THE ELECTRIC FUTURE COMES ON TWO WHEELS

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According to WHO 9 out of 10 people on the planet breath polluted air, killing each year 7 million people, primarily in poor countries in Asia and Africa. The WHO concludes that about a quarter of all deaths from heart disease, stroke and lung cancer can be attributed to air pollution.

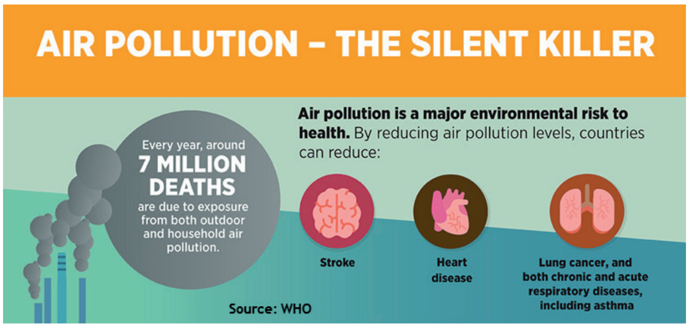

Figure 1: Technologies and changed mobility concepts will be key in the future to battle air pollution to reduce millions of deaths worldwide.

Just two years ago a blue sky in cities like Beijing and even Shanghai were seldom occasions. During the last two years the situation has improved significantly as China took big steps at the government level declaring war on air pollution. The health argument was a strong driver imposing increased challenges to the industry to reduce its environmental impact. Many polluting companies were forced out of business if not being compliant to the increased governmental restrictions. India, in contrary, is today home to six of the world's top 10 polluted cities, with Delhi being the sad leader in this infamous ranking (Source: WHO). Not a single Chinese city can be found on such megacity rankings anymore.

We can expect an increased air pollution cleanup movement of Indian government in the coming future, initially targeting mega cities of big concern such as New Delhi, Varanasi and Patna. In November 2018 the Delhi local government released a draft policy which targets 25% of all new vehicle registrations in the city to be electric. The transport department will incentivize all vehicle segments that run electric. Just as China, the world's largest electric vehicle market, has turned into a global engine for the electrification of cars, India could become a frontrunner for the electrification of motorcycles and scooters.
For majority of the developing world, the key to reducing pollution is a transition from combustion to battery-powered 2-wheelers such as motorcycles and scooters. A focus on affordable products coupled with a rapidly expanding charging infrastructure could quickly make it convenient for buyers to plug into green 2-wheelers.

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In large Southeast Asian economies such as India, Vietnam or Thailand, the number of households that own two-wheelers exceeds 80%. In India, 2-wheelers, mainly motorcycles, account for threequarters of vehicles on the roads and contribute a whopping 30 percent to the country's pollution. Electric cars however, even low-end ones, won't have a short term impact in these countries. Cost is the highest barrier. Next it turns out that in many Asian megacities, also massive traffic jams are quite a barrier. In Mumbai, the average speed of city buses has declined from 10 miles per hour to 5.5 miles per hour over the last decade[1]. No surprise that also commuters who could afford buying a car often look to bikes and scooters as they allow a much higher mobility in crowded cities.

Cleaning up the region's air can only be achieved by strict emission reductions from the related combustion engines of these two-wheeler. In addition to above barriers, parking is already now a burden and will continue to become more severe in the future for cars in megacities, especially since real estate cost keeps on rising.

If the pricing of e-scooters is right, customers are ready to switch. Contrary to electrical cars which strongly depend on the availability of a proper charging infrastructure, the battery e-scooters can be designed in a portable manner. This is especially helpful in mega cities where consumers do not have the opportunity to charge the car at their own home place. The dependency on charging stations can be significantly reduced.

While in the public electrification of cars takes a bold position driven by iconic brands such as Tesla or Neo, lots of startups are currently driving a silent revolution in the 2-wheeler market transforming the transportation business sustainably. Large players are not only developing own electrical offerings, they are increasingly acquiring EV start-ups to speed-up their roadmaps and portfolio availability. For Investors, the 2-wheeler market is an attractive and low risk opportunity to test the water before making bigger investments in the much higher capital-intensive electrical car segment.

With about 200M electrical scooters on the road, China is today the leading country, with about 30M e-scooters added every year[2]. However, the growth in China is expected to flatten due to increased regulation with respect to performance, range and fire safety aspects. In America and Europe renting out electric kick-scooters is taking many American cities by storm. In the Netherlands, known for its huge enthusiasm on biking, one out three new bikes is electric, allowing many cyclist to replace car journeys. In Germany, the largest European economy, electric two-wheelers are also on the rise. 1 out of 5 bikes sold is by now already electric. The **Deutsche Post**, which has recently started to operate electrical trucks and can already be at eye level with big players such as **BMW** in terms of electrical units sold, has also some 12.000 two and three-wheelers operational. Electrical 2-wheelers are becoming increasingly affordable and even the charging infrastructure is expanding fast.

