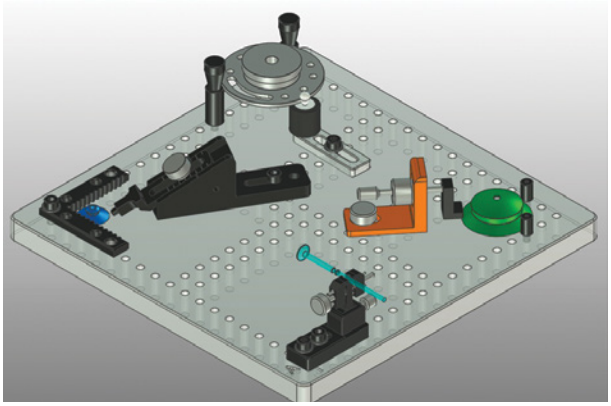
3D Printing Collaboration

Stratasys (Prairie, Minnesota) announced the expansion of its GrabCAD Software Partner Program in collaboration with **Oqton** (Ghent, Belgium) and **Riven** (Berkeley, California). The GrabCAD Software Partner Program enables two-way connectivity between 3D printers, additive manufacturing and enterprise applications. Oqton provides users with a machine-agnostic, cloud-based software platform that leverages artificial intelligence to automate repetitive tasks and utilizes intelligent IoT capabilities to automate the end-to-end additive manufacturing workflow. Riven provides software which utilizes 3D reality data from scanners and proprietary algorithms. This allows engineering and manufacturing teams to cut iterations and time-to-part while improving the customer experience.

For more information, visit http://info.hotims.com/82332-400

SPOTLIGHT: SOFTWARE

Modeling Software



Renishaw (Wotton-under-Edge, United Kingdom) announced the release of FixtureBuilder 8.0, the latest version of its 3D fixture modelling software. FixtureBuilder allows users to design metrology fixturing set-ups without having to go near their co-ordinate measuring machines and other inspection devices. This reduces the amount of unproductive set-up time and increases the productivity of inspection machines. Renishaw states this software can be used with a CAD model of the part to be inspected, which is imported into FixtureBuilder, so that the fixture can be built around it. The entire fixturing set-up, along with the part, can then be exported into inspection programming software.

For more information, visit http://info.hotims.com/82332-401

Adhesion promoter

PPG (Strongsville, Ohio) announced the launch of PPG ONECHOICE ADPRO MAX pigmented adhesion promoters. PPG states that the single-component undercoat eliminates the need to apply a sealer by providing exceptional topcoat adhesion to uncoated bumpers, fascias and other automotive plastics. The adhesion promoter is available in three colors: white, gray and dark gray. When blended, these colors can create up to five different shades of gray, which according to PPG ensures optimal topcoat coverage. The adhesion promoter also can be top coated after three to eight minutes of air dry depending on booth conditions and can deliver gloss holdout.

For more information, visit http://info.hotims.com/82332-402

PE foam reference

Gergonne Industrie (Oyonnax, France) has introduced its next-generation 10080 polyethylene foam reference. The company claims that the latest version is more flexible and elastic than the previous generation, thus offering a better overall performance in terms of adhesion and conformability, as well as improved temperature and UV aging resistance. The foam reportedly demonstrates good cohesion on all types of substrates and is intended to affix parts of differing materials that are subjected to mechanical constraints. Gergonne also claims that its rigid siliconized paper liner is perfectly adapted to half-flesh cutting for production of custom and one-off parts.

For more information, visit http://info.hotims.com/82332-403

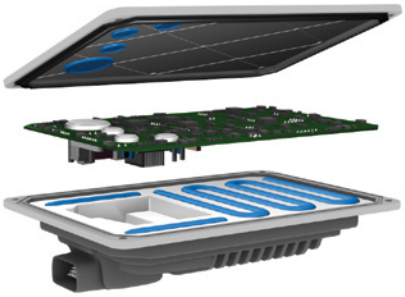
SPOTLIGHT: TEST & MEASUREMENT TOOLS

Oscilloscopes

Tektronix (Beaverton, Oregon) has launched a new version of its mixed signal oscilloscope, the 5 Series B MSO. The new model reportedly features some enhancements to existing features and delivers more versatility while continuing to provide high-fidelity waveforms, unique spectrum analysis capabilities, and flexible signal access. The new B version includes updates like a new auxiliary trigger input that lets users synchronize the oscilloscope to an external signal without consuming any of the 4, 6, or 8 full-capability input channels. The maximum frequency output has increased from 50 MHz to 100 MHz, which Tektronix claims enables higher frequency stimulus for measurements such as Bode plots and impedance measurements.

For more information, visit http://info.hotims.com/82332-404

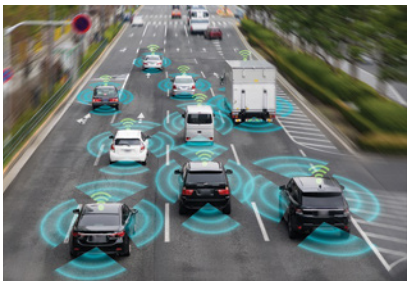
Thermally conductive gap filler



Dow (Midland, Michigan) has introduced DOWSIL TC-4535 CV, a thermally conductive gap filler. The two-part heat-cure silicone is a thermally conductive adhesive with a low bond line thickness. Dow states that this compound is a soft and compressible material once cured. The compound is designed to dissipate the heat from PCB module assemblies mounted on printed circuit board to heat sink, providing a reliable cooling solution for modules like an engine or transmission control unit. The compound is comprised of a 1-to-1 mix ratio with a low hardness and viscosity to minimize internal stress generation, fill small gaps, and improve manufacturing speed for complex and high-volume electronic devices.

For more information, visit http://info.hotims.com/82332-406

PBT materials for radar



SABIC (Riyadh, Saudi Arabia) has launched two new materials, the LNP THERMOCOMP WFC06I and WFC06IXP compounds, which were developed for use in front and back enclosure covers (respectively) of radar units. The new glass-fiber-reinforced polybutylene terephthalate (PBT) grades offer a very low dissipation factor and dielectric constant to help support the transmission of higher-frequency radar signals. They also feature low warpage that allows designers to potentially create new, thinner covers that improve signal transmission. Furthermore, these new products can contribute to efficient radar unit assembly by supporting high-speed, high-precision laser welding. The company reports that the WFC06I compound provides excellent laser transmission performance compared to other PBT materials.

For more information, visit http://info.hotims.com/82332-405

Electrical-component compound

Henkel (Düsseldorf, Germany) has introduced Loctite AA 5885, a one-component UV-only cured in place gasket for automotive electronics applications. The compound is designed to protect sensitive electrical components and is capable of curing under UV light in under 30 seconds. Henkel states that this cure time allows customers to expedite gasketing and increase production efficiency. Henkel also claims that this product offers an optimal combination of structure and softness with excellent durability even when exposed to high-pressure water spray, automotive fluids or the high temperatures of the under-hood environment. This compound has a wide range of applications including ECUs, battery packs, control modules, fuse boxes, actuators, sensing systems and ADAS control modules.

For more information, visit http://info.hotims.com/82332-407

BEVs, batteries and new-vehicle cost

Your recent [March] article on Our Next Energy was interesting. CEO Mujeeb Ijaz should be congratulated for his company's belief in LFP [lithium iron phosphate] cell chemistry, which is emerging as the most rational recipe for thermal stability, performance and cost. Most of the OEMs getting into the BEV game are focusing on power, power, power, rather than energy. Now it's time to consider what constitutes a practical, safe, and affordable vehicle. It appears that ONE's Ijaz and his team are in that camp. EVs are the future, just not the immediate future.

Martin Sbelle
Sunnyvale, Calif.

Racing Toward Zero

Although I am not an engineer, I am an SAE member and I read each issue of *Automotive Engineering*. I have a long-winded question about battery electric vehicles. If you can reply, I would be interested in your thoughts. I have finally realized that many people believe battery-electric vehicles are the best solution to reducing the CO_2 output of cars. There seems to be little criticism of BEVs, even in some car magazines. However, plenty of engineers and scientists can easily list their drawbacks. So why is there so much support for BEVs?

In their book *Racing Toward Zero*, authors Kelly Senecal and Felix Leach make an excellent case that "the future is eclectic," not just battery electric. BEVs will play a suitable role, but so will hybrids and ICE vehicles. I strongly agree, yet many people seem convinced that BEVs will predominate. One explanation for that is in John Heywood's [MIT professor, combustion-engine expert and SAE Fellow] forward to *Racing Toward Zero*. He says, "Advocates [for EVs] have claimed much of the discussion playing field...".

I think good examples of that are the mistaken interpretations or willful distortions of the car companies' announcements about electrifying their fleets. I think some advocates genuinely believe the companies are changing their fleets to BEVs, while others deliberately distort the announcements to promote BEVs. In addition, some car companies have released statements with vague titles. For example, Senecal and Leach note that, despite the headline "Volvo Cars to go all electric," the company actually says its fleet will become electrified, which is different from being all electric. Even considering these explanations, I am still mystified by the promotion of BEVs. Am I missing something?

David Krall
Monterey, Calif.

David, thanks for sharing your thoughts. Recent events, including the semiconductor crisis, the Ukraine war, and growing concerns about strategic mineral sourcing —and rising EV costs — have put hybrids back into the longer-term vehicle-propulsion discussion. And yes, the general media's ongoing confusion over "electrified" and "electric" is frustrating and does consumers a disservice. — Ed.

EV vs. hybrid cost

I am concerned that too much emphasis is being placed on the $60,000 average transaction price of a typical EV, versus the extremely reliable and durable, $34,000 [inflation adjusted] price of our 2007 Toyota Prius. Amazing durability and reliability of our Hybrid, now at 126,000 miles, averaging 45 mpg. So far only oil and filter changes every 7,000 miles, and still no need for brake replacement. The 400- mile range requires only a half-hour stop for a call of nature, refueling, and a fast food lunch instead of multi-hour EV battery recharging.

Even our gas-fueled 31 mpg Honda Civic uses less well-to-wheel energy and emits less emissions than that of a Midwest EV requiring a battery charge from energy generated primarily from about 60% natural gas, 30% coal, and 10% wind and solar.

Continuing emphasis needs to be placed on now-50 mpg Hybrids.

Joseph J. Neff
Indianapolis, Indiana

The writer is retired chief engineer at both Cummins and Peterbilt Motors, and former VP at transit bus builder Gillig.

READERS: Let us know what you think about *Automotive Engineering* magazine. Email the Editor at Lindsay.Brooke@sae.org. We appreciate your comments and reserve the right to edit for brevity and clarity.

COMPANIES MENTIONED

AD INDEX

Integrating a plug-in hybrid Jeep

At no other time in the auto industry's history has the role of vehicle integration and synthesis been so important. The growth of electronic content, the melding of mechanical and electrical engineering and the increased focus on electrified propulsion have made integration/synthesis teams vital to ensuring that design spec and requirements are maintained through prototypes, testing and validation in order to meet market standards and exceed customer expectations.

Eunjoo Hopkins is vehicle synthesis manager on the 2022 **Jeep** Grand Cherokee 4xe (called "4-by-e" by **Stellantis** engineers; see p.11). She joined the former FiatChrysler in 2009 as a powertrain engineer and only recently moved over to vehicle integration. "I've worked in propulsion systems for most of my career here thus far, including the [Chrysler] Pacifica Hybrid," she told **SAE** Media during the Grand Cherokee 4xe media launch in Texas. "I moved into integration/synthesis because I wanted to experience the other aspects of vehicle development."

Integration, she explained, "is all about what we call 'the sciences' — aerodynamics, safety, NVH, vehicle dynamics. We have to make sure we meet the 'science' goals established for the program, all the way back to component design," she noted. For the Grand Cherokee 4xe, that includes metrics such as foundation braking feel as well as regen braking. Calibration falls under powertrain, however. "If there is a metric we don't meet, we go back and redesign the component," Hopkins asserted. "We're also responsible for holding ride-and-drives with our executives to get their inputs and buy-in to make sure our products meet customer expectations."

Highlights of our conversation with Hopkins follow.


Eunjoo Hopkins

LINDSAY BROOKE

If there is a metric we don't meet, we go back and redesign the component.

Is most of the Grand Cherokee 4xe's PHEV powertrain carried over from the Jeep Wrangler 4xe?

