Nickel-Zinc Batteries for Hybrid Electric Vehicles and Stationary Storage

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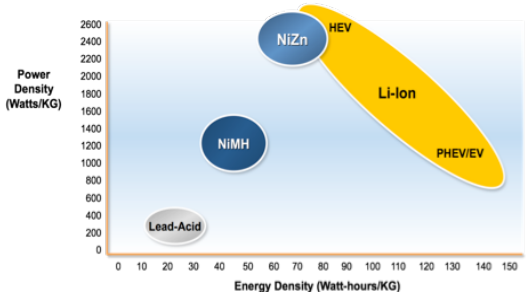
ABSTRACT

PowerGenix is the leading developer of Nickel-Zinc (NiZn) batteries – a technology that has significant advantages over other advanced battery chemistries in energy and power density, cost, safety, toxicity and recyclability. Compared to Nickel-Metal Hydride (NiMH) batteries, NiZn is 30 percent lighter and smaller. Compared to Lithium-ion (Li-ion) batteries, NiZn can provide similar power density at less than half the cost. Additionally, NiZn contains no lead, cadmium, mercury or other toxic heavy metals, is nontoxic and noncombustible, and is easily recyclable. As such, NiZn batteries are an ideal solution for applications that demand large amounts of power in a small, lightweight and safe package, including micro-hybrid (start/stop) vehicles, mild and full hybrid electric vehicles (HEVs), frequency and voltage regulation services (grid storage), and uninterruptibe power supplies (UPS).

Keywords: nickel-zinc, battery, energy storage, hybrid vehicle, grid storage, UPS

1 INTRODUCTION

Nickel-Zinc (NiZn) is an extremely safe and environmentally friendly battery chemistry that outperforms lead-acid, NiMH and Nickel-Cadmium (NiCd) batteries in a smaller and lighter form-factor, and avoids the high cost and safety issues associated with Li-ion. NiZn batteries are 30 percent lighter and smaller than conventional NiMH batteries and NiCd. NiZn provides similar power density to Li-ion. The energy and power density advantages of NiZn are illustrated in Figure 1.



. **Figure 1:** Energy Density Comparison

Because NiZn uses an aqueous electrolyte, it has none of the safety issues associated with Li-ion, which uses an organic electrolyte subject to fire and explosion. NiZn batteries contain no lead, cadmium, mercury or other toxic heavy metals, and are easily recyclable. These advantages are increasingly important as governments around the world continue to mandate the recycling of rechargeable batteries.

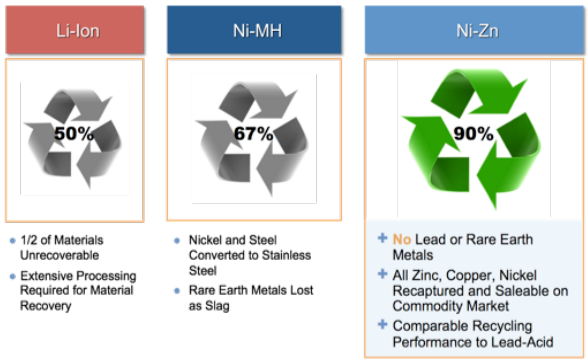


Figure 2: Recyclability

Finally, NiZn batteries offer high-power energy storage solutions at a very competitive price. NiZn is at least 30 percent lower cost than NiMH. Compared to high power Li-ion automotive cells, NiZn has a 50 percent cost advantage based on lower material and manufacturing process costs. These advantages are illustrated in Figure 3.

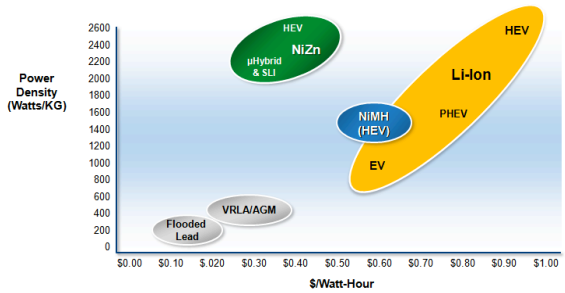


Figure 3: Cost Competitiveness

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2 TECHNOLOGY

Until recently, technical problems with zinc instability prevented NiZn batteries from being a viable solution. PowerGenix has invested significant resources in the development of NiZn technology and solved the traditional technical problems associated with NiZn batteries. These innovations have been largely driven by advances in materials development and science.

Utilizing a combination of patented materials and components (electrolytes, electrode compositions, and separator coatings), PowerGenix has minimized the issues of dendrite formation and shape change in the zinc electrode during cycling. In addition, PowerGenix has optimized the electrode electrical connects to the cell cover assembly and outer can to reduce internal resistance and increase power density.