In California e-scooters are booming big time, especially when coupled with rental models. **Bird Rides** has evolved into a real "unicorn" faster than any other American startup before it. Just by a few clicks on an app users can unlock these e-scooters. Each ride only costs $1 plus 15 cents per minute. Within only one year the company valuation of **Bird Rides** valuation has now reached $2bn. The penetration of electrical two-wheelers is expected to explode once ride hailing giants such as **Uber** and **Lyft** start offering a full package mobility service. In April 2018 Uber acquired **Jump**, an e-bike start-up. **Lyft** is rumored to take over **Motivate**, yet another e-bike firm.

The range and lifespan limitation of current electric two-wheelers is mainly the result of lead-acid batteries used. To push performance, the two-wheeler market is quickly starting to apply compact, lightweight, and reliable lithium-ion batteries. The prices of such batteries have come down significantly during the last decade. While still being rather high to push electrical cars mainstream, its acceptance it's two-wheelers will be much easier due to rather moderate range requirements for most mega cities, hence keeping cost and weight under control.

Typical ranges for such e-scooters are around 70-80km, with max speed of about 60kph: an ideal combination for Asian mega cities. The Lithium ion batteries can be charged in about 60min to 80% capacity.

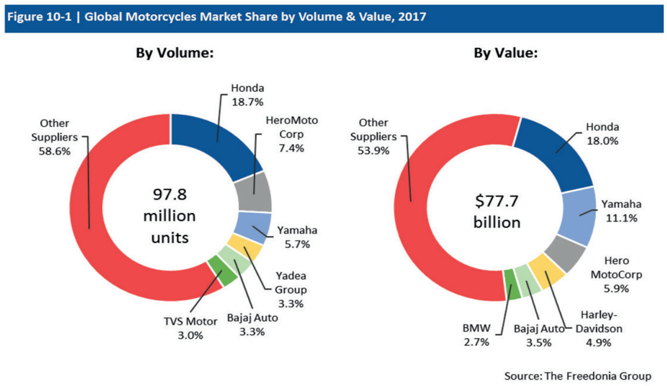

Figure 2: Global motorcycle market by volume and value in 2017 (Source: The Freedonia Group).

Figure 2 shows the global market of motorcycles in 2017 listed by volume (left) and value right. In production volumes the market is dominated by Asian Pacific companies, with Hero, Bajaj and TVS Motor taking majority of the stake due to their prime focus on low cost models. Japanese, US and European manufacturer such as Honda, Yamaha, Harley, BMW are however taking the bigger share of value due to their main focus on the high-end segment.

Just as China has evolved as the world's largest electric vehicle market, motorcycles and scooters could pave the way in India towards mass-scale electro-mobility. Once the Indian government authorities are coming up with a clear roadmap

1 https://timesofindia.indiatimes.com/city/mumbai/peak-hour-best-bus-speed-halves-in-10-years/articleshow/65569847.cms

2 https://www.sixthtone.com/news/1001569/china-to-roll-out-stricter-standards-for-electric-bikes

for electrification of the transportation segment, electrical vehicles will start to boom in India. The two-wheeler segment would be the first and easiest to embrace electrification. This clarity will also start to boost local Indian made critical components such as battery modules or e-motors. The Automotive Research Association of India is currently working to prepare electric vehicle regulations and benchmarks for the segment.

Hero MotoCorp has acquired a 26-30% stake in **Ather Energy** while they are in parallel also development inhouse EV capabilities through Hero Electric.

TVS Motor Company, India's third largest two-wheeler player, has launched various hybrid and a pure-electric scooters. In December 2018 TVS acquired ~15% of **Ultraviolette Automotive**, an electric 2-wheeler and energy infrastructure start-up located in Bangalore.

Bajaj Auto is another major two-wheeler player which has commenced development of electric vehicles.

Tork Motorcycles, a Pune-based start-up, plans to launch an electric motorcycle in the Indian domestic market during 2019.

The start-up **Ampere Vehicles** has already sold more than 20,000 electric vehicles thus far.