Yes, but with more refinements. Being able to pick up the propulsion system from Wrangler allowed us to move the program along much more quickly. The challenge, however, was the different electrical architectures of the two vehicles. The Wrangler's architecture is very different from the WL [internal code for the new Grand Cherokee] in how it does 'wake up' and 'sleep,' for example. That's where a lot of complication came in for us, in integrating [the hybrid system] with the vehicle architecture. Grand Cherokee and Grand Wagoneer have all-new electrical architectures, as Tom Seel [Grand Cherokee vehicle line engineer] has noted.

The PHEV system combines P1 and P2 electric machine positions. What do you call that combination?

We call it a 'P1-P2!' Integrating the hybrid transmission into the Grand Cherokee, seamlessly, is where our learnings from Wrangler came in. To make its engagement and disengagement smooth in all operating modes, including engine-on/engine-off and at launch, required a lot of hard work in terms of control-algorithms and calibration. The vehicle has a separate transmission controller, which 'plays nice' with the supervisory controller.

A key to any electrified Jeep is thorough and robust sealing of the battery, controllers and the high-voltage harness from water intrusion. Did sealing the Grand Cherokee pose challenges?

We used industry standard specifications for sealing. We didn't do anything special. We made sure that we validated those requirements at the VP [prototype] stage. When we hand-build our prototype vehicles, we use as much of the actual factory processes as possible. Before we put this vehicle through our first water fording test, we contacted all the DREs [design release engineers] to make sure the parts they supplied truly did pass the component-level testing.

The WL team drove the Grand Cherokee 4xe over the 22-mile Rubicon Trail on electric power only. How much did regen braking play a role in getting through that journey?

That's interesting. Doing the Rubicon Trail is a low-speed event; not a lot of power is used. When you tip out of the throttle, you're using the electric machine to absorb that energy.

On that run, we typically used the forward motion of the vehicle and the driver's foot to modulate vehicle speed. In the end I believe we still had some battery energy left. ■

BATTERY & ELECTRIFICATION Technology

May 2022

Leading the Charge:

FAST 40

Supplement to

AUTOMOTIVE ENGINEERING TECH BRIEFS

BATTERY & ELECTRIFICATION Technology

Innovations in Power & Energy Storage

May 2022

Solving the EV Battery Recycling Challenge

A Systems Approach to Manufacturing Better Batteries

How Ultracapacitors Can Help the Transition to EVs

Solidifying the Future of Solid-State Batteries

Leading the Charge:

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AUTOMOTIVE ENGINEERING TECH BRIEFS

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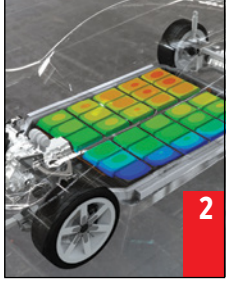

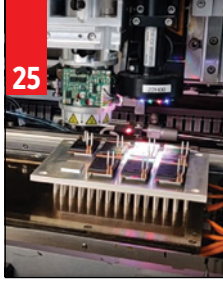

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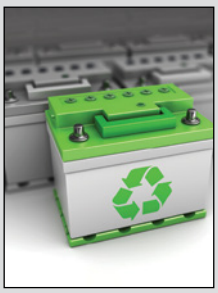


ON THE COVER

All the components of a Lithium-Ion (Li-ion) battery are valuable and can be recovered and reused. Although engineers are making progress improving methods of recyclability, relatively few Li-ion batteries end up being recycled. Learn more on Page 9 about Idaho National Laboratory's new Li-ion battery material recycling technology.

(Image by Shutterstock/Mmaxer)

The Rechargeable Renaissance

From the design concept to product delivery and beyond, electric vehicle battery development must be a connected process if manufacturers are to achieve the greatest success.

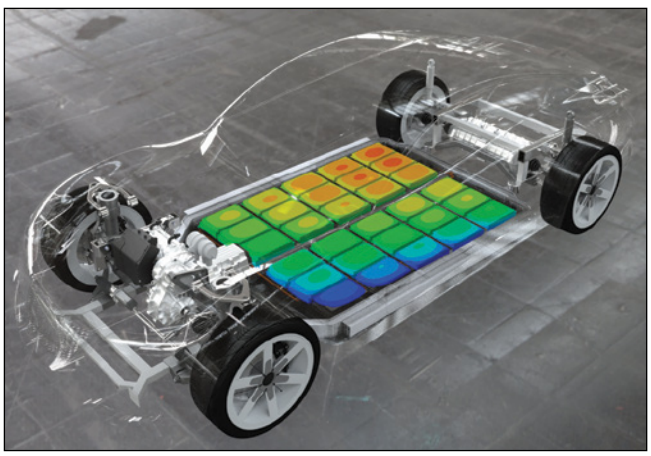
After years of lukewarm reception and limited funding, it looks as if the battery electric vehicle (BEV) market is finally going full throttle. According to a recent *Forbes* article, Schmidt Automotive Research recently reported that BEV sales more than doubled in 2020 to nearly 750,000 and jumped again in 2021 with sales of more than one million vehicles, despite an ongoing chip shortage and pandemic-related disruptions.

As Mary Barra, CEO of GM, explained in her investor presentation, "From Automaker to Platform Innovator," the future is about sustainability and inclusiveness, powered by batteries. Cost reduction and adoption depend on next-generation materials, and will enable new products and services, such as autonomous taxis and delivery trucks.

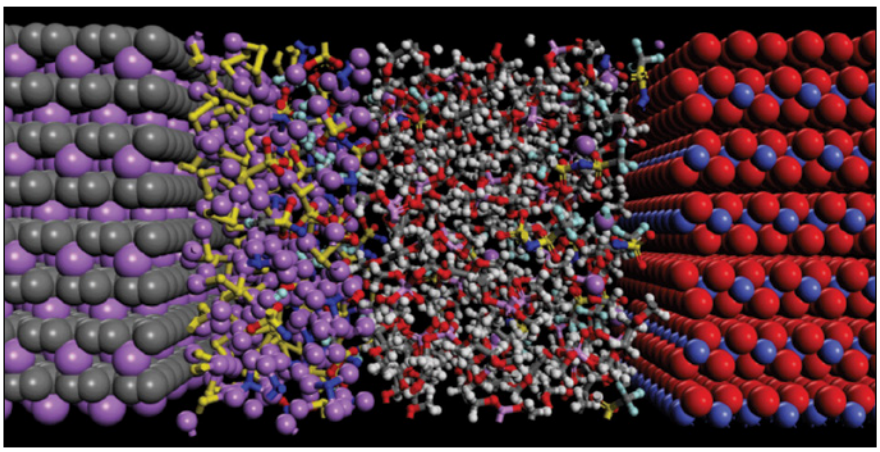
Carlos Tavares, CEO of the newly formed automaker Stellantis N.V. (a merger between Fiat Chrysler and the PSA Group), stated, "There's a new world coming. Now, the machine is on, and we are going fast forward."

Green is Good

The reasons for BEV popularity are clear: higher performance, simpler maintenance, and operational cost reductions. In addition, governments everywhere continue to tighten regulations on emissions while petroleum supply and costs remain unstable, with the latter trending inexorably upward. Battery prices are coming down — an 87 percent reduction between 2008 and 2020 — albeit not to the levels the auto industry and consumers would like. Add to this a growing sense among the driving public that spaceship Earth deserves greater care than what she's seen thus far, and it's no wonder that BEV adoption is on the rise.



This simulation indicates hot and cold areas in an electric vehicle's battery pack. Such visibility allows designers to address potential problems well in advance of the product release.



With the anode and cathode sitting at either side, this image illustrates the complex electrochemical environment within a typical battery cell.

Still, a great deal of effort remains before battery power overtakes fossil fuel in transportation and mobility. For instance, so-called "range anxiety," a significant concern for many users, is slowly starting to abate. Last year, the median EV battery range surpassed 250 miles for the first time and, at the top end of the market, EV battery ranges have reached 400 miles. With next-generation battery chemistries that allow for lighter cells, EV battery ranges and lifespans will continue to increase. With that comes high manufacturing costs, potential raw material shortages (namely, lithium), and manufacturing complexity, as Chevrolet learned the hard way with its Bolt EV, the risk of fire. Governments and administrations are also addressing the shortage of BEV charging infrastructure, a situation compounded by long charging times.

Despite these not so insignificant challenges, the writing is on the wall: Battery-powered electric vehicles represent the future of road haulage and transportation. Automakers wishing to keep ahead on the BEV superhighway must adopt a flexible approach for a constantly evolving vehicle market, as well as an agile structure to adapt to the new businesses that may spawn. They must either develop in house, or partner with suppliers, to manufacture large quantities of high-energy density batteries. Those batteries must be safe, quick to charge, and provide better ranges than that of the gas and diesel alternatives.

Battery Anatomy

Accomplishing each of these will mean shifting away from the status quo, starting with the materials. As already noted, battery makers currently face strong competition for lithium, most of which is mined in Australia and South America but then shipped to China for refining. If startup companies like Sila Nanotechnologis and Ion Storage Systems have their way, however, much of that demand will shift in favor of abundant sodium or ceramic systems.

Doing so will take much more than a plentiful raw material source; it will also take visibility into the complex inner workings of batteries, whatever they are made of. That's because batteries are living things — their chemistries change over time and use, which is why they are (unfortunately) known for capacity fade, occasional combustion, and eventual failure.

Building a better battery requires a thorough understanding of the continuous interaction between the anode, cathode, and other battery materials. Designers need to model and simulate the behavior of the electrolyte as well as the mixed metal oxides electrode coatings, polymer binders, and other chemical constituents in the cell. Most importantly, they need to be able to predict how this electrochemical soup will evolve with different use profiles over Mays and miles.

Micro to Macro

Chemistry is only the beginning, however. The "battery" inside an electric vehicle actually comprises hundreds of individual parts. Comprehensive modeling of the entire system requires accurate representations of each cell, followed by the modules, and then the battery pack as a whole. As these different components and subassemblies come together, the mechanical, thermal, and electrical dynamics begin to change and the choices multiply.

Where heat buildup might not be a concern with an individual cell, nestle several dozen of them alongside one another in a battery module and the laws of thermodynamics begin to play a much larger role. Similarly, electrical carrying capacity, conductivity, and voltage levels all change — often dramatically — as batteries grow in complexity. It's only through analysis of the micro, macro, and every level in between that designers can achieve an optimal battery configuration.

Then there are mechanical and environmental considerations. The battery pack in a typical passenger car weighs 450 kilograms (992 lbs.) or more. Within are the rows and rows of the modules just mentioned, each of which must be held securely and without movement even in the face of vibration, acceleration, and possible collisions or rollovers. Such a structure calls for extreme strength, stiffness and above all, safety.

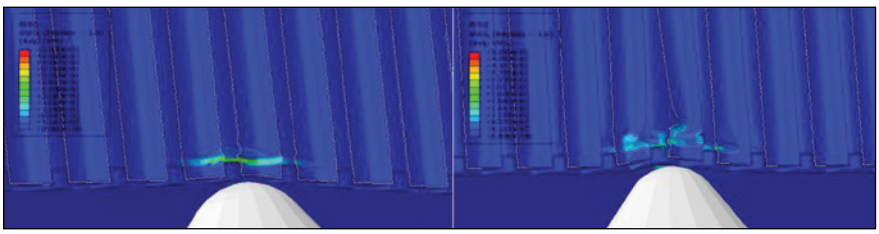
Complicating matters even further is the battery pack's operating environment, which can vary from Canadian cold to sub-tropical heat. Throw in some rain, snow, salt spray, mud and dirt, and even the most robust container designs are put to the test. The question then becomes: How to test? How to see inside the functioning battery? How can battery manufacturers assure long-term performance and dependability in an extremely complex product with no moving parts? Not only that, how can they design the system for in use, safe upgrades and updates?

Traditional automakers might suggest real-world testing, with thousands of miles cruising automotive proving grounds and weeks or even Mays in environmental test chambers. But, given the rapid pace of change in today's BEV market, such legacy testing methods are prohibitive and difficult to optimize. A better, more accurate and cost-effective solution is modeling and simulation. This provides unprecedented, iterative views within the cell at the macro- and micro-scales, without the complexity

and uncertainty of older testing methods. Lastly, this can help with safety and recycling. For example, many governments are developing "Digital Battery Passports" designed to contain information on the battery pack, its lifespan and any deviation from expected behaviors. Models and connected data are a key element of this.

The Production Floor and Beyond

Once an optimized battery design is delivered, what then? A manufacturing engineer might tell you this is when the real work begins. There is an element of truth to this. As with the design process, battery manufacturing needs connected, end-to-end solutions with visibility into the product, the process and beyond. Without this visibility, which must also encompass the entire testing, fabrication and assembly process, manufacturers are left scrambling to identify the source should an issue or defect arise.



