



# The future of automotive

By Dr. Tamim P. Sidiki & Yu Bin

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The transition to electrical cars is transforming the automotive industry. While we see disruptive change across the industry, the greatest impacts are seen in four main areas: new mobility concepts, connected autonomous driving, powertrain electrification, and new partnership models. As digitization drives convergence between the automotive and electronics industries, the car of the future is becoming more and more like a smartphone on four wheels.



Figure 1. Convergence between the automotive and electronics industries.

### Electrical cars

Consumer acceptance of electrical cars continues to rise. Driven by increasingly tighter emissions regulations, dropping battery prices, better charging infrastructure and longer driving ranges, optimistic predictions show that electric vehicles (including hybrid, plug-in hybrid, battery electric and fuel cell) will represent a total share of 35% of new vehicles sold in 2025, with the peak demand occurring in mega-cities where emissions regulations will be the most stringent.

In addition, regulations put into place by the Chinese government on the battery range and number of electric vehicles are creating a big push for electrification in automotive. While Chinese manufacturers have a competitive edge due to their unmatched access to the raw materials needed for vehicle electrification, as well as their leading global position in battery technologies, this power play is forcing foreign manufactures that want to do business in China to invest heavily in electrification.

The battery remains the most costly part of an electric vehicle, in the same way the combustion motor has always been the most costly part of an internal combustion engine (ICE). Batteries reach cost parity with internal combustion engines at around \$150-200 US/per kWh.

Once there is no difference in cost between electric cars and cars based on internal combustion engines, we will reach a tipping point where consumer demand for electric vehicles will increase exponentially.

The success of electric vehicles in the market has been hotly debated for some time. A few industry pioneers, such as Tesla, have moved aggressively ahead, while current market leaders have continued to bet on internal combustion engines. Today, the majority of industry experts agree that the internal combustion engine will gradually disappear over the next 20 to 30 years, so we will see the major players decrease their investment into traditional internal combustion engines. As electric vehicle penetration increases, the transition will be bridged by hybrid ICE/EV technology with performance improvements on the combustion side that focus on reducing fuel consumption, as well as CO2 and NOx emissions. Car manufacturers and tier suppliers will use the income generated from ICE technology to fuel EV innovations and new mobility concepts, as they evolve connected cars to the point of fully autonomous driving. Radical repositioning like this often requires new management, as companies sell off parts of the business that focus on old technology and refocus their strategy on new market conditions.

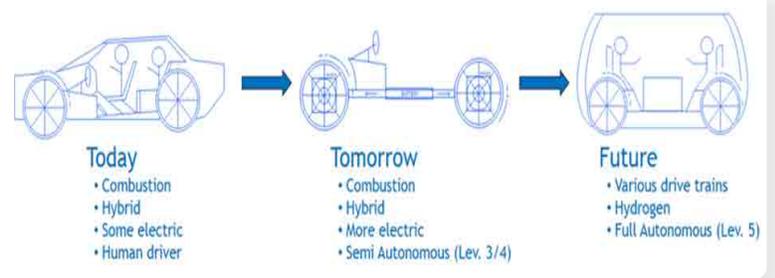


Figure 2. Disruptive transformation in the automotive industry.

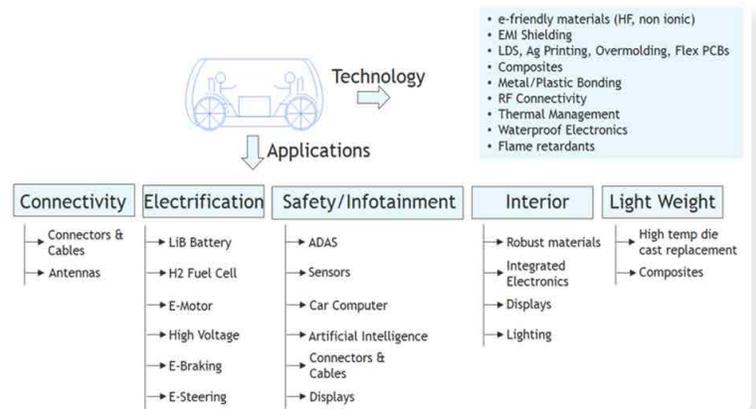


Figure 3. Innovations in the future of the automotive industry will main focus on five major application areas, as well as driving the underlying technology needs.

