EVS24
Stavanger, Norway, May 13-16, 2009

Lithium-ion for hybrid vehicles and electric vehicles: ready for mass market introduction!?

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As a system supplier, MAGNA STEYR supplies complete energy storage solutions. With its three modular battery concepts (power battery, energy battery and battery for commercial vehicles), MAGNA STEYR can cover all electric drive systems.
Both technological and commercial challenges in the introduction of Li-Ion technology to the market and proposed solutions using concepts which have already been implemented will be presented in the paper.

Keywords: lithium battery, battery management, energy storage, market

1 Drive technologies of the next decade?

In 2020 the overwhelming share of vehicles will still be driven by combustion engines. Hybrid vehicles of Japanese manufacturers are already in high-volume production today, and North American OEMs already have their first hybrid vehicle on the market. Unit-number forecasts by market research companies all agree on 3-5 million hybrid vehicles a year by 2015. All the notable manufacturers have been working very intensively on electric vehicle designs, especially in the last two years. Electric vehicles will initially remain a derivative with quantities of several thousand items/ year per platform. Plug-in hybrid vehicles and electric vehicles with range extenders will play an essential role in the bridging technology towards a pure electrification of vehicles. From 2015 high-volume quantities of more than 100,000 items/ year are expected.
Although the development of hydrogen vehicles is still being focused on, they will most likely only be deployed in fleet operation in the next few years.

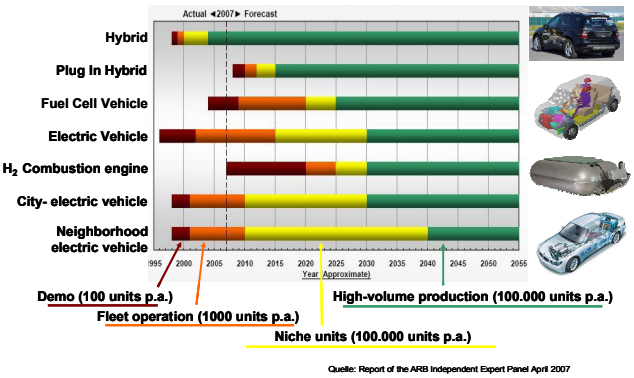

Figure 1: Alternative drive systems – forecast of market development. [1]

2 Battery technologies and their opportunities on the market

Figure 2 shows a comparison of the power and energy densities of the available storage technologies.

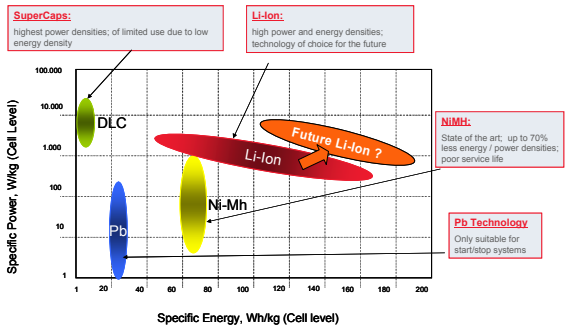

Figure 2: Power and energy densities of storage technologies.

Battery systems using NiMh technology are currently the state of the art for hybrid vehicles. The limited energy/ power densities coupled with a comparatively short service life rules out expectations of a high market potential. Double-layer capacitors (DLC) have the highest power density. But due to their very low energy content they only have limited use for microhybrid applications in serial hybrid buses. Li-Ion technologies offer both high power densities and high energy densities. New materials and technologies currently being researched are showing great potential for the further improvement of performance and costs. Li-Ion technology is the technology of choice and plays a crucial role in future alternative drive concepts.

Figure 3 is a summary of the current state of development of high-voltage NiMh and Li-Ion battery technologies.

NiMH Technology

- Cylindrical and prismatic cells on the market/ only three manufacturers.
- More than 1 million vehicles are on the market.
- Very limited power, energy and service life.
- Costs for added value too high • little opportunity on the market.

Li-Ion Technology

- Cylindrical and prismatic cells in development / manufacturers in JP, Korea, US, EU
- Safety discussion has led to new technologies.
- Promising technology regarding power, energy and service life.
- First introductions to the market will be in 2009.

Figure 3: Stage of development of battery systems for electric and hybrid vehicles

The most important technological and commercial aspects to be solved in order for Li-Ion technology to achieve broad acceptance in the automobile market are enumerated in Figure 4. To summarize: Li-Ion technology is still at the beginning stages and will clearly improve regarding performance and safety. Standardization and mass production at the highest quality standards are the key to reduction of costs and achievement of the required reliability and service life.

Technological

- Clear requirements and directions on the part of OEM.
- Increase of Energy/ power densities ➔ new materials.
- Increase in service life
  - -Improvement of Li-Ion technologies
  - - Intelligent battery management.
- Integrated safety concept.
- Cold-temperature behavior needs improving.
- Intelligent thermal management.
- Reduction of necessary monitoring electronics.

Commercial

- Significant cost reduction for next battery generation.
- Mass production is to be carried out.
- Standardization of cell design
- Standardization of batteries.
- Service life – guarantee.
- Investors / reliable undertaking by OEMs/ policy.

Figure 4: Technological and commercial objectives for the broad introduction of Li-Ion technology.

3 MAGNA STEYR Product Portfolio

As a system supplier, MAGNA STEYR supplies complete energy storage solutions. With its three modular battery concepts (power battery, energy battery and battery for commercial vehicles), MAGNA STEYR can supply applications for hybrid, electric and fuel-cell vehicles.