These two images show how one cell design (at left) handles impact deformation better than the other. Without advanced simulation capabilities, small differences like these would likely go undetected.

It's a steep hill to climb, to be sure, and it is made harder by the current pace of change in the EV industry. All is not lost, however. In battery innovation and production, a systems approach unifying real and virtual data with models can help manufacturers innovate more quickly, with better capabilities, at lower cost, so that they win the race to EV dominance.

From Dassault Systèmes' perspective, such capabilities are the next step forward in enabling BEV, the next chapter in agile manufacturing, and the fundamental underpinning of a more sustainable future. Indeed, many of the G8 countries and the leading global automotive manufacturers see battery vehicles as the tipping point for a greener world.

This article was written by Michael Doyle, Material Sciences Fellow, Corporate Research at Dassault Systèmes R&D (Vélizy-Villacoublay, France). For more info visit ***http://info.hotims.com/82321-420****.*

Ultracapacitor Solutions *to Address Energy-Storage Needs of Vehicles*

Already established for hybrid-electric systems, ultracapacitors are well-placed to assist in the transition to battery electric vehicles.

Lamborghini Aventador's ultracapacitor-based engine start-stop system helps reduce CO_2 emissions. (Photo: Lamborghini)

As the electrification of automobiles continues to accelerate, the need for a safe, reliable, high-power energy-storage technology is greater than ever. Ultracapacitors already have an established place in Voltage Stabilization Systems (VSS) for internal-combustion engine (ICE) stop-start applications. By providing additional voltage support during a high-current cranking event, voltage levels are maintained to allow proper operation of accessories without interruption and enable proper operation as battery state-of-health declines.

The nearly five million stop-start systems in production-car use today include vehicles such as the PSA 308 and many other diesel platforms, several General Motors vehicles and even current stop-start/hybridized models from supercar legend Lamborghini. In racing, Toyota used ultracapacitors in its highly successful LeMans TS040.

With continued pressure on automotive OEMs to reduce CO_2 emissions, stop-start systems have become a standard feature, not just an upgrade option, for many global ICE and hybrid-electric vehicle (HEV) platforms, but major OEMs such as GM, Ford, Stellantis, and others now have aggressive targets of 40-50 percent fully electric vehicle (EV) sales by 2030. To meet these goals, there is heavy investment in electric

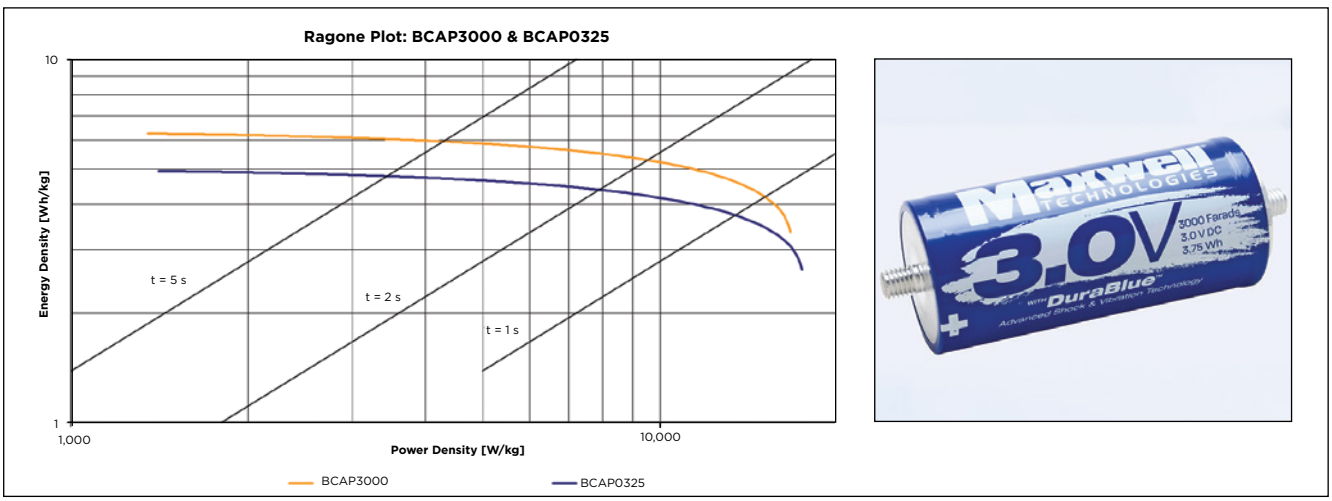
Maxwell DuraBlue vibration comparison to industry standards; the RMS acceleration for ISO 16750-3 is 5.9 Grms, three times higher than SAE J2380 with an acceleration of 1.9 Grms. (Photo: UCAP Power/Maxwell Technologies)

drivetrains as well as redesigns of nearly all electronic systems in the vehicle. Analysts expect $330 billion or more to be spent on light-vehicle electrification over the next five years.

Examples of automotive applications for which ultracapacitors are in use:

- Circuits to enable recessed door handles to pop out in case of an accident or loss of power. Having a stored burst of high power available to open the door from a secondary energy source, an ultracapacitor, is not only practical but also a safety feature that can save lives.
- Accessory power applications that include: Electronic Power Assist Steering (EPAS), Electronic Power Assist Braking (EPAB), as well as power liftgate and plow features.
- In autonomous driving vehicles where an emergency backup energy source is required, ultracapacitors can provide the short-duration power needed to get the vehicle to the side of the road in the event of a failure of main drivetrain power.
- Body electrical systems including door, seat, window, trunk and other electrically actuated subsystems.
- Customer amenities such as electrically driven air-conditioning, quick heat for seats, steering wheel and passenger cabin.

Many automotive-related safety-critical loads typically are short-duration, high-power situations. Powertrain functions such as power boosting and energy recuperation, as well as body electrical systems are medium-term loads. Although batteries are ideally suited to deliver energy for long-term events, such as cabin air-conditioning during the idle-stop mode of an ICE stop-start system, they are not designed to satisfy the most important requirements of short- and medium-term loads: to provide



Maxwell BCAP3000 cell and Ragone Plot. (Photo: UCAP Power/Maxwell Technologies)

bursts of power in the seconds time frame over many hundreds of thousands of cycles.

Ultracapacitor Technology

Compact in size, ultracapacitors can deliver much higher peak power compared to batteries and store an incomparably higher amount of energy than conventional capacitors. Ultracapacitors from Maxwell Technologies offered under the trademark DuraBlue, for example, currently are available on the market in larger cylindrical-format cells with capacitance up to 3000 Farads. These cells incorporate advanced shock and vibration technology and when combined with Maxwell's patented electrode formulation and manufacturing process, result in a product line specialized for the most demanding requirements of the transportation industry.

For applications requiring a smaller form factor, Maxwell has developed a 325F cell, the BCAP0325. A high-power cell with ultra-low Equivalent Series Resistance (ESR), it is ideally suited for automotive applications. The cell is AEC-Q200 qualified and provides one of the longest lifetimes available in the industry. Feature and performance metrics include:

- Small (33 mm) form factor
- 1 million cycle capability
- PCB mountable
- Compliant to UL, RoHS and REACH standards

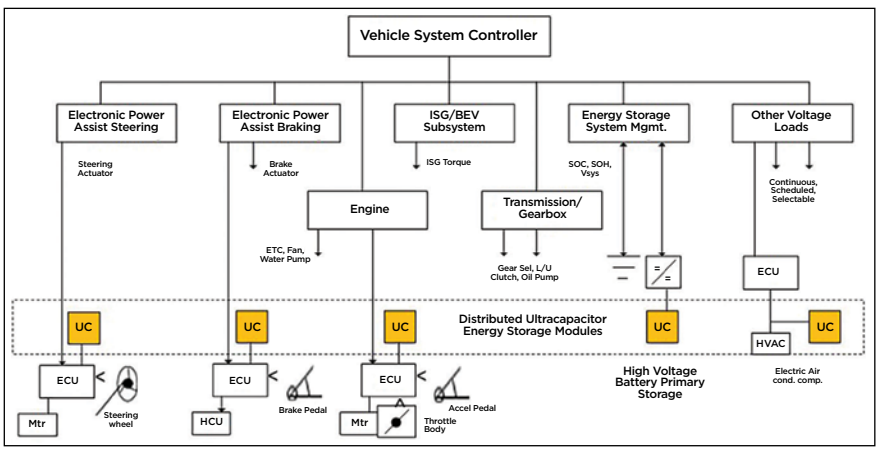
Safety-Critical X-by-Wire Applications of Distributed Power Modules

An electrical system architecture with modular and distributed power modules is one method of addressing the need for power and redundancy required by the safety-critical and security systems in automotive applications. Distributed ultracapacitor modules alleviate electrical distribution system voltage sag and transients by supplying peak power locally, while requiring only the average power from the vehicle's primary power supply. This essentially decouples the high transient power load from the vehicle's primary power supply system.

A further requirement of safety-critical applications is the necessity of redundant power supply in the event of loss of the main electrical distribution system branch circuit for x-by-wire functions. Distributed power modules located at critical loads, such as electric power-assist steering system, offer the vehicle designer additional redundancy for safety-critical applications.

As outlined above and prevalent in the market today, ultracapacitors are an excellent tool for vehicle engineers to specify in support of high-power, short-duration loads. With their extremely fast charge and discharge capabilities, unmatched cycling durability, wide operating temperature range, long lifetime and environmentally friendly design, ultracapacitors offer many benefits in a small, lightweight package. Maxwell Technologies' line of DuraBlue and AEC-Q200 qualified ultracapacitors are ideally suited to meet these demands.

This article was written by Troy Brandon – GM, VP Marketing, and David Wright – VP Engineering, UCAP Power, Maxwell Technologies (San Diego, CA). For more info visit ***http://info.hotims.com/82321-422.***



Distributed module architecture for vehicle safety-critical and hybrid functionality. (Photo: UCAP Power/Maxwell Technologies)

Developing a Better Way to Recycle Lithium-Ion Batteries

Researchers at Idaho National Laboratory have demonstrated a more environmentally friendly way to recover critical materials from discarded lithium-ion batteries.

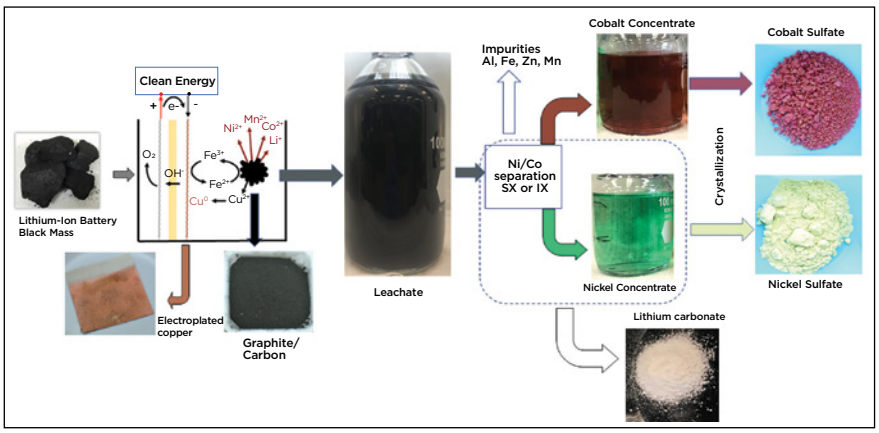
tawan/Shutterstock.com

Decarbonizing transportation is key for meeting U.S. greenhouse gas reduction targets because moving people and goods is the largest direct source of climate-altering emissions. Consequently, analysts predict a coming surge in electric vehicle sales.

According to BloombergNEF, for example, worldwide passenger electric vehicle sales will rise from 3.1 million in 2020 to 14 million in 2025. By 2040, BloombergNEF analysts say as much as 90 percent of all new passenger vehicle sales will be electric. A 2022 survey by AutoPacific found three out of four American consumers considered electric vehicles the way of the future.

Those electric cars, trucks, buses, and other vehicles need batteries. Although other options are being considered, the leading technology today to power those vehicles is lithium-ion (Li-ion) batteries. However, putting tens of millions of new electric vehicles on the road every year will create a critical materials supply challenge.

"If we convert a significant fraction of our fleet, we could start running into supply problems, mostly cobalt, nickel and lith-



Li-ion battery black mass is fed to the EC-Leach system producing a leachate solution containing critical metals, which are separated downstream to produce cobalt, nickel, and lithium products for use in new batteries. Biproducts such as copper and graphite can be reused.

ium," said Tedd Lister, an INL staff scientist. He is also a member of a research team that developed a new Li-ion battery material recycling technology that is more efficient and environmentally friendly than current methods.