## Lithium ion batteries

The use of electric cars has steadily increased with the greater regulatory focus on environmental issues. The market has introduced a variety of alternative electric vehicles, including hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), extended-range electric vehicles (E-REVs), and fully electric vehicles (EVs) with batteries as their only energy source. Moving beyond the standard nickel metal hydride (NiMH) battery, the latest generation of lithium ion batteries (LiBs) have much higher output and energy density, leading to growing usage across a variety of applications. The advantage to LiBs is that they are compatible for use in all electronics applications, from smartphones to electrical drive trains for cars. The cost of LiBs has come down by a factor of ten over the last decade. As of 2018, they need only a drop in cost by another factor of two to reach parity with internal combustion engines.

A LiB cell as a basic building block of a battery contains the electrodes, separator, and electrolyte. The electrolyte conducts the lithium ions from the positive to negative electrodes. The flammable electrolyte used in LiBs can pose safety hazards, such as short circuits or leakages that lead to fires or explosions, so the safety standards are much higher than those for standard acid-electrolyte batteries. One way to improve safety is with the use of dedicated additives, such as succinonitrile (SN). Adding SN to the electrolyte improves the specific gravity, charge-discharge efficiency, thermal stability and cycling performance of LiBs, as well as the overall safety and service life of the battery. DSM is one of the largest global SN producers, delivering a product of the highest purity for use in LiB electrolytes for automotive, as well as for notebooks, smartphones and outdoor equipment.

LiBs are composed of multiple interconnected cells stacked inside a housing, with an electrical control unit that drives the cells, and protects them from overloading or charging too fast. The battery cell housing ensures that each battery remains in position in spite of vibration or impact, withstanding all the harsh conditions the vehicle is exposed to. Since the individual cells are connected via busbars safeguarded by fuses, mechanical stability of the total system is essential. Any displacement of the cells will change the contact resistance and electrically stress the fuses, leading to potential failure of the cells or the entire module.

This need for mechanical stability is one of the main reasons that thermally conductive PPS were developed for this application. DSM's Xytron TC5070C and TC5018I grades provide high dimensional stability, best-in-class chemical and temperature resistance, intrinsic flame retardance, and high thermal conductivity to ensure that the heat generated within the cells is conducted away to the active and/or passive heat sink of the module. This breakthrough innovation in PPS polymer science eliminates the typical flash formation during injection molding to enable good processability with no rework required after molding.



Figure 4. Battery cell housing for cylindrical LiB cells made from thermally conductive plastic from DSM.

To support high-capacity batteries, DSM has proposed replacing battery trays made from conventional plastics with those made from thermally conductive plastics. This enables the high thermal loads created during the charging and discharging of the individual cells to spread via the thermally conductive materials to either metallic bus bars, or to the additional water cooling system. At the same time it will greatly improve the total thermal management of the battery module, achieving higher efficiency and longer battery life. Depending on battery design, next to PPS also thermally conductive Arnite PET and Stanyl PA46 compounds can be used (see Figure 12 for a complete overview).



Figure 5. Prismatic battery cell seal.

Another area where high-performance plastics are used in batteries is in the sealing of prismatic cells. The main purpose of the material is to avoid electrolyte leakage at the cell contacts. The material must be highly resistant to chemicals, and provide very strong bonding between plastic and metal. Xytron PPS material is used in this type of seal, and demonstrates excellent direct bonding to metal without the further need for adhesives or glues. It outperforms other PPS materials in processability with very low flash during injection molding.