Mahindra Two-Wheelers in Pune, a division of **Mahindra & Mahindra** as one of the Pune based players also intensively working on electrical two-wheelers. They have on hand experience already with electric cars as well as through their US-based GenZe venture which is manufacturing and selling electric two-wheelers.
Among other new entrants into the EV space are Gurgaon-based **Twenty Two Motors** and **Okinawa Autotech**. Twenty Two Motors, headquartered in Manesar, has opened a state-of-the-art manufacturing facility in Bhiwadi, Haryana in Q2 2018 targeting a capacity of ~50.000 two-wheelers per year.
2019 will be a year where we will see many new electrical models being launched, primarily being purchased by consumers in metro cities where the daily commutes are seldom more than 70km.

Foxconn is well known in the Consumer Electronics world as the largest contract manufacturer. In e-scooters this spot has been taken by **Ninebot**, a Chinese firm, which also owns Segway. They are offering off-the shelf e-scooters for just $300-400$ to various brand owners.

Many e-bikes are powered by gears from **Bosch**, the world's largest automotive tear1, this although the company only started with this technology in 2009. More than 70 e-bike brands today acquire the drive train, displays and also battery packs from **Bosch**, components of highest value.

Besides electrification there is a strong move towards smart connectivity, pushing for functions such as touchscreen dashboards, round-the-clock connectivity, personalized profile-based drive modes and cloud data access. In fact, like in the automotive market, we see a strong conversion between 2-wheelers smartphones with various functions of the Consumer Electronics industry being gradually incorporated also into two-wheelers (see Figure 3).

Figure 3: Convergence between the 2-wheeler and electronics industries.

Figure 4 shows some of the key building components of an electrical scooter. DSM as a global chemical multinational is offering an entire portfolio of engineering plastics for these components.

Lithium ion batteries
The latest generation of lithium ion batteries (LiBs) have much higher output and energy density compared to lead-acid batteries, leading to growing usage across a variety of applications.

The advantage of 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.

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 despite of vibration or impact, withstanding all the harsh conditions the vehicle is exposed to.

Figure 4: Electrical Power System of an e-scooter with its typical components.

Figure 5: Typical 2-Wheeler battery housing

Depending on design and OEM specifications as well as certain preferences of the manufacturer/molder, various materials such as PA, PC/ABS and even PP have been used by molders. Given its good combination of high chemical resistance and mechanical strength, together with easy injection molding processability and availability of solid UL94-V0 compounds, DSM Akulon polyamide-based compounds are good materials for such external housings.

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 or may put unnecessary mechanical tension on the cell housing, 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 compounds 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.

To support high-capacity batteries, DSM has proposed replacing battery trays made from conventional plastics with those made from thermally conductive plastics (see Figure 6). This enables the avoidance of local hot spots 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.

Figure 6: Passive battery cooling with battery tray made of conductive plastics (left). Battery specific thermal analysis to identify the impact of hot spots (right).

Figure 7 shows the impact of thermally conductive plastics on the cycling performance of a lithium ion battery module. The use of a thermally conductive plastics can extend the cycling capacity by some 20% during the charging as well as de-charging stage before the battery control unit shuts down the battery due to overheating. Figure 4 also shows, that this effect can be achieved by some level of thermal conductivity in the range of 1.5-4W/mK. Pushing thermal conductivity much higher, does not have any further supporting effect. This is because thermal conductivity in such applications is convection limited.

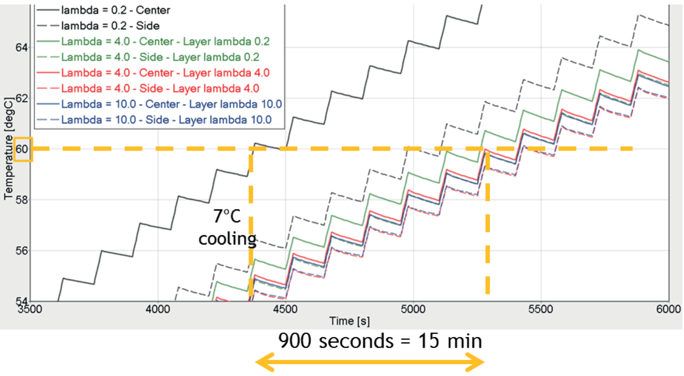

Figure 7: Passive battery cooling with battery tray made of conductive plastics (left). Battery specific thermal analysis to identify the impact of hot spots (right).

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 (see Figure 8), 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.

Figure 8: Passive battery cooling with battery tray made of conductive plastics (left). Battery specific thermal analysis to identify the impact of hot spots (right).