Tighter Recycling Loop

Battery recycling is vital because one solution to the looming supply issue would be a closed-loop setup, with batteries processed at end-of-life to recover cobalt, lithium, and other critical materials that can then be used to make new batteries.

Significant recycling already takes place. In 2018, 20 companies worldwide recycled just under 100,000 metric tons of Li-ion batteries, about half of the global volume of batteries disposed that year. Recovering materials can involve direct recycling, pyrometallurgy, and/or hydrometallurgy.

Direct recycling attempts to employ a tighter recycling loop and retain more manufacturing value. A major target is the rejuvenation of the cathode material, so that it can be directly reused in a battery of the same type. In practice, however, because battery formulations change rapidly and Li-ion batteries are designed to last a decade or longer, the value of this approach is limited. Another challenge is the need to segregate collected batteries by manufacturer and production time, since every manufacturer uses unique cathode material.

Pyrometallurgical processes can accept different kinds of batteries, using high temperatures (above 700 °C) in a furnace to smelt the battery into an alloy. Hydrometallurgical refining using acids and other chemicals then separates and recovers cobalt, nickel, and copper from the alloy, while the lithium is extracted from the waste slag. Because of the temperatures required, the recycling process can have a significant carbon footprint if fossil fuels provide the energy for the smelting.

One way to reduce the greenhouse gas emissions from Li-ion battery recycling is to use hydrometallurgy alone to leach out materials. Often this involves use of sulfuric acid and hydrogen peroxide because the combination is very effective; reported yields for the target metals are over 90 percent when the leaching is conducted at temperatures above 40 °C. Making the chemicals, though, has significant negative environmental impacts and presents safety risks, as does transporting and storing them.

An Electrochemical Boost

As described in the peer-reviewed scientific journal, *Resources, Conservation and Recycling,* an INL team investigated a different approach employing an electrically driven hydrometallurgical process. INL researchers developed an electrochemical-assisted leaching method that continuously regenerates Fe2+ in small concentrations. The Fe2+ reacts with the Li-ion battery cathode metals to promote their extraction into the aqueous phase. The team achieved near complete metal leaching from Li-ion battery "black mass," material recovered from shredded Li-ion batteries that contains the active battery components.

The electrochemical boost to the leaching process is an important component in achieving the goal of a greener Li-ion batteries recycling solution.

"Electrochemistry is the transformation of electrical energy into chemical bonds or chemical bonds into electrical energy," said Luis Diaz-Aldana, an INL electrochemical scientist and team member. "The vision that we had is that we can use this electricity as a green reagent. So that it can substitute for a significant amount of chemicals."

He added that the electricity could come from a carbon-free source, such as a solar panel array, a wind farm, a hydroelectric dam, or a nuclear power plant. This would reduce total emissions associated with the new recycling process as compared to competing processes to an even greater degree.

The process has been scaled from the initial proof-of-principle demonstration to a system that can process over 0.5 kg/day. From an industrial battery recycler, the team obtained metal oxide black mass composed of the anode and cathode powder recovered from a mixture of different Li-ion batteries.

The black mass contained lithium, cobalt, manganese, nickel, and aluminum in observed formulations, such as $LiCoO_2$, $LiMn_xCo_yO_2$, $LiNi_xMn_yCo_zO_2$, $LiCu_xMnO_2$, and $LiNi_xCo_xAl_zO_2$. Along with these lithium-containing materials, more than 30 percent of the weight in the black mass was nonmetallic, including graphite from the anode and elsewhere, carbon material and polymeric bits of battery separators.

Nickel and cobalt salts isolated from Li-ion batteries.

The INL researchers put the black mass on one side of the bipolar membrane in a sulfuric acid — iron sulfate solution, along with a stir magnet and a stainless-steel cathode mesh. They put water and a nickel anode on the other side of the membrane. They then operated the chamber at a -0.3 V cathode potential, causing the cobalt, lithium, manganese, and nickel to leach out of the cakes at efficiencies over 96 percent, a near total recovery of these critical materials from the shredded Li-ion batteries. The copper plated out on the electrode and the graphite also deposited in a form suitable for further processing.

This material extraction occurred at room temperature, at an estimated electrical consumption of 232.3 kWh per ton of black mass. The researchers calculated that using the electrochemical approach would cut the cost of chemicals by as much as 84 percent as compared to following the traditional sulfuric acid-hydrogen peroxide method. In addition to those cost savings, less chemical consumption would also mean less environmental impact from chemical production, storage, transport, and disposal.

Overall, the decrease in chemical consumption and room-temperature operation should shave about 80 percent off the cost of chemicals and energy, according to an analysis by the researchers. Optimization of the process could make those savings even greater, for both operating and capital costs.

The electrochemical process has been patented and research into complementary processes continues, Lister said. The output from the leaching process, for example, is a critical material-rich solution and the dissolved metals must be separated and converted into products suitable for manufacturing new cathodes. This is an area of active development, with considerable progress made toward the final goal of a sustainable commercial Li-ion battery recycling process. "We'll have a complete package we can show somebody," he said.

This article is written by Hank Hogan, President, Hank Hogan Writing and Editorial, for Idaho National Laboratory (Idaho Falls, ID). For more info visit ***http://info.hotims.com/82321-421****.*

INL researcher Meng Shi operates the EC-Leach system.

Manufacturing Advances in Solid-State Batteries

Promising new research chips away at the impediments to introducing solid-state batteries for the high-volume — but high-expectation — automotive market.

Discs MIT and Brookhaven National Laboratory researchers used for testing a new processing method for coating the separator material in solid-state batteries. On the left is a sample of the solid electrolyte material known as LLZO. At center, the same material coated with the cathode material used in their tests. At right, the LLZO material with a coating of gold that facilitates measuring its electrical properties. (Photo: Pjotrs Žguns)

Battery engineers targeting electric vehicles (EVs) continue to research designs with solid-state electrolyte because of the alluring twin promises of significantly higher energy densities – which lead to longer driving range – and greatly enhanced safety that comes with eliminating liquidous electrolytes. Additional presumed advantages for solid-state batteries are quicker recharging and longer lifespan – not to mention the potential to

Prototype solid-state battery cells manufactured by Solid Power. (Photo: Solid Power)

reduce the amount of critical, high-cost minerals required for lithium-ion battery chemistries.

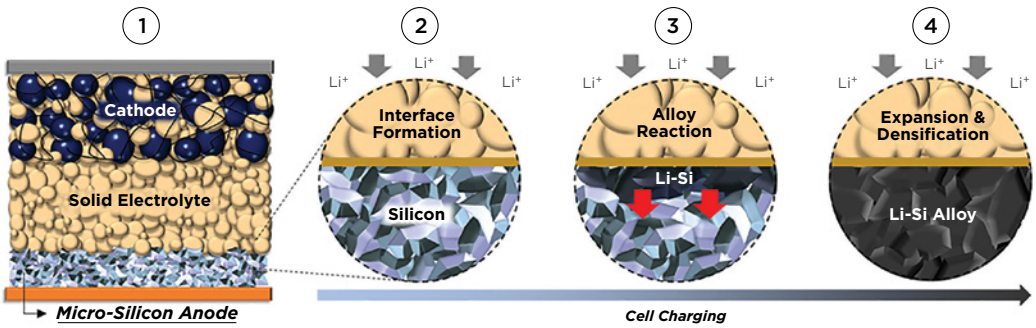
Solid-state technology is far from perfected for automotive-scale production and with increasing global interest in EVs as an answer to climate change and fossil-fuel supply concerns, barely a May passes without the breathless announcement of some new battery breakthrough. But promising recent research and development on several fronts appears to be bringing solid-state battery designs closer to production readiness — and it was reported in late January, 2022, that Chinese automaker Dongfeng Motor launched a demonstration program of 50 Dongfeng E70 EVs using solid-state batteries developed in collaboration with Ganfeng Lithium. Although scant detail is available, the Ganfeng solid-state batteries employ a "flexible-diaphragm" technology to facilitate lithium-ion travel while also curbing formation of lithium dendrites, a common problem that inhibits energy retention and recharging performance.

Process as a Pathway

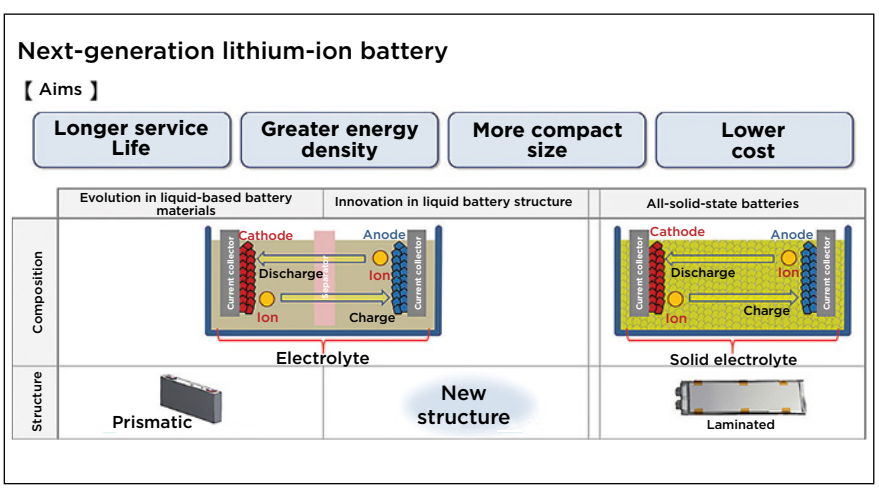
Partially addressing the issue of dendrite formation as well as other performance- and longevity-related factors, research announced by a research team from MIT and Brookhaven National Laboratory indicates a comparatively quick and low-cost process may help eliminate a costly manufacturing step that currently is necessary to achieve the best performance from solid-state batteries. The researchers believe their method can bring more efficiency and value to the solid-state battery manufacturing process.

The researchers looked at the critical interface between the solid-state electrolyte (usually some type of ceramic material) and the cathode and anode materials on each side of the electrolyte. The electrode materials typically are sintered at high heat to the electrolyte to assure physical bonds that yield the best possible conductivity. But now, to achieve the best material bonding, special coatings were needed at the interface of the electrolyte and the cathode layer. Sintering, which for ceramic materials usually is performed at temperatures of 1,000 °C (1832 °F) or higher, causes atoms from each material to migrate into the other to form bonds.

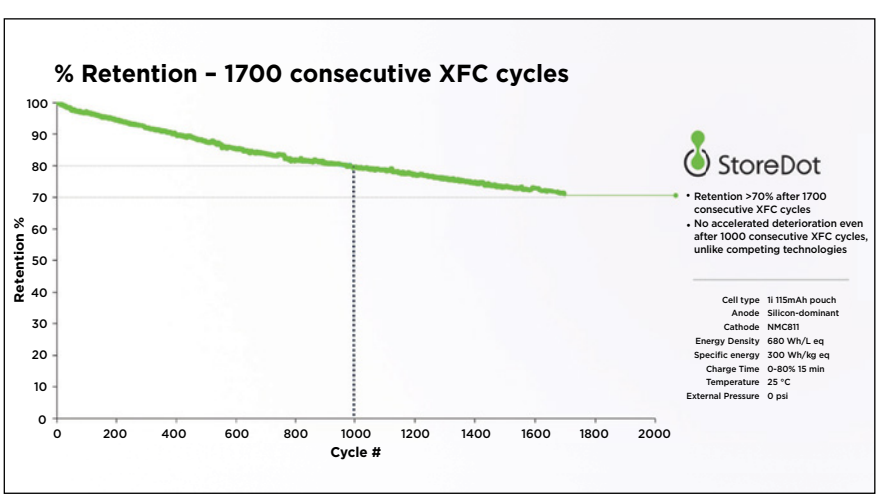
The team's experiments, said an *MIT News* article summarizing the work, showed that at temperatures anywhere above a few hundred degrees, detrimental reactions take place that increase the resistance at the interface, but only if carbon dioxide is present, even if in meager amounts. The researchers demonstrated that sintering in the total absence



The process of the UCSD/LG Energy Solution silicon-anode solid-state battery: 1) The all-solid-state battery consists of a cathode composite layer, a sulfide solid electrolyte layer, and a carbon free micro-silicon anode. 2) Before charging, discrete micro-scale Silicon particles make up the energy dense anode. During battery charging, positive Lithium ions move from the cathode to the anode, and a stable 2D interface is formed. 3) As more Lithium ions move into the anode, it reacts with micro-Silicon to form interconnected Lithium-Silicon alloy (Li-Si) particles. The reaction continues to propagate throughout the electrode. 4) The reaction causes expansion and densification of the micro-Silicon particles, forming a dense Li-Si alloy electrode. The mechanical properties of the Li-Si alloy and the solid electrolyte have a crucial role in maintaining the integrity and contact along the 2D interfacial plane. (Photo: UCSD)



Toyota's planned progression to solid-state batteries envisions initial solid-state use in hybrid-electric rather than fully electric vehicles. (Photo: Toyota)



Energy-retention plot for StoreDot's "silicon-dominant" XFC battery cell, the company's interim step toward a silicon-intensive solid-state battery. (Photo: StoreDot)

of carbon dioxide and maintaining a pure oxygen atmosphere, could create very good bonding at temperatures up to 700 degrees – and without forming the undesirable, resistance-inducing compounds.