## Hydrogen Fuel Cells

At the same time that nearly every major player is developing drive trains based on lithium ion batteries, many manufacturers are also exploring the option of hydrogen fuel cells – particularly in Japan, Korea and Germany. These manufacturers are pushing hydrogen infrastructure for a number of reasons. Rather than carrying the required energy in the form of heavy weight batteries, the energy can be produced on board through a stack of fuel cells. Fuel cells charge six times faster than LiBs, and have a longer driving range – although the driving range for LiBs is improving quickly. There are also concerns about the availability of lithium, which is mainly sourced in China and Chile, and cobalt, two-thirds of which comes from the Republic of Congo.

Significant allies have recently been announced, which will pave the way for hydrogen infrastructure that will enable fuel cell technology. While the efficiency of fuel cells lags behind LiBs, fuel cell infrastructure is not reliant on lithium, reducing dependence on China for supply. This does not resolve the need for access to other rare earth minerals, such as neodymium and dysprosium – two rare earth minerals that are crucial during the high-temperature sintering of high-performance permanent iron-boron magnets used in e-motors. China is also strategically positioned to dominate the supply of these essential raw materials, as the world’s third largest hydrogen producer, and the first country to run a fuel cell-based tram. In the latest update of the strategic 5 years plan for China, fuel cell development plays an essential role. China is investigating significantly in fuel cells and strives to install 3000 hydrogen fuel stations by 2030 across China. For electrified future of transportation China is betting on both LiB and H2 fuel cell technology.



Figure 6. Geopolitical push for hydrogen fuel cells.

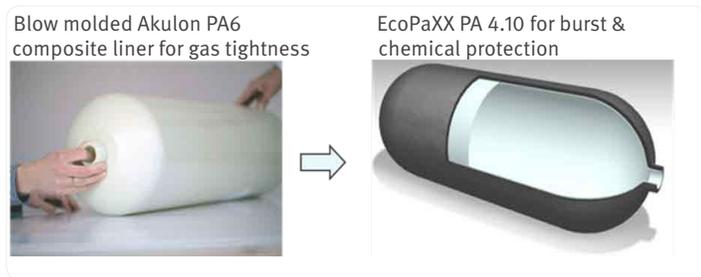


Figure 7. Hydrogen gas tank made from DSM's Akulon PA6 for the liner, and EcoPaXX PA410 composite.

In the future it can be expected that both technologies will coexist, depending on its specific application area. The cost for installing the required infrastructure for charging batteries or fueling up hydrogen tanks is comparable. The first mover which can install more fuel stations faster will have a big strategic advantage.

In a fuel cell hydrogen is reacting with the oxygen from the air generating water vapor, heat and electricity. The source of energy generation will be permanently on board and the bat-

tery can be trimmed down to a much smaller size. However, the hydrogen needs to be transported in heavy, big gas tanks with pressures of 700 bar and more. DSM successfully launched a Compressed Natural Gas (CNG) tank made from engineering plastics, and has built on this platform to successfully demonstrate a lightweight hydrogen gas tank without the use of steel. The inner liner is made from blow-molded Akulon PA6, and ensures a tight inner tank that does not allow any escape of hydrogen by evaporation. The outer composite structure is made from EcoPaXX PA410 tapes to ensure the tank is protected against high burst pressures of 700bar or above, which is essential for hydrogen storage. EcoPaXX also provides the highest chemical resistance against compounds such as salt spray. The Akulon/EcoPaXX solution provides excellent mechanical performance between -40°C and 85°C, superior to that of competitive aromatic polyamides. It demonstrates very good compatibility with hydrogen compared with alternative High Density Polyethylene (HDPE) solutions. It is a more economical solution that PA11, outperforms POM solutions on burst pressure, and offers full recyclability and much higher burst pressures than epoxy-based solutions.

### High Voltage System

Electric vehicles require high-voltage charging and interconnection systems to enable sufficient power to drive the main e-motor, and acceptable battery charging times. Yet, with high voltages, engineers need to take extra care in the design of parameters such as dielectric strength, creep, and tracking resistance, as well as dedicated color coding to enable safe handling by operators, as well as rescue teams in the event of an accident.



Figure 8. High-voltage connectors and plugs.