Some of the specific material and design improvements developed by PowerGenix include:

- Proprietary electrolyte additives and formulations
  - Reduce zinc solubility, prevent dendritic formation
- Zinc electrode additives
  - Control electrode shape change
- Nickel electrode past formulations
  - Improve efficiency, power delivery and charge acceptance
- Proprietary separator coatings
  - Inhibit dendrite formation
- Low resistance current collectors and electrode electrical connections
  - Improve power delivery and charge acceptance
- Positive and negative electrode compositions that do not contain any heavy metals
  - Designed for production on existing NiCd and NiMH manufacturing equipment

The material and design improvements have been used to produce NiZn batteries with high power density and long life without compromising the inherent advantages of NiZn technology in energy density, cost, environmental profile and safety.

The versatility of the NiZn chemistry is illustrated by the discharge curve of the sub-C cell at various rates in Figure 4.

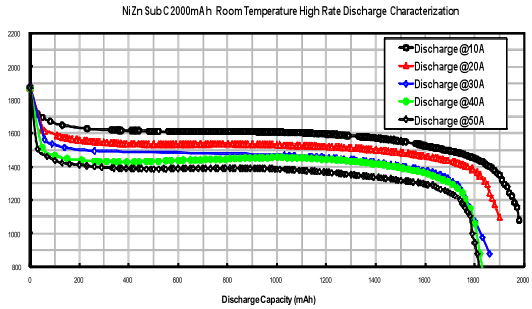


Figure 4: Sub-C Discharge Characteristics

3 COMMERCIAL APPLICATIONS

These characteristics make NiZn batteries an ideal solution for applications that demand large amounts of power in a small, lightweight and safe package

3.1 Consumer Batteries and Power Tools

PowerGenix is already enjoying commercial success in the consumer rechargeable battery market, where the higher voltage of NiZn batteries (1.6V) provides the optimal user experience in devices designed to operate on 1.5V alkaline disposable batteries. The higher voltage of the 1.6V NiZn battery relative to 1.2V NiMH and NiCd rechargeable batteries means that for the first time, there is no performance penalty for substituting rechargeable batteries for disposables.

NiZn batteries are also an excellent replacement for NiCd and NiMH batteries in power tools and lawn and garden equipment. NiZn's higher energy density enables 30 percent smaller/lighter and less expensive power packs. NiZn is a non-toxic replacement for NiCd batteries. NiZn can also be an equal or higher power alternative for Li-ion batteries in these same devices at half the cost and with complete safety.

3.2 Mild/Full Hybrid Electric Vehicles

PowerGenix NiZn batteries can be a drop-in replacement for NiMH batteries in HEV applications. In a Toyota Prius trial, PowerGenix NiZn batteries provided greater power in a pack that was two-thirds the size and 30 percent less expensive than the standard NiMH pack in the vehicle.

Parameter	PEVE Ni-MH	PGX NiZn
Form Factor	Prismatic	Cylindrical
Number of Cells	168	128
Nominal Voltage	201.6 V	204.8 V
Nominal Capacity	6.5 Ah	6.5 Ah
Pack Energy	1,338 Wh	1,357 Wh
Pack Peak Power	20 kW	**26 kW**
Gravimetric Energy Density	46 Wh/kg	**69 Wh/kg**
Bare Pack Weight	29.1 kg	**19.2 kg**

Figure 5: Comparison of NiMH and NiZn Prius Battery

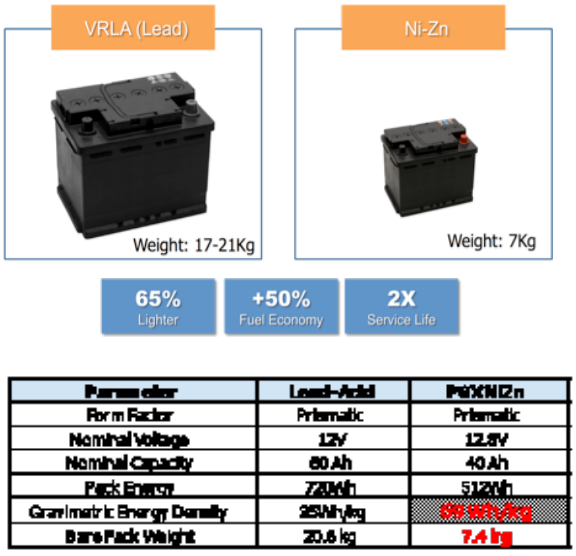
Automakers are increasingly specifying Li-ion batteries for HEVs due to their higher power density compared to NiMH. PowerGenix NiZn batteries can provide similar power and energy density to Li-ion for HEV applications. This means that a NiZn HEV pack can be similar to Li-ion in size and weight, at half the cost, with no safety issues. PowerGenix is currently developing prismatic cells for HEV applications and anticipates having test vehicles on the road in the second half of 2011.