The performance of the cathode-electrolyte interface made using this method, said professor of nuclear and materials science and engineering Bilge Yildiz, who also coauthored the technical paper describing the research in the journal *Advanced Energy Materials*, was "comparable to the best interface resistances we have seen in the literature," she told *MIT News*. But those favorable resistances were achieved using the extra step of applying coatings. "We are finding that you can avoid that additional fabrication step, which is typically expensive," Yildiz added.

The researchers now are analyzing the durability of these specially sintered bonds during extended battery cycling. But the new findings potentially could rapidly be applied to battery production, Yildiz said. "What we are proposing is a relatively simple process in the fabrication of the cells. It doesn't add much energy penalty to the fabrication" and the added costs should be negligible.

Toyota, which has its own development program for solid-state batteries, also is concerned with the potential for long-term performance degradation related to lithium dendrite formation. Toyota Motor Corp. CTO Masahiko Maeda said in a mid-2021 virtually conducted media briefing attended by SAE Media that in the company's ongoing solid-state battery research, "we found that short service life was an issue. To solve this and other issues, we

need to continue development, mainly of solid electrolyte materials." He also stressed that the company would prefer to first launch solid-state batteries in hybrid-electric vehicles (HEVs).

"One of the reasons that Toyota is starting with HEVs is because it wants to introduce solid-state batteries to the market as soon as possible, gain customer feedback and continue to evolve them, Maeda said. "Rather than building a large-scale production line for BEVs, which require a large number of batteries, it is better to start with HEVs, which have smaller batteries and a development process with which Toyota is familiar. This would allow solid-state batteries to be introduced to the market faster, as well as enable improvement of the manufacturing technology for them."

Pushing Ahead with Silicon

Graphite (carbon) mostly has served as the industry's choice for anode material during lithium-ion batteries' initial volume-production phases. But attention is shifting to anode material with improved characteristics; silicon and lithium metal are front-runners and silicon — currently used in small ratios in the anode of some production-battery lithium-ion chemistries — remains the focus of new and emerging research efforts and various startup companies.

Late 2021 saw the announcement of new research from the University of California at San Diego (UCSD) pairing solid-state electrolyte with an all-silicon anode to create what the scientists are calling "a silicon all-solid-state battery." As reported by UCSD's News Center, the work resulted in a "laboratory-scale full cell that delivers 500 charge and discharge cycles with 80 percent capacity retention at room temperature, which represents exciting progress for both the silicon anode and solid-state battery communities."

Although silicon can deliver up to 10 times the storage capacity of a graphite anode, lithium-ion batteries with silicon added to the anode to boost energy density see impact on the number of charge cycles and energy retention. Much of those performance compromises is due to the interaction of silicon anodes and the liquid electrolytes used in all current production lithium-ion batteries. "For silicon anodes, we know that one of the big issues is the liquid electrolyte interface instability," said UCSD nanoengineering professor Shirley Meng, the corresponding author on a paper about the research published in the journal *Science*. "We needed a totally different approach," Meng, Director of the Institute for Materials Discovery and Design UCSD, told the UCSD News Center.

The UCSD researchers reported that they eliminated the carbon and the binders usually employed with all-silicon anodes. They also looked to micro-silicon, which is not as highly processed, and thus less-expensive, than nano-silicon typically used for anodes. The micro-silicon anode then was teamed with a sulfide-based solid electrolyte that experiments demonstrated is extremely stable for use with all-silicon anodes. By totally eliminating carbon in the anode, the team markedly reduced the interfacial contact (and corresponding performance-reducing effects) with the solid electrolyte, avoiding continuous capacity loss common with liquid-based electrolytes.

"The solid-state silicon approach overcomes many limitations in conventional batteries. It presents exciting opportunities for us to meet market demands for higher volumetric energy, lowered costs, and safer batteries especially for grid energy storage," said Darren H. S. Tan, the first author of the *Science* paper. Tan also is the CEO and co-founder of a startup, UNIGRID Battery, which has licensed the technology for the silicon all-solid-state battery.

Meanwhile, any number of startups also continue to concentrate silicon-based solid-state battery designs. StoreDot, for one, aims to have a silicon-based solid-state battery (dubbed XED, or Extreme Energy Density) sometime in the 2028 timeframe. The company has said resulting energy density from silicon-based lithium-ion batteries can enable DC fast charging that delivers up to 25 miles (40 km) of range per minute while reducing long-term performance degradation. Another, Colorado's Solid Power, is developing its own silicon-intensive anode and pairs it with a proprietary sulfide-based solid electrolyte. BMW and Ford have invested in Solid Power and BMW has intimated it targets a mid-2020s launch for EVs using solid-state technology.

Another solid-state battery developer, QuantumScape, has said graphite anodes are responsible for many of the limitations of contemporary lithium-ion batteries. QuantumScape, which since 2015 has collaborated with the Volkswagen Group, is hoping for energy density of "close to" 1000 Wh/liter for its novel battery design that is manufactured without an anode — charging the cell causes an anode of pure lithium metal to form.

This article was written by Bill Visnic, Editorial Director, Mobility Media, SAE International. For more info visit ***http://info.hotims.com/82321-423****.*

Leading the Charge: FAST 40

From multinational battery developers to commercial-vehicle components manufacturers merging new-age motors with established power-transfer technologies, *Battery & Electrification Technology's* Fast 40 presents some of the most important names in electrification. Entities from the automotive, commercial-vehicle, and aerospace sectors are represented, as their work developing electrification strategies for their respective industries touches economies on nearly every continent — and their parallel engineering paths converge to accelerate transportation's transition to electrification.

AESC (Automotive Energy Supply Corp.)

Established in 2007 as a joint venture between Nissan Motor Co., NEC Corp., and NEC Tokin Corp, AESC (Automotive Energy Supply Corporation) develops and produces high-performance lithium-ion batteries for light vehicles. To date, its batteries manufactured in Japan, the U.S., and Europe have all been installed in over 600,000 EVs with a zero rate of critical malfunction.

www.envision-aesc.com/en/

Airbus

Airbus developed the first all-electric, four-engine aerobatic aircraft in 2010. Since then, the company has developed several successful electric/hybrid aircraft, including the E-Fan 1.1, a 60 kW all-electric aircraft that flew across the English Channel in 2015.

www.airbus.com

Airflow

Founded in 2019 by five former Airbus Vahana team members, Airflow's M200 aircraft, scheduled to make its debut in 2025, will be able to carry 2,000 pounds of cargo, nine passengers, and be 100-percent carbon neutral. It will require just 400 feet of takeoff and landing distance and have a reputed 500-mile range.

www.airflow.aero

Akasol

Recently acquired by BorgWarner, German brand Akasol supplies a third-generation battery system for commercial vehicles that reportedly has the highest energy density available on the market. A service life of up to 4,000 charging cycles also is achieved.

www.akasol.com/en/battery-systems

Allison Transmission

Allison's eGen Power series of fully integrated electric axles is designed to fit between the wheels of medium- and heavy-duty trucks and buses, replacing the vehicle's traditional powertrain. It also integrates a two-speed gearbox in the central housing, enabling the high starting gradeability and increased top speed and efficiency.

www.allisontransmission.com

American Battery Solutions

American Battery Solutions produces custom and off-the-shelf battery packs for buses and medium- and heavy-duty trucks. These battery systems include integrated liquid cooling and battery-management systems with ASIL-C functional safety.

www.americanbatterysolutions.com

BAE Systems

With decades of experience designing integrated flight controls and propulsion systems, BAE Systems now is investing heavily in flight and safety critical systems to enable the future of hybrid and all-electric aircraft. Three primary focus areas are energy-management systems, integrated control systems, and power conversion systems.

www.baesystems.com

BorgWarner

One of the oldest names in automotive power transmission, BorgWarner offers a full line of EV, hybrid, and ICE products including battery systems, EV transmissions, electric machines and drive modules, e-axles, power electronics, battery charging and thermal management solutions.

www.borgwarner.com

Bosch

From e-bikes to electric heavy trucks and railcars, Bosch has systems solutions for every electrified vehicle including battery-electric drive systems, e-axles, fuel-cell electric drives, hybrid-electric technologies including 48-V solutions, and thermal management.

www.bosch.com

BrightVolt

BrightVolt develops solid-state lithium battery chemistry and has sold over 15 million primary/nonrechargeable solid-state batteries worldwide. The company's new "platform" solid-state polymer electrolyte is aimed at secondary/rechargeable Li-ion batteries used in consumer electronics and e-mobility applications. The company's proprietary technology is polymer matrix electrolyte (PME).

www.brightvolt.com

BYD

BYD currently is ranked as the world's 4th largest battery manufacturer, specializing in safe LFP (lithium-iron phosphate) cell chemistry, as well as electric motor design and engineering. Based in China, BYD has North American headquarters in Los Angeles, CA, and a 550,000-ft^2 electric-bus manufacturing facility in Lancaster, CA.

https://en.byd.com/

Contemporary Amperex Technology Ltd. (CATL)

For the past five years, China-based CATL has been ranked as the world's largest EV battery supplier and a major developer of lithium-based cell chemistries. CATL has among its OEM customers Tesla, NIO, and Volkswagen and Fisker's upcoming Ocean SUV. Additionally, CATL has developed other battery technologies such as sodium-ion cells as well as its own recently announced EV battery-swap brand.

www.catl.com

Continental

High-voltage current sensing for 400-800-V EVs, battery impact detection systems, and intelligent battery sensing for the vehicle's conventional 12-V battery — essential for micro-hybrid stop-start operation — are technologies engineered for electrified vehicles by Continental Automotive.

www.continental-automotive.com

Cummins

Cummins' New Power business works with multiple OEMs to integrate its battery packs and modules for application in trucks, buses, and off-highway machines. Cummins also released its new PowerDrive 8000 system for terminal tractors, which will be powered with up to 182 kWh of fast-charging Cummins batteries and equipped with DC-fast charge technology.

www.cummins.com/new-power

Dana

Global Tier 1 supplier of e-mobility products for light, commercial and off-highway vehicles, including in-house expertise in gearboxes, low- to high-voltage motors, inverters, controls, and thermal and battery management.

www.dana.com

Denso

Denso's decades of experience as an automotive electronics leader is being harnessed for electrified vehicles. The company is a volume producer of electric-powertrain system control and lithium-battery control systems, battery monitoring and battery current sensors, DC-DC converters, electric machines and drive modules, thermal management, and hydrogen control technologies for fuel-cell vehicles.

www.denso.com/us-ca/en/

Eaton

Eaton formed a new ePowertrain business unit to focus on products from its electrified-vehicle (EV) transmission, reduction gearing, and differential portfolios for commercial and light-duty EVs. Its portfolio of multispeed transmissions includes 2-, 4- and 6-speed electrified commercial-vehicle transmissions based on architecture typical of automated manual transmissions and with shifting synchronized without a clutch.

www.eaton.com/us/en-us/products/emobility.html

EVE Energy North America

EVE is a leader in developing and manufacturing lithium battery cell chemistries, including lithium thionyl chloride ($Li/SOCl_2$) and lithium manganese dioxide (Li/MnO_2), as well as developing lithium rechargeable cells and customized portable power source solutions.

www.evebatteryusa.com

FEV

One of the world's top engineering consultancies, FEV serves its OEM partners by developing technical solutions and work on new standards for innovative energy storage systems, focusing on battery energy density, safety, packaging, production strategies, and testing.

www.fev.com

GaN Systems

GaN Systems aims to obsolete silicon as the mainstay of computer chips with gallium nitride (GaN), a hard and mechanically stable wide-bandgap semiconductor that offers higher breakdown strength, faster switching speed, higher thermal conductivity, and lower on-resistance. These attributes lead to EV power systems that are smaller, lighter, less expensive and have up to 25 percent less power loss.

www.gansystems.com

Heart Aerospace

Swedish-based Heart Aerospace is in the process of developing a 19-passenger electric aircraft called the Heart ES-19 that can travel 250 miles and has a backup generator for energy reserve and range extension. United Airlines and commercial aviation holding company Mesa Air Group have already placed orders for approximately 200 electric aircraft, the first of which should be ready for delivery in 2026.

www.heartaerospace.com

Hyliion

Hyliion produces electrified powertrain systems that can augment or fully replace diesel- or natural gas-fueled commercial-vehicle powertrains. Its Hybrid eX solution designed for Class 8 trucks bolts onto existing or new OEM truck chassis.

www.hyliion.com

LG Energy Solution

Global researcher, developer, and builder of lithium-ion batteries for automotive EV, IT, and ESS applications. Worldwide production sites and supplier to several major automakers.

www.lgensol.com

Lightning eMotors

The Loveland, CO-based company claims to be the first commercial EV manufacturer to offer electrification of both legacy OEM platforms and purpose-built vehicles. Its eChassis platform accommodates various battery sizes and configurations, as well as different powertrain integrations and wheelbases.

www.lightningemotors.com

Magna

Multinational Tier I supplier of electrified powertrain components and systems for passenger and commercial vehicles. eDrive portfolio includes components for EV, HEV, and PHEV applications.

www.magna.com

Upcoming... Webinars

Driving Interconnection System Reliability to Meet New Drivetrain Electrification Demands

Tuesday, May 17, 2022, at 11:00 am EDT

Rapidly expanding automotive megatrends, such as drivetrain electrification and autonomous driving, have led to a sharp demand for ever-lighter vehicle body weights. Evolving architectures, along with the resulting increase in body control modules, require even more connections to PCBs, presenting challenges – and opportunities – to PC board manufacturers. This 60-minute Webinar addresses not only challenges faced by manufacturers but also new approaches that can be taken with press-fit technology.