The industry has selected orange for the color of all components in the high voltage system and main charging path of batteries. DSM offers a wide range of flame retardant plastics that deliver the required electrical performance, with Comparative Tracking Index (CTI) of more than 600V, dielectric strength of more than 30kV, and a Relative Temperature Index (RTI) of 140°C. Based on the materials Akulon PA6, PA66, or PPA within the ForTii product family, these materials offer the high mechanical strength of polyamides, and work with a variety of assembly designs – including press fit, wave soldering, and reflow soldering. These compounds are halogen-free, and free from red

phosphorous, so that they can achieve the high CTI required for these applications. Additionally, by avoiding any ionic heat stabilizers, DSM has ensured full protection against potential electric corrosion of assembly bins or critical aluminum bonding wires within semi-conductor chips. These compounds are available in a variety of colors, including the orange color used to denote components directly in the high voltage system as well as blue colors for the increasingly relevant 48K charging system that is driven by AUDI and others.

### Connected autonomous driving

Imagine getting into your car, and settling in for a safe commute where you catch up on last night's episode of your favourite show. Connectivity is paving the way for autonomous driving, which will transform this scenario into reality. As the total attainable automotive market shifts towards on-demand services and media data, companies like Silicon Valley-based Waymo, NVIDIA, Intel and Qualcomm, as well as leading Chinese IT companies like Baidu and Tencent, are making an aggressive entrance into the new world of automotive.

The first level five, fully autonomous vehicles are expected in 2020. Level five vehicles require no assistance from a human driver – in fact, these vehicles do not even require a steering wheel. Manufacturers are just starting to introduce the underlying car computer technology, as well as crucial Advanced Driver Assistance Systems (ADAS). These systems play a key role – not only to develop and test the technology, but more importantly to lay the foundation for a safe, secure and ethical approach to autonomous driving.

In traditional vehicles, the electronics architecture is based on Electronic Control Units (ECUs). Different systems interconnect through the Controller Area Network bus (CAN bus). High-end cars that contain a lot of integrated electronics typically carry 60 to 80 ECUs, making for a complex structure that will not easily scale to the future needs of highly connected cars or fully autonomous cars. Autonomous cars will generate terabytes of data, requiring high-performance computers on-board that can handle the massive amounts of data from the vehicles and its surroundings with the lowest possible latency.

The above chart shows the strategic alliances formed to develop competitive car computer platforms. In addition to being amongst the world's most powerful computers, these platforms increasingly rely on artificial intelligence to process the vast amounts of data required to ensure safety, and a smooth interface between the vehicle, the environment and the user. NVIDIA is currently leading the race towards autonomous driving, closely followed by other major players such as Intel, Waymo, Cruise and Argo AI.

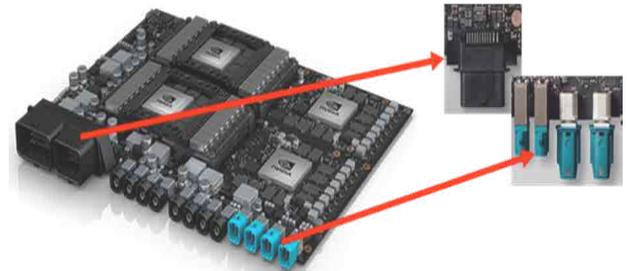


Figure 10. The latest Drive PX Pegasus board from NVIDIA. (Source: NVIDIA)

NVIDIA's Drive PX Pegasus board is one of the leading car computers. It contains a Volta Graphics Processing Unit (GPU), which is the brain of the car, as well as a set of crucial connectors on the board that interface with the car's sensors. High-speed FAKRA connectors in blue and black bridge between the GPU and the various RADAR, LiDAR, camera and SONAR detection systems. The GPU is a massive parallel computing unit that takes input from all of the sensor systems, and interprets the external data to ensure the car reacts in a safe and appropriate way. The larger black connectors interconnect the CAN bus, and interlink the infotainment system.