Connectors

Two-wheelers 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. Majority of lithium-ion battery in two-wheelers are running at 36V, some of the newer ones with larger capacity are also operating at 48V or higher. This is quite an increase from the traditional 12V. To increase safety and reliability of the electrical system, especially when designers are forced to squeeze additional electronics functionality into the already confined available space of a two-wheeler, a design can increase creep distance between two conducting electrical pins. However, in many cases an increase of creep distance is not possible without changing the pitch of the electrical pins. In such cases, the designer can upgrade the insulating plastic to one with a higher CTI value. Without any design changes the risk of tracking can significantly be reduced.

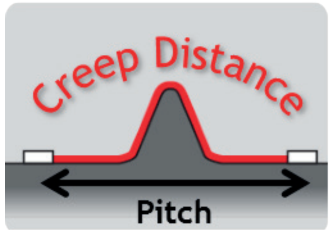

Figure 9: Creep distance between two electrical contacts.

Figure 9 shows the creep distance between two contacts. Creep distance is the actual surface distance of the insulating plastic. If the pitch between the contacts remains the same, the creep distance needs to be increased to avoid tracking between these pins at higher voltage.

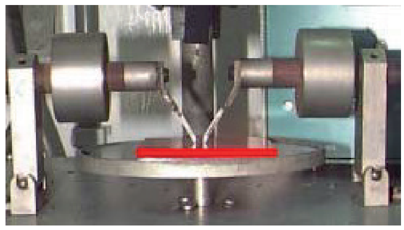

Figure 10: Typical test set-up for CTI measurements.

The surface resistance of an insulation material can be reduced due to contamination and environmental influences such as dust, moisture, dirt, ...
Such contaminations always increase the risk of leakage currents and arcing. There are in principle three alternatives for a product designer to handle this risk:

- The creepage distance of the electrical contacts can be increased
- The electronic components can be sealed in a box keeping the contamination out
- A high CTI insulation plastic can be used

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.

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 2-wheeler, as well as throughout the manufacture of parts through the various tier processes, connectors ideally 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

The best-in-class material solutions, ForTii JTX2 and ForTii Ace JTX8, combine the best of two plastics worlds: They 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. DSM also offer ForTii T11, a UL94-V0 @ 0.2mm alternative materials that delivers the highest level of flame retardancy.

With the move to electrical two-wheelers in the future, the risk of a potential fire resulting from the higher applied electrical voltage will increase. It can therefore be expected, that in the future we will see requirements for flame retardancy especially in the actual electrical path (charging plug, ECU, e-motor, battery) will increase.

Integrated Electronics
2k molding and hot stamping are used as a standard to manufacture MIDs (Molded Interconnect Device).
Both methods require product-specific tooling to create a circuitry on components. The continuous drive to miniaturization and complexity of part design leads to a considerable rise in tool cost. Furthermore, any design change which would be identified after testing of prototypes would lead to changes in the molds.

Laser Direct Structuring can be used to locally plate the surface of any 3D structure. It can be done right after injection molding of such components. The injection molding is performed with a special compound that contains small amounts of Cu-additives that are IR laser sensitive. The laser beam ablates the polymer surface hence enriches the exposed area with the Cu nuclei, the surfaces is at the same time also roughened leading to a strong, chemical anchoring of the Cu plating to the Cu-rich nuclei. Subsequent metallization, Cu surface passivation and assembly result in final products.

There are hardly any design limitation with LDS technology as long as the structure can be realized in one or two layers.

LDS technology avoids these issues and improves efficiency, in specific for low to mid volume production runs.

LDS technology consists of three steps (see Figure 11):
A. 1-shot molding
B. IR laser activation
C. Cu metallization and e.g. Ni/Au passivation

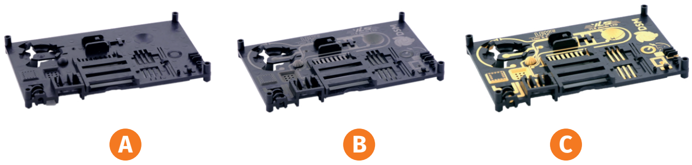

Figure 11: Typical test set-up for CTI measurements

Laser Direct Structuring (LDS) technology offers a broad range of advantages to designers and manufacturer. It;

- enables significant component count, space, height and cost reduction
- enables rapid prototyping and volume production of new designs without changes in the mold upon design changes
- enables integration of new functionalities (Semiconductors + Magnets + ...in one package
- increases product reliability by simplified design
- simplifies manufacturing to only three process steps (molding, laser structuring, metallization)
- offers a short and environmentally friendly process
- avoids chemical surface activation (no acids used)
- omits the use of photoresists and wet- or dry- etching

LDS technology has progressed significantly in the last few years. Main characteristics are