Speakers:

Siegfried Beck
Product Manager,
TE Connectivity

Boris Kertscher
Product Manager,
TE Connectivity

Please visit www.techbriefs.com/webinar279

Webinars on Demand!

Shorten Electric Vehicle Development Cycle Using NI and AVL Virtual Testing Solution

As electric vehicle (EV) powertrains grow more complex, model-based design and testing promise true insight, detailed communication, and engineering and operational process efficiency. Automotive test engineers who are focused on electric powertrain development want to shift as much test as possible to simulation earlier in the development process. This 45-minute Webinar examines how model-based FPGA simulation and an integrated systems approach combine flexibility with off-the-shelf delivery.

Speakers:

Martin Abart
Senior Product Manager,
Smart Calibration and Virtual Testing,
AVL

Brandon Brice
Senior Solutions Marketing Manager,
Transportation,
NI

Manuel Hofmann
Principal Field Marketing Manager,
Automotive (EMEA),
NI

Abhishek Singh
Senior Application Support Engineer,
AVL

Please visit www.techbriefs.com/webinar265

Transform EV Design and Development Through Pervasive Engineering Simulation

This 30-minute Webinar examines how several OEMs and major suppliers have made progress in their electrification journey using powerful and comprehensive simulation engineering software, addressing areas such as:

- Electric machine design, analysis, and verification solutions from concept design to detailed electromagnetics
- System-level design, analysis, and optimization solutions for power electronic systems
- Solutions for battery and battery management systems (BMS) and the coupling of different physics

Speaker:

Zed Tang, Ph.D.
Global Solution Architect,
Electrification,
Ansys

Please visit www.techbriefs.com/webinar270

Maxwell Technologies

Develops and manufactures energy storage and power-delivery solutions. Focus on ultracapacitor applications for consumer and industrial electronics, renewable energy, automotive, transportation and information technology.

www.maxwell.com

Meritor

Meritor, which recently entered into an agreement to be acquired by Cummins, has begun production of its 14Xe ePowertrain, a fully integrated, all-electric drive system for Class 8 trucks. The modular design enables the interchangeability of key components, including electric motors, transmissions, gearing, and brakes.

www.meritor.com

Northvolt

Sweden-based battery cell manufacturer Northvolt offers high-performance "green" lithium-ion cells based on proprietary Lingonberry NMC chemistry. Available in cylindrical and prismatic formats, the cells reportedly offer a minimum 1000+ charging cycles, are 95 percent recyclable and will utilize 50 percent recycled raw materials by 2030.

www.northvolt.com

ONE (Our Next Energy)

Developer of advanced EV Battery & Electrification Technology. Focus on hybrid battery-chemistry applications that incorporate lithium-ion phosphate chemistry.

www.one.ai

Panasonic

Designs, engineers, and manufactures lithium-ion battery systems for EV, HEV, and PHEV applications. Worldwide production facilities supply major automotive OEMs.

https://na.panasonic.com/us/

QuantumScape

Researcher and developer of anode-less lithium-metal solid-state batteries for EVs. More than 10 years of R&D efforts and 200 patents and patent applications.

www.quantumscape.com

Rolls-Royce

Rolls-Royce currently envisions four key markets where hybrid-electric technology will play a key role: small propeller aircraft, urban air mobility, commuter aircraft, and regional aircraft. Among current projects is the Magnus eFusion, a two-seat training aircraft that serves as a flying testbed for the sub-100 kW propulsion systems developed by Rolls-Royce Hungary.

www.rolls-royce.com

Samsung SDI

Developer of prismatic-format lithium-ion batteries for EVs, PHEVs, and HEVs. Also manufactures low-voltage system that combines supercapacitor technology with conventional battery storage.

www.samsungsdi.com

Schaeffler

Global Tier I developer and supplier of electrified-vehicle driveline components. Portfolio includes traction motors, electric-drive modules, and wheel-hub motors.

www.schaeffler.com/en/index.jsp

Siemens

Global research, engineering and manufacture of electric drive systems for consumer and commercial vehicles. Manufacturer of consumer EV chargers.

www.siemens.com/global/en.html

SK Innovation

Developer and producer of lithium-ion battery systems for EVs PHEVs and HEVs. Global footprint of manufacturing facilities supplies variety of automotive OEMs.

http://eng.skinnovation.com/

Standard Lithium

Developer of patent-pending LiSTR direct lithium extraction process claimed to drastically reduce the recovery time of extracting lithium from brine. Flagship development site located in the southern U.S.

www.standardlithium.com

StoreDot

Research and development of nanosilicon EV battery anode as well as solid-state Battery & Electrification Technology. Development focus is to speed recharging times and enhance safety.

www.store-dot.com

Wright Electric

Wright Electric, a New York-based company funded by NASA, the U.S. Department of Energy, and the U.S. Air Force among others, specializes in developing technology for large commercial airplanes. The company is designing the all-electric Wright Spirit, a 100-passenger airplane designed for one-hour flights.

www.weflywright.com

ZF

Multinational Tier I supplier of EV drive-system components and electrical-system software for consumer and commercial vehicles, as well as other modes of mobility. Passenger-vehicle portfolio includes modular electrified axles and all-wheel-drive solutions.

www.zf.com/mobile/en/homepage/homepage.html

Extending Battery Life of Small Drones

A built-in wireless electrification line battery charging system to extend flight time and patrol U.S. borders.

University of Houston, TX

A continuous flight of small drones over its perimeter could enhance security of the nation's border, but there is one small problem: The battery limitation of small drones (they last about 30 minutes) is a major obstacle to continuous flight time.

To address this problem, Gino Lim, R. Larry and Gerlene (Gerri) R. Snider Endowed Chair of Industrial Engineering proposed the use of drones with a built-in wireless electrification line (E-line) battery charging system. Lim pioneered that technology in 2017.

"Smart border patrol using small-size drones may provide significant help in patrolling areas inaccessible to patrol agents, reduce agent response time, and increase the safety of patrol agents working in dangerous regions. To strengthen border security and reduce the need for patrolling via human agents, we propose the use of drones coupled with the use of E-lines for continuous border surveillance," Lim reported in the journal *Computers & Industrial Engineering*. The paper's first author is Navid Ahmadian, a former doctoral student in Lim's lab.

The E-line system charges the drones during their surveillance, enables a continuous and seamless flight over the border and eliminates the need for battery charging stations. Continuous monitoring sends live information about different locations of the borderline to the designated control centers, helping enhance border security and reducing the necessity of systems operated by people.

The battery limitation of small drones is a major obstacle to continuous flight time. (Photo: University of Houston)

"This work provides an optimization model to determine the optimal number of drones, the optimal length of the E-line, and the optimal location of the E-line system required for border surveillance," said Lim.

In developing their model, the team reviewed a case study of a segment of the U.S.-Mexico borderline spanning 22.8 miles and located between two border crossings within the Cochise County limits in Arizona.

Although drones have been the subject of many studies, few studies have focused on the implementation of the drone for continuous border surveillance.

In previous work Lim provided a template for drone routes targeting chronic patients in rural areas to assist in medicine delivery via drone.

For more information, contact Laurie Fickman at lafickman@uh.edu; 713-743-8454.

Micro-Supercapacitors Enable Fast Charging

The supercapacitors are so small that they can fit on the system circuits which control various functions in almost all electronics.

Chalmers University of Technology, Sweden

Micro-supercapacitors could revolutionize the way we use batteries by increasing their lifespan and enabling extremely fast charging. Now, researchers at Chalmers University of Technology have developed a method that represents a breakthrough for how such supercapacitors can be produced.

Supercapacitors consist of two electrical conductors separated by an insulating layer. They can store electrical energy and have many positive properties compared to a normal battery, such as much more rapid charging, more efficient energy distribution, and a much greater lifespan without loss of performance, with regards to the charge and discharge cycle. When a supercapacitor is combined with a bat-

tery in an electrically powered product, the battery life can be extended many times — up to four times for commercial electric vehicles. And whether for personal electronic devices or industrial technologies, the benefits for the end consumer could be huge.

But in practice, today's supercapacitors are too large for many applications where they could be useful. They need to be about the same size as the battery they are connected to, which is an obstacle to integrating them in mobile phones or electric cars. Therefore, a large part of today's research and development of supercapacitors is about making them smaller.

Agin Vyas, doctoral student at the Department of Microtechnology and Nanoscience at Chalmers University of Technology, and his colleagues have been working with developing 'micro' supercapacitors. These are so small that they can fit on the system circuits which control various functions in mobile phones, computers, electric motors, and almost all electronics we use today. This solution is also called 'system-on-a-chip'.

One of the most important challenges is that the minimal units need to be manufactured in such a way that they become compatible with other components in a system circuit and can easily be tailored for different areas of use.

The new paper published by Vyas demonstrates a manufacturing process in which micro-supercapacitors are integrated with the most common way of manufacturing system circuits (known as CMOS).

"We used a method known as spin coating, a cornerstone technique in many manufacturing processes. This allows us to choose different electrode materials. We also use alkylamine chains in reduced graphene oxide, to show how that leads to a higher charging and storage capacity," said Vyas.

"Our method is scalable and would involve reduced costs for the manufacturing process. It represents a great step forward in production technology and an important step toward the practical application of micro-supercapacitors in both everyday electronics and industrial applications."

For more information, contact Agin Vyas at agin@chalmers.se; +46 31-772 1000.

A High-Energy Density Lithium-Ion Battery

The battery could be used in a wide range of technologies including drones, electric vehicles, and household electricity storage systems.

National Institute for Materials Science, Japan

National Institute for Materials Science (NIMS) and Softbank Corp. have developed a lithium-air battery with an energy density over 500Wh/kg — significantly higher than currently lithium-ion batteries. The research team also confirmed that this battery can be charged and discharged at room temperature. In addition, the team found that the battery developed by the team shows the highest energy densities and best cycle life performances. These results signify a major step toward the practical use of lithium-air batteries.

This research team had previously developed original battery materials that significantly increase the performance of lithium-air batteries in ALCA-SPRING-supported research. The team then developed a technique to fabricate high-energy-density lithium-air cells at the NIMS-SoftBank Advanced Technologies Development Center. Finally, the team created a new lithium-air battery by combining these new materials and the fabrication techniques.