While connectors are old technology that lack the appeal of the semiconductor chips, they are essential, as even the most powerful computer would prove ineffective if any of these interconnects were to fail. These connectors must ensure the highest reliability and safety over the lifetime of the vehicle, even in the most harsh and aggressive environmental conditions, including dust, moisture, temperature cycling, chemical exposure, and intense vibrations.

To ensure safe and reliable operation during the use of the car, as well as throughout the manufacture of parts through the various tier processes, connectors need to meet the following requirements:

- Unlimited shelf life (JEDEC MSL1)
- No pin corrosion (insulation material free from halogens and red phosphorous, and without ionic heat stabilizers)
- High continuous use temperatures of 150-180°C
- Excellent chemical resistance
- High ductility
- High electric strength and CTI of 600V and above (PLC0)

DSM's dedicated ForTii product line addresses these diverse needs. Our best-in-class material solutions, ForTii JTX2 and ForTii Ace JTX8, combine the best of two plastics worlds. They

OEM				
Automotive Tier1				
AI Component				
AI Software				
HD Maps				

Figure 9. Artificial intelligence strategic alliances for car computers.

combine the dimensional stability and low moisture absorption of polyesters together with the high mechanical strength of polyamides. ForTii Ace JTX8 is the only material available around the world that meets JEDEC MSL1, while ensuring zero blistering over an infinite shelf life. And with the highest mechanical strength, it ensures excellent reliability during and after assembly, as well as after years of use in harsh conditions. These environment-friendly grades are free from halogen, red phosphorous, and ionic heat stabilizers. We also offer ForTii T11, a UL94-V0 @ 0.2mm alternative materials that delivers the highest level of flame retardancy.

### Safety and infotainment

Critical electronics systems like ECUs and power management modules are typically housed in metallic enclosures. The metal housing provides environmental protection for the board, and conducts the heat of the processor and power transistors away to prevent overheating. At the same time, it effectively shields electromagnetic interference (EMI) caused by adjacent radio frequency signals that may interfere with the sensitive integrated circuits (ICs), and lead to malfunction.

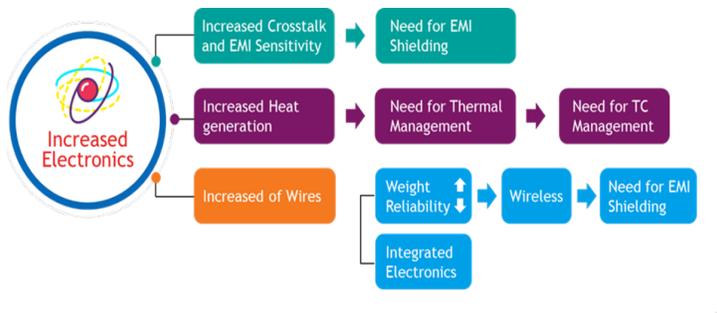


Figure 11. The increase in automotive electronics drives the need for thermally and electrically conductive plastics.

EMI shielding and thermal management are becoming increasingly important in automotive electronics. Critical applications such as ECU covers or covers for infotainment displays with high brightness require a combination of both. Our portfolio includes materials with different combinations of thermal and electrical conductivity to meet the requirements of a wide variety of applications. While electrical and thermal conductivity can be tuned by the use of different additives, the underlying polymer matrix defines the mechanical strength of the compound. Our polymer scientists work to find the right level of the additive while ensuring the materials still passes the required drop and impact tests for various applications. We have developed compounds with in-plane thermal conductivity levels up to 14W/mK, and shielding levels of around 40-60dB for the frequency range 20MHz to 1.5GHz.

DSM's portfolio of thermally conductive plastics are used commercially across a variety of applications. Grades that enable the replacement of full metal enclosures include electrically conductive fillers that lead to shielding

efficiencies of around 40dB/mm of plastic thickness. Replacing die-cast aluminum housings by engineering plastics that combine thermal conductivity with electro-magnet interference can lead to weight reductions of 50%, while enabling more advanced designs that include extra design features such as the inclusion of brand logos in the plastic housings.