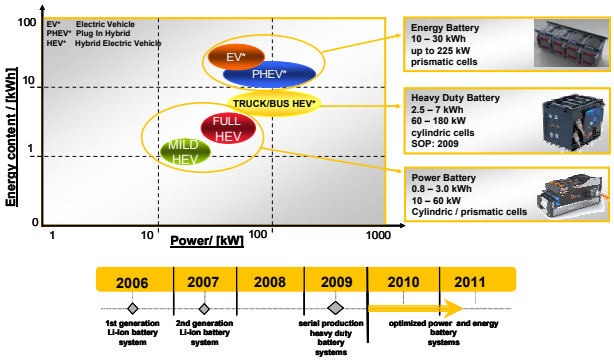

Figure 5: MAGNA STEYR's product portfolio for Li-Ion battery systems

3.1 Power batteries for hybrid vehicles

Apart from enhanced driving pleasure, hybrid vehicles provide fuel-consumption savings of up to 20%. Hybrid vehicles require battery systems with the highest power density; high energy content is dispensed with for reasons of package, weight and costs. Mild hybrid concepts with electric power requirements between 15 and 30 kW aim in particular at reducing CO_2 and damaging emissions. Full hybrid vehicles with 30 to 60 kW

of installed electrical power offer an additional unlimited electrical range of several kilometers.

Magna Steyr offers serial production solutions for power batteries based on cylindrical cell technology. The next generation for 2012 is already being validated on the test bed and uses prismatic cells to optimize package and weight.

3.2 Energy battery for electric and plug-in hybrid vehicles

The electrical range is the most important design criterion in electric and plug-in hybrid vehicles. This is limited by the capacity and indirectly by the installation space and weight of the electrical energy storage system. The most important development objective for energy batteries is the increase of energy density and thus also the reduction of installation space and weight. Currently the energy density of the complete battery system lies at approximately 10 kg per Kilowatt hour (1kWh = approximately 5-7 km range).
MAGNA STEYR's modular concept enables applications for different manufacturer requirements to be made. Modules with 12 prismatic Li-Ion cells each with 33Ah / 45Ah and 65Ah capacities guarantee an optimum utilization of the installation room (for modules with 45Ah cells and approximately 2kWh energy content, see Figure 6).

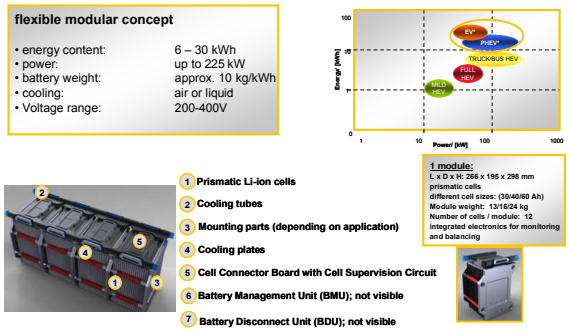

Figure 6: Li-Ion battery systems for electric vehicles and plug-in hybrid vehicles.

3.3 Power batteries for hybrid commercial vehicles

Owing to the high potential of fuel savings by hybridization (e.g. more frequent start/ stop operation in the case of city buses) and future legislation (exhaust-gas standards), there will be a significant market for hybrid commercial vehicles in the future. In summer 2009, MAGNA STEYR will already be supplying the first fully approved serial batteries with 120kW rated power for city buses and refuse collection vehicles.
Further battery sizes (75 kW and 180 kW) based on modules of the 120 kW system are being developed and will be available for serial use from 2010.

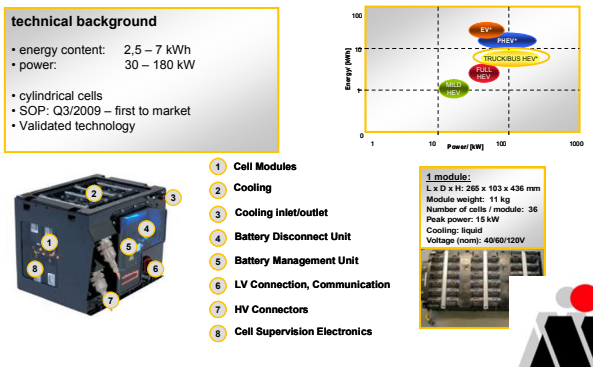

Figure 7: Li-Ion battery systems ready for serial production for hybrid commercial vehicles – SOP Q3/2009

4 Conclusion and outlook

Li-Ion technology is the technology of choice for energy storage systems and plays a crucial role in future alternative drive concepts. MAGNA STEYR's modular battery system concepts facilitate applications for hybrid and electric vehicles which fulfill different manufacturer requirements. In summer 2009, customers will be receiving the first fully approved serial Li-Ion batteries. The next generation for 2011 is already being validated on the test bed and uses prismatic cells to optimize package and weight.

References

[1] Report of the ARB Independent Expert Panel, 2007-04

Author

Peter Pichler studied at the Technical University of Graz Electrical Engineering. In 2002 he received his doctorate at the University of Leoben. From 2002 until 04/2003 Dr. Pichler was Head of the Advanced Development Department at ATB Antriebstechnik. In May 2003 he became Head of Alternative Propulsion Systems at MAGNA STEYR. Since January 2008 Peter Pichler works as Product Manager for electrical energy storage systems.