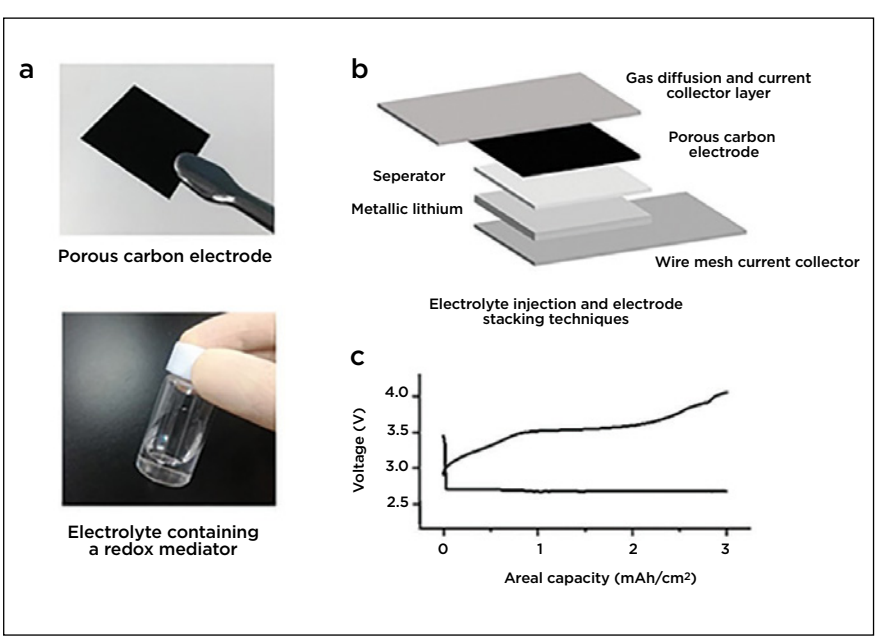


Figure. (a) New materials for lithium-air batteries developed by ALCA-SPRING project. (b) Cell fabrication technique developed by the NIMS-SoftBank Advanced Technologies Development Center. (c) Demonstration of stable discharge/charge cycles of lithium-air batteries with energy density over 500Wh/kg operated at the room temperature. (Photo: NIMS)

The team is currently developing higher-performance battery materials and plans to integrate them into the newly developed lithium-air battery with the aim of greatly increasing the battery's cycle life. The team then plans to expedite efforts to put the battery into practical use at the NIMS-SoftBank Advanced Technologies Development Center.

This project was carried out by a research team led by Shoichi Matsuda (Senior Researcher, NIMS), Manai Ono (Postdoctoral Researcher, NIMS), Shoji Yamaguchi (Specialist Staff, NIMS) and Kohei Uosaki (Research Fellow, NIMS; also Director, NIMS-SoftBank Advanced Technologies Development Center). This work was mainly supported by the JST ALCA-SPRING program and the NIMS-SoftBank Advanced Technologies Development Center.

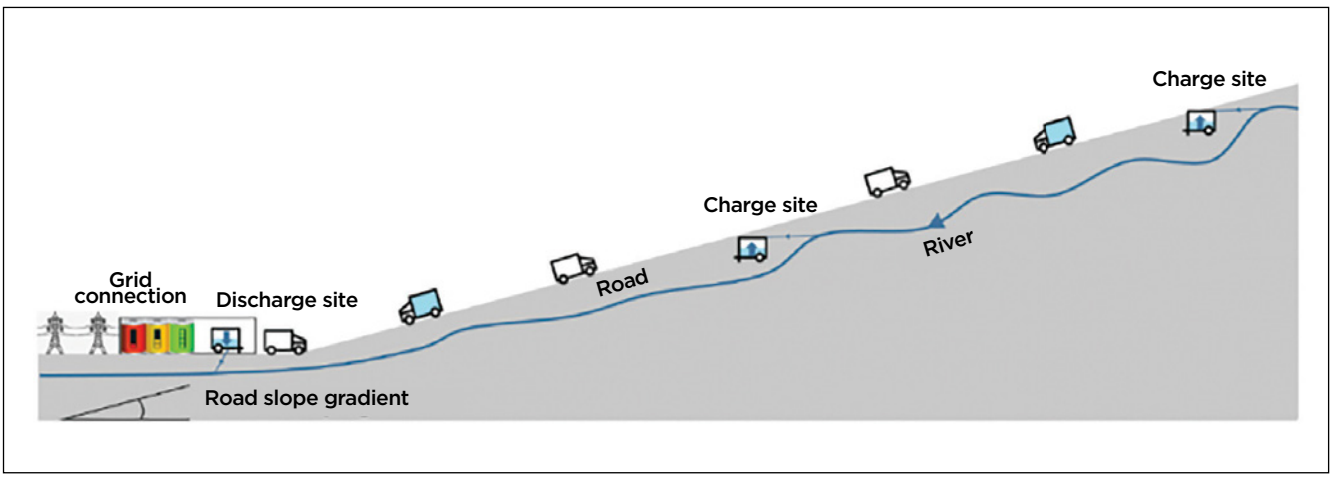
Lithium-air batteries have the potential to be the ultimate rechargeable batteries: They are lightweight and high capacity, with theoretical energy densities several times that of currently available lithium-ion batteries. Because of these potential advantages, they may find use in a wide range of technologies, such as drones, electric vehicles, and household electricity storage systems.

For more information, contact Shoichi Matsuda at Matsuda.Shoichi@nims.go.jp; 81-29-860-4637.

Hydropower Technology Swaps Dams with Electric Trucks

Electric trucks could provide a clean solution for electricity generation in mountainous regions.

International Institute for Applied Systems Analysis, Laxenburg, Austria



Schematic description of the system where the empty truck moves up the mountain to collect the containers filled with water at the charge site and the truck with the full container goes down the mountain generating electricity. The water is then unloaded at the discharge site. (Photo: IIASA)

In steep mountain regions, the potential for generating electricity from a small stream of water is high, however, the hydropower potential of these regions remains untapped as it requires storage reservoirs, which have environmental and social impacts. International Institute for Applied Systems Analysis (IIASA) researcher Julian Hunt and an international team of researchers developed a new technology called Electric Truck Hydropower that could become a key method for electricity generation in steep mountainous regions. The results of the study have been published in the *Energy Journal*.

Electric Truck Hydropower would use the existing road infrastructure to transport water down the mountain in containers, applying the regenerative brakes of the electric truck to turn the potential energy of the water into electricity and charge the truck's battery. The generated energy could then be sold to the grid or used by the truck itself to transport other goods. Electric Truck Hydropower could also generate electricity in combination with solar and wind resources or provide energy storage services to the grid.

The proposed technology is a clean source of electricity that is competitive with solar, wind, and conventional hydropower. Cost estimates show that the levelized cost of Electric Truck Hydropower is $30-100 per MWh, which is considerably cheaper than conventional hydropower at $50-200 per MWh. The environmental impacts of Electric Truck Hydropower are also significantly smaller than that of conventional hydropower.

"This technology does not require dams, reservoirs, or tunnels, and it does not disrupt the natural flow of the river and fish passage. The system requires only roads, which already exist, charging and discharging stations similar to small car parks, a battery facility connected to the grid, and the trucks," said Hunt.

When looking at the global reach of this technology, the research team estimated that Electric Truck Hydropower could generate 1.2 PWh electricity per year, which is equivalent to about 4 percent of global energy consumption in 2019.

The technology could harness the previously untapped potential for hydropower on steep mountain ranges. The regions with the highest potential are the Himalayas and the Andes.

"It is an interesting electricity generation alternative due to its high flexibility. For example, if a country is in an energy crisis, it can buy several electric trucks to generate hydropower," Hunt said. "Once the crisis is over, the trucks can be used to transport cargo," he added.

For more information, contact Ansa Heyl at +43 2236 807 574.

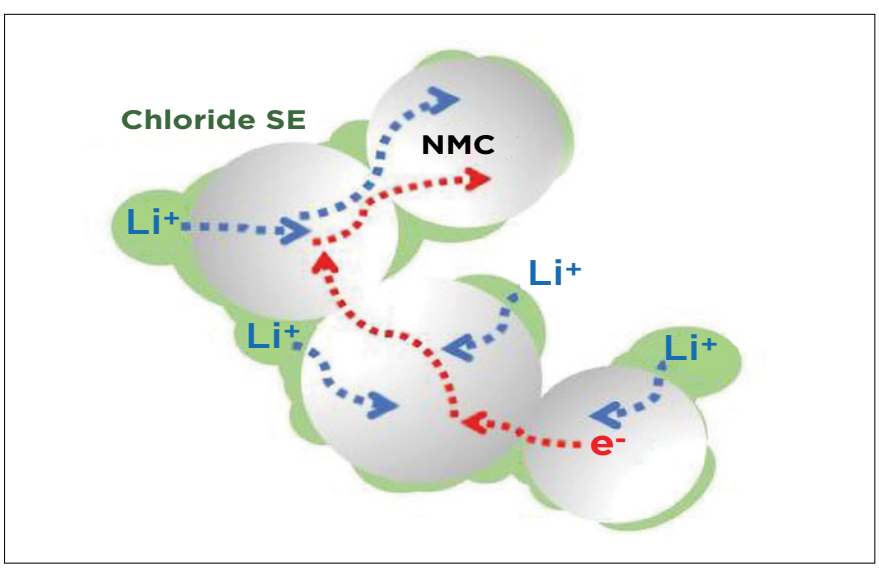
New Material Offers Promise for Solid-State Batteries

A new chlorine-based solid-state electrolyte for lithium-ion batteries could lead to higher safety and increased energy density.

Argonne National Laboratory, DuPage County, IL

Researchers from the University of Waterloo, Canada, who are members of the Joint Center for Energy Storage Research (JCESR), headquartered at the U.S. Department of Energy's (DOE) Argonne National Laboratory, have discovered a new solid electrolyte that offers several important advantages.

This electrolyte, composed of lithium, scandium, indium, and chlorine, conducts lithium ions well but electrons poorly. This combination is essential to creating an all-solid-state battery that functions without significantly losing capacity for over a hundred cycles at high voltage (above 4 volts) and thousands of cycles at intermediate voltage. The chloride nature of the electrolyte is key to its stability at operating conditions above 4 volts — meaning it is suitable for typical cathode materials that form the mainstay of today's lithium-ion cells.



Chlorine-based electrolytes like the one shown here are offering improved performance for solid-state lithium-ion batteries. (Photo: Linda Nazar/University of Waterloo)

Current iterations of solid-state electrolytes focus heavily on sulfides, which oxidize and degrade above 2.5 volts. Therefore, they require the incorporation of an insulating coating around the cathode material that operates above 4 volts, which impairs the ability of electrons and lithium ions to move from the electrolyte and into the cathode.

The team wasn't the first to devise a chloride electrolyte, the decision to swap out half of the indium for scandium based on their previous work proved to be a winner in terms of lower electronic and higher ionic conductivity.

One chemical key to the ionic conductivity lay in the material's crisscrossing 3D structure called a spinel. The researchers had to balance two competing desires — to load the spinel with as many charge carrying ions as possible, but also to leave sites open for the ions to move through.

It is not yet clear why the electronic conductivity is lower than many previously reported chloride electrolytes, but it helps establish a clean interface between the cathode material and solid electrolyte, a fact that is largely responsible for the stable performance even with high amounts of active material in the cathode.

The research was funded by the DOE's Office of Science and Office of Basic Energy Sciences with some support from Canada's National Sciences and Engineering Research Council.

For more information, contact media@anl.gov; 630-252-5580.

Using Silver Sintering in Traction Inverter Assembly

Traction inverter power density (KW/L) and efficiency ($/KW) strongly impact electric vehicle (EV) weight, driving range, and cost of ownership. Unfortunately, traditional soldered power modules are not designed for EV traction and suffer from several limitations, which are directly related to poor design and misspecification of thermal and electrical attach layers in the inverter assembly.

ESI Automotive was approached by a leading tier one automotive supplier who needed to improve the reliability and power levels of its inverter for high-end hybrid and EV vehicles. Its previous generation design suffered from several limitations including voltage overshoots during switching, high thermal resistance, and early failures during power cycling and thermal cycling. After exploring multiple solutions, reliability remained an issue. Fortunately, silver sintering held the key.

By working closely with the customer on their material and application process development, soldering and wire bonding was replaced with a fully sintered module. This new approach delivered significant reliability gains in the form of a 10-fold improvement in power cycling, reduced inductance (lower voltage overshoots), improved thermal transfer, and lower thermal resistance. The end inverter also had double the current capability and 80 percent higher power density at half of the weight of the original inverter. These benefits combined create a compelling case for the use of sintering molded SiC modules.

Module Sintering Process

To compensate for the reversible thermal warpage of overmolded modules, thicker bond lines (75-125µm) are needed to mate surfaces and to mitigate stress, since the difference in thermal expansion of the module and heat sink could be >15ppm for each °C rise in temperature.