	Grade Name	Strain @ break	TC In-plane [W/mK]	TC Through h-plane [W/mK]	Surface Resistivity [ $\Omega\text{m}$ ]	Dielectric Strength [kV/mm]	CLTE [ $1/^\circ\text{C}$ ]	UL94
High thermal conductivity	Stanyl® TC 502	1.1	14	2.1	1 E5	NEI	0.25 E-4	HB
	Stanyl® TC 551	0.6	14	2.1	1 E5	NEI	0.4 E-4	V0
	Stanyl® TC153	0.6	8	1	1 E13	EI	0.25 E-4	V0
	Xytron® TC5070C	0.7	7	1.8	1 E5	NEI	0.2 E-4	V0
High mechanical performance	Amite® AV2 370 XL-T	1.5	1.65	0.8	3 E11	1 kV/mm	0.25 E-4	HB
	Stanyl® XL-T (P698A)	2.5	0.8	0.6	1 E12	5 kV/mm	0.2 E-4	HB
	Stanyl® TC168	1.6	2.1	0.9	1 E13	EI	0.21 E-4	V0
	Stanyl® TC170	2.5	2.1	0.9	1 E13	EI	0.2 E-4	HB
	Xytron® TC5018I	1.3	1.8	0.8	1 E13	EI	0.2 E-4	V0
Performance improvement on std. plastics.	Akulon® TC185	2.5	1.1	0.9	1 E12	EI	0.5 E-4	V0
	Akulon® TC186	1.2	1.6	0.8	1 E13	EI	0.5 E-4	V0

Figure 12. Overview of thermally conductive compounds in the DSM portfolio.

### Advanced Driver Assistance Systems (ADAS)

Self-driving vehicle technology presents a significant growth opportunity for car manufacturers. According to BI Intelligence, close to 10 million self-driving cars will be on the road by 2020. BCG Research forecasts that the autonomous car market will reach \$42 billion by 2025, growing to \$77 billion by 2035. By 2030, one out of every ten newly registered vehicles will be equipped with full self-driving functionality.

To facilitate this disruptive change in a way that improves safety and convenience versus a car with a human driver, manufacturers have been developing ADAS systems over the last few years. As we move closer and closer to fully autonomous driving, we will see vehicles that simultaneously use a growing number of these systems.



Figure 13. RADAR systems are a prominent ADAS example.

## Partnership models

The increasing complexity in the design and manufacture of cars is pushing the boundaries of the traditional automotive supply chain. More and more, we are seeing intense partnership models, with increased co-operation between tiers, and even between competitors. We have already looked at the complex and diverse partnerships required to develop AI-based autonomous cars – no company can afford to fully control design and manufacturing on their own.

It's no longer as simple as outsourcing certain supply chain steps, since the technological requirements are so complex. We are currently seeing the evolution of an intense, multi-company supply chain based on resident engineers, where key designers are working together under one roof to reach the same target. This is the only way to meet the short cycle times and intense exchange between different parties that is needed to develop autonomous vehicles.

For involvement at any tier of the industry, this means that early involvement in a project is becoming even more relevant than it is today. Every part of the design is crucial. Replacing components or materials later in the development cycle becomes increasingly challenging, and the value of implementing material changes within a cross-company design team becomes far less relevant – unless, of course, a major technical issue leaves no other choice but to replace the material or component. DSM approaches all of our material sales as a partnership, where we offer full design and engineering support through every stage of development.

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Royal DSM is a global science-based company active in health, nutrition and materials. By connecting its unique competences in Life Sciences and Material Sciences DSM is driving economic prosperity, environmental progress and social advances to create sustainable value for all stakeholders simultaneously. DSM delivers innovative solutions that nourish, protect and improve performance in global markets such as food and dietary supplements, personal care, feed, medical devices, automotive, paints, electrical and electronics, life protection, alternative energy and bio-based materials. DSM and its associated companies deliver annual net sales of about 10 billion euros with approximately 25,000 employees. The company is listed on Euronext Amsterdam. More information can be found at [www.dsm.com](http://www.dsm.com).