3.3 Micro-Hybrid ("Start/Stop") Vehicles

Micro-hybrids, or "start/stop" hybrids, are one of the most promising markets for PowerGenix NiZn batteries. In a micro-hybrid, the engine shuts off while the vehicle is stopped or slowing down and the battery powers auxiliary functions. When the driver presses the accelerator, the vehicle starts back up. The fuel economy improvement is typically 5 to 8 percent, though it can be higher under certain urban driving conditions. Most important, the system cost is very low, making micro-hybrids the most cost-effective method of reducing vehicle emissions and improving fuel economy through vehicle electrification. Automakers plan to deploy millions of micro-hybrids in the next several years and the system is poised to become a standard in many parts of the world.

At present, auto OEMs are relying on traditional flooded lead-acid batteries or enhanced absorbed glass mat (AGM) lead-acid technology for micro-hybrids. However, both types of lead-acid batteries have critical weaknesses in the micro-hybrid driving regime. Most importantly, the ability of lead-acid batteries to accept charge declines rapidly – by over 60 percent in the first year – which significantly lowers the vehicle's fuel economy. Under the frequent start/stop regime of micro-hybrids, lead-acid batteries will also need to be replaced more frequently than conventional starter batteries. As a result, auto OEMs are searching for more effective energy storage solutions that meet micro-hybrid requirements at a competitive cost.

Powergenix NiZn is ideal for micro-hybrids due to its high power and high charge acceptance, low system weight (half the weight/size of lead-acid), long calendar life and low system cost. Unlike other advanced battery chemistries, NiZn can replace lead-acid in micro-hybrids at a competitive cost.



Parameter	Lead-Acid	PGX NiZn
Form Factor	Prismatic	Prismatic
Nominal Voltage	12V	12.8V
Nominal Capacity	60 Ah	40 Ah
Pack Energy	720Wh	512Wh
Gravimetric Energy Density	25Wh/kg	69 Wh/kg
Bare Pack Weight	20.6 kg	7.4 kg

Figure 6: Comparison of Lead-Acid and NiZn for micro-hybrid

3.4 Stationary Storage

PowerGenix NiZn technology also offers an effective solution for high-power applications in stationary storage. At the utility scale, NiZn can meet the high-power requirements for systems that regulate frequency and voltage on the power grid to compensate for fluctuations caused by variations in generation and demand. NiZn's lower capital cost make it a more effective solution than other advanced battery technologies. Compared to lead-acid, which has a lower capital cost, NiZn provides a better total cost of ownership over a typical 20-year utility lifespan due to lower maintenance and replacement requirements and much higher round-trip efficiency.

NiZn can also serve as an effective backup power source for utility substations or other critical installations. For the IT industry, NiZn provides a highly compact and reliable backup power source that can meet redundancy requirements without displacing space required for servers.

3.5 Military Applications

The U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) has purchased PowerGenix NiZn prismatic batteries to test as a possible replacement for the lead-acid "6T" batteries

currently in use. The most widely deployed battery format, 6T is used in 95 percent of U.S. military vehicles.

The advantages of NiZn batteries compared to the current lead-acid chemistry in the 6T are remarkable. The NiZn battery can deliver more than twice the energy (specific energy ~70Wh/kg) in less than half the space (volumetric energy density ~ 150Wh/L). As the U.S. military develops more sophisticated technologies for use in high risk, demanding environments, outfitting these vehicles with lighter and more powerful batteries such as NiZn will increase performance and safety.

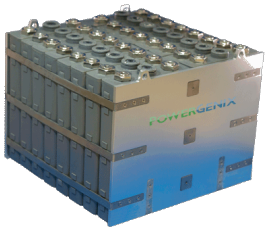


Figure 7: PowerGenix "6T" prototype

4 CONCLUSIONS

PowerGenix NiZn battery technology is an ideal chemistry for high-power applications. NiZn offers a superior balance of power and energy density, cycle and calendar life, safety, and cost compared to other advanced battery chemistries. PowerGenix NiZn can enable vehicle-makers to meet the critical requirements of micro-hybrids and HEVs with a stronger value proposition for consumers, thereby broadening the market for low emission vehicles. In military applications, NiZn can meet the higher power requirements of today's military vehicles while also providing extended run-time without safety risks.

NiZn also provides similar benefits for stationary storage applications. NiZn's advantages enable more efficient operation of electrical grids through regulation of frequency and voltage. PowerGenix NiZn is an ideal solution for backup power, particularly in applications that require compact energy storage packages, low maintenance and high safety.