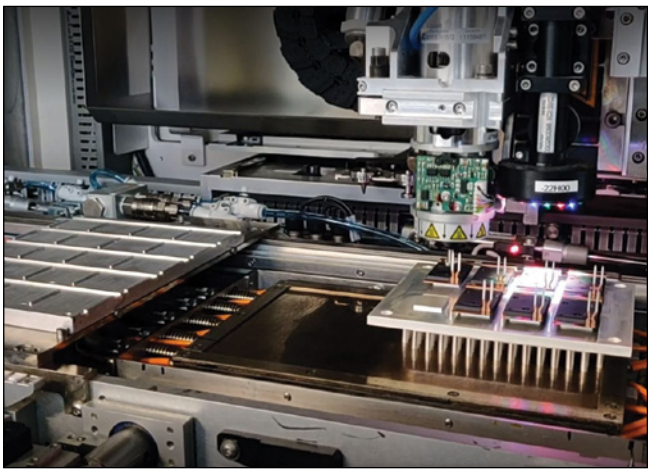
A screw-based dispense valve was adapted with a custom flat nozzle to enable thick deposits (>400um) of sintering paste to be rapidly applied onto the pads, eliminating significant material waste and cleaning issues. High-speed implementation is easy with the use of existing robot technology, and paste dispense for most inverter assemblies can be done in below 30 seconds.

The paste is then dried prior to the placement of the modules. Alternatively, modules can be placed directly onto the wet pads (via the pick-place machine) before drying, which is done at 130-140 °C (for 15-60 minutes depending on module size) to remove the solvents. Finally, the stack is put through the sintering step in a heated press at 250 °C at 8-12 MPa.

Sinter Joint Characterization

The sintering layer then underwent shear, thermal shock, and power cycling testing.

Larger strong sintered joints (above 200 mm^2) required a custom shear tool on a 250KN Instron tester for shearing). All assemblies exceeded a 500kg load before mechanical failure, which consistently occurred as a result of failure in the epoxy molding compound. These tests demonstrate that while shear values cannot be used as a standalone quality specification, they are a reliable indicator of assembly quality.



The end inverter had double the current capability and 80 percent higher power density at half of the weight of the original inverter. (Photo: ESI Automotive)

Thermal Shock Testing

The silver sintered and SAC305 soldered module-heatsink assemblies were subjected to liquid-liquid thermal shock testing for 1000 cycles at between -40 °C and 125 °C. Sintered assemblies easily withstood cycles with <5 percent delamination while identical modules based on SAC305 preforms had almost completely delaminated before 500 cycles.

Thermal Impedance and Power Cycling

The soldered and sintered MOSFET module and heat-sink assemblies underwent power cycle testing at a constant temperature gap of 125 °C between the junction and the coolant.

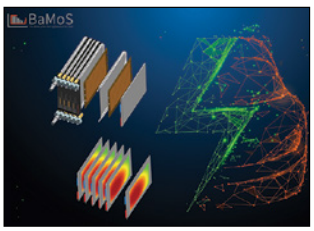
The initial thermal resistance (measured collectively from die to the cold plate) of the soldered assembly was >10 percent higher than for the heat sink. This difference is substantial as it means sintered assemblies can operate successfully with higher power inputs (and temperatures) for the same thermal dissipation.

Prior to cycling, the sintered part could withstand higher currents (~3A higher) for the same temperature differential. When power-cycled with long ON and OFF cycles (to heat up the module to heat-sink joint), the soldered part gradually heated up at a consistently lower current level to maintain the same differential. After 22,000 cycles, a 15 percent reduction in current, the established failure threshold, was recorded. After 56,000 cycles, the sintered part displayed minimal current degradation and remained operational.

Our data illustrates the benefits of combining module to heat sink sintering with silver sintered die attach. Such advancements represent a new frontier for EV traction power modules and inverters, which are becoming increasingly demanding where reliability and power density are concerned. From a systems level perspective, the much-improved current ratings, weight savings, and reduced cooling requirements will accelerate the uptake of sintering technology in power assembly stacks, especially for high-end EVs.

This article is contributed by Gyan Dutt, Power Electronics Specialist, ESI Automotive (Waterbury, CT). ***For more info visit http://info.hotims.com/82321-424.***

NewProducts



Battery Management Solution

InnovationLab (Heidelberg, Germany) has launched BaMoS, its battery monitoring solution for automotive applications. BaMoS uses ultra-thin printed pressure and temperature sensors to capture detailed battery data down to the individual cell level, which can be used to extend battery lifetime by up to 40 percent. The system captures detailed, cell-level pressure and temperature data, obtained from ultra-thin printed sensor foils which can be placed between individual battery cells. As battery cells expand and contract during the charge-discharge cycle, a pressure-sensitive foil can monitor this 'breathing', to measure the state of charge, detect any irregular behavior, and prevent overcharging. This cell-level information delivers valuable insights into state of health and performance, helping R&D teams to improve their battery designs and battery monitoring solutions.

For more info visit http://info.hotims.com/82321-400

Nano Energy Convertor

ROHM Semiconductor (Kyoto, Japan) announced the availability of a new evaluation board, the REFLVBMS001-EVK-001, which facilitates the verification of the operation of ultra-efficient battery management solutions for the expanding IoT field. The REFLVBMS001-EVK-001 is equipped with a power supply IC (buck DC/DC converter IC) and reset IC (voltage detector IC) utilizing original Nano Energy ultra-low current consumption technology. In addition, it consists of a battery charger IC that supports low-voltage rechargeable batteries, along with the NGK INSULATORS's thin, large capacity EnerCera® li-ion rechargeable battery. The battery charger IC is suitable for a wide range of charge voltages; it is capable of charging, monitoring, and discharging batteries, making it ideally suited for compact IoT devices.

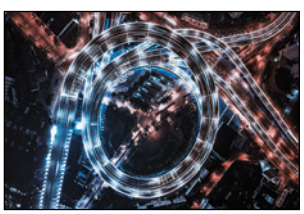
For more info visit http://info.hotims.com/82321-401

Automotive-Qualified High-Voltage Switcher ICs

Power Integrations (San Jose, CA) has added two new AEC-Q100 qualified, 1700-volt rated ICs to its InnoSwitch™3-AQ family. The new devices are the industry's first automotive-qualified switching power supply ICs to incorporate a silicon carbide (SiC) primary switching MOSFET. Delivering up to 70 watts of output power, the new ICs are targeted for use in 600- and 800-V battery and fuel-cell electric passenger vehicles, as well as electric buses, trucks, and a wide range of industrial power applications. Highly integrated InnoSwitch ICs reduce the number of components required to implement a power supply by as much as 50 percent, saving significant circuit-board space, enhancing system reliability and mitigating component sourcing challenges.

For more info visit http://info.hotims.com/82321-402

One-Box Signaling Tester



Rhode & Schwarz (Munich, Germany) has introduced high-performance 5G automotive measurements with comprehensive test coverage including RF, protocol and application testing using the new R&S CMX500 one-box tester covering the entire development cycle from chipsets to TCUs and entire vehicles. The R&S CMX500 provides extensive testing capability, supporting all 5G NR deployments covering LTE, 5G NR FR1 and FR2 in non-standalone (NSA) and standalone (SA) mode, for both FDD and TDD with an effortless setup and outstanding performance. The 5G tester reaches its high performance with its ability to handle data rates of 10 Gbps and beyond.

For more info visit http://info.hotims.com/82321-403

R-Car V4H for Automated Driving

Renesas Electronics Corporation (Tokyo, Japan) unveiled the R-Car V4H system on chip (SoC) for central processing in advanced driver-assistance (ADAS) and automated driving (AD) solutions. The R-Car V4H achieves deep learning performance of up to 34 TOPS (Tera Operations Per Second), enabling high-speed image recognition and processing of surrounding objects by automotive cameras, radar, and lidar. The R-Car V4H targets the highest volume zones of automated driving: Level 2+ and Level 3. It also supports surround view and automatic parking functions with impressive 3D visualization effects such as realistic rendering.

For more info visit http://info.hotims.com/82321-405

Automotive Relays

CIT Relay & Switch (Minneapolis, MN) offers automotive relays from low current up to our highest switching capacity of 80amps with voltage ranging from 6VDC to 72VDC. PC pin and quick connect mounting methods offer multiple choices for the design engineer, along with the option of mounting tabs in plastic and metal. Automotive relays can be found in just about every car, truck, tractor, bus, golf carts, and more. Used to enable a low amperage circuit to switch on and off a higher amperage circuit like headlights, relays are also used to switch multiple things at the same time using one output. A single output connected to multiple relays allow opening and/or closing simultaneously. CIT also offers automotive relays with a shroud option and sockets for mounting solutions.

For more info visit http://info.hotims.com/82321-406

Communication Gateways

Battery Energy Storage Systems require communication capabilities to connect to batteries and peripheral components, communicate with the power grid, monitor systems remotely, and much more. Intelligent networking is also required in order to connect to cloud solutions or SCADA systems. This connection can be made by using SG (Smart Grid) gateways from HMS Industrial Networks Inc. (Bedford, NH) that support both energy and industrial fieldbus protocols, as well as protocols required for cloud connection. The SG gateways enable centralized control as well as remote access for predictive maintenance, logging or data visualization using the i4SCADA solution from the HMS-owned company WEBfactory. The SG gateways also provide robust cybersecurity features, such as firewall, OpenVPN, TLS encryption and user management.

For more info visit http://info.hotims.com/82321-408

Diagnostic Solutions

Softing Automotive Electronics GmbH (Munich, Germany) and Kvaser AB (Mölndal, Sweden) together are offering a sturdy plug and play solution for diagnostic tasks in after-sales which can withstand even the toughest requirements in the repair shop environment. The combination of intuitive diagnostic software from Softing and the high-performance vehicle interface from Kvaser is the ideal solution for error localization, repair, and commissioning of individual components as well as entire vehicle systems, including electric vehicles and mobile working machinery. The individual after-sales tester Softing TDX.workshop, developed by OEMs and suppliers, supports service technicians in the efficient repair and maintenance of vehicles and their components. The Kvaser U100 fits in perfectly with this, flexibly and intuitively enabling high-performance vehicle communication using CAN and CAN-FD.

For more info visit http://info.hotims.com/82321-409

Lithium-Ion Battery Storge Solutions

Denios (Louisville, KY) has introduced new storage containers designed specifically for lithium-ion batteries. Ideal for new, questionable, damaged, defective, or end-of-life batteries, they protect employees, facilities, and the environment. Li-ion batteries from 1 KG to 10KG up to 100W, which are commonly used in smaller devices such as power tools, e-bikes, medical devices, laptops, tablets, mobile devices, and more, can be safely stored. With two hours of fire resistance, and integrated forklift pockets for easy relocation, these purpose-built containers protect against fire hazards due to thermal runaway, deep discharge, mechanical deformation, or chemical reaction. Each unit features solidly welded construction for a long service life, with integrated vents for passive ventilation. Lockable, hinged lid and doors keep the contents safe from unauthorized personnel.

For more info visit http://info.hotims.com/82321-407

AC Power Conversion Capacitors

Cornell Dubilier Electronics (Liberty, SC) offers high current, AC harmonic filter capacitors with dual, built-in, fail-safe protection systems, one at each end of the capacitor. Type PCD capacitors are designed to meet the demands of AC filter applications rich in system total harmonic distortion (THD). This series has a patented dual protection system utilizing self-healing metallized polypropylene and a mechanical pressure interrupter designed to operate while bus bar mounted or bottom stud mounted to ensure a safe open circuit mode in the event of overload or end of life. Typical applications include uninterruptable power supplies, AC input/output tuned filters (harmonic reduction), line conditioning, noise suppression, and variable speed drives.

For more info visit http://info.hotims.com/82321-410

Automotive Ethernet Protection

Nexperia (Nijmegen, Netherlands) has expanded its portfolio of automotive ethernet ESD protection devices. The three new devices are AEC-Q101 qualified and OPEN Alliance IEEE 100BASE-T1 and 1000BASE-T1 compliant ElectroStatic Discharge (ESD) protection devices designed to protect two bus lines from damage caused by ESD and other transients. PESD2ETH1GXT-Q, PESD1ETH1GLS-Q, and PESD1ETH1GXLS-Q are silicon-based and provide greater reliability, and an improved diode capacitance of 1 pF (max) ensures better signal integrity. These devices are fully compliant with the IEEE OPEN Alliance 100BASE-T1 and 1000BASE-T1 test specifications, which means there is no requirement for customers to perform their own qualification. These ESD protection devices are available in a choice of the smallest possible leaded (SOT23) and leadless (DFN1006BD-2 / SOD882BD) packages to provide maximum design flexibility.

For more info visit http://info.hotims.com/82321-404