- Resolution: ~100µm line width and ~45µm pitch
- Laser drilled Vias enabling 2nd layer contacts
- No clean room requirement, no extreme chemicals or temperatures
- Proven mechanical strength of electrical traces
- Proven performance against Ag and Cu migration

Different materials are available for use in LDS technology. While PC/ABS (Polycarbonate/Acrylonitrile Butadiene Styrene) is well established in low temperature applications which do not require atomized lead-free soldering, PPAs (Polyphthalamide) and LCPs (Liquid Christal Polymers) have been traditionally used for the high performance area of reflow soldering. While suitable for the actual processing temperature, significant issues arise at the reflow temperature window around 260°C. Due to a drop-in material stiffness and low HDT (Heat Distortion Temperatures) warpage occurs omitting certain critical applications. Furthermore, LCPs are known for rather low adhesion to metals leading to possible delamination in applications where e.g. metallic lead frames are overmolded by LCP such as the use in air cavity packages.

DSM ForTii LDS compounds have been developed to offer a well-balanced material for electronics components requiring lead free reflow soldering. ForTii is characterized by high mechanical strength and temperature resistance on the one side and a solid MSL 2 performance according IPC/JEDEC J-STD 020D. In miniaturized applications with walls thicknesses £0.5mm even MSL1 levels have been tested.

LDS is an exciting technology that is well proven already. Latest advancements in new product development and availability offers good technical solutions for previous technical challenges with delamination, warpage and mechanical strength. This combined with significant improvements on the laser technology such as presented by LPKF will lead the path to a broader penetration of the technology making LDS well positioned versus 2K molding and hot stamping alternatives.

Electrical Control Systems

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 over- heating. At the same time, it effectively shields electro- magnetic interference (EMI) caused by adjacent radio frequency signals that may interfere with the sensitive integrated circuits (ICs), and lead to malfunction.

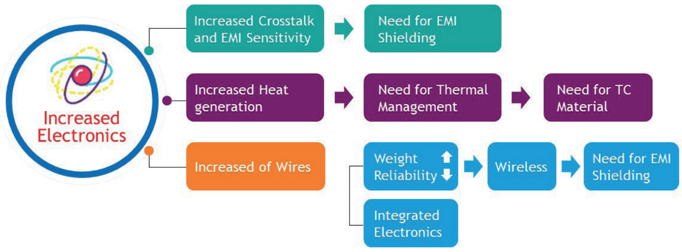

Figure 12. The increase in automotive electronics drives the need for thermally and electrically conductive plastics.

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.

The DSM 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. DSM 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. DSM has 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 conductive plastics is 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-plane [W/mK]	Resistivity [Ωm]	Electrically (Non) Insulative	CLTE [1/C°]	UL94
High thermal conductivity	Stanyl® TC 502	1.1	14	2.1	1 E5	ENI	0.25 E-4	HB
	Stanyl® TC 551	0.6	14	2.1	1 E5	ENI	0.40 E-4	V0
	Stanyl® TC153	0.6	8	1	1 E13	ENI	0.25 E-4	V0
	Xytron® TC5070C	0.7	7	1.8	1 E5	ENI	0.20 E-4	V0
High mechanical performance	Arnite® AV2 370 XL-T	1.5	1.65	0.8	3 E11	EI	0.25 E-4	HB
	Stanyl® XL-T (P698A)	2.5	0.8	0.6	1 E12	EI	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
	Stanyl TW241B3	2	0.8	0.4	1E6	ENI	0.25E-4	HB
	Stanyl TW200B6	2	1	0.5	1E5	ENI	0.08E-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 11: Overview of thermally conductive compounds in the DSM portfolio.

E-Motors and Gears

Conclusions

Very certainly we will see a strong growth of electrical two-wheelers in the coming future, especially in growing economies such as India, Thailand or Vietnam with their mega cities two-wheelers will be the natural bridge to improving air quality but also to allowing future mobility in crowded cities. The option to have the battery in a modular design which can be easily removed allows rather independency of battery charging from the availability or future construction speed of a proper electrical infrastructure. Hence it can be expected that the market penetration of two-wheelers will progress at significantly higher speed than for electrical cars.

For two-wheeler engineers at Ems but also at tiers, DSM can be of great added value by bringing in long-term track record in both two-wheelers as well as consumer electronics. With deep applications expertise, ongoing strong commitment to research and technology, DSM is an ideal development partner in a rapidly changing automotive world. Well proven technologies and applications can be fast transferred from the electronics to the two-wheeler world reducing time to market and boosting safety and reliability.