

The Future of Battery Technologies – Part I



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This paper is the first in our ongoing series about batteries. This installment provides an overview of battery technologies. In future installments, we will spotlight lithium batteries – various types, respective advantages and disadvantages, applicable test methods and overall safety. This white paper was authored by Dr Annika Ahlberg Tidblad, Intertek’s resident expert in battery testing. Her background is in research at KTH, the Swedish Royal Institute of Technology, with PhDs in applied electrochemistry and corrosion science, along with ten years of experience in battery technology.

The Future of Battery Technologies – Part I – Overview

A “battery” is the generic term for an electrochemical source of electricity, which stores energy in a chemically bound form, and which can convert this directly into electric power. A battery cell consists of two electrodes, called the anode (+ pole) and cathode (- pole), separated by a fluid or solid electrolyte, and conductors. Batteries can be divided into primary and secondary systems. Primary batteries are disposable batteries, i.e. batteries that cannot be recharged, and their conversion of chemical energy into electrical energy is irreversible, which means that the chemicals are consumed while the battery discharges. Secondary batteries can be recharged, and the electrode material is reconstituted using an electric charge, so that discharge process can be repeated a multitude of times during the lifecycle of the battery.

When Selecting a Battery, Technical Requirements and Cost are Key

The choice of primary or secondary batteries depends on financial factors and the technical requirements imposed by its intended use. In general, primary batteries are principally used for applications with low energy consumption, in which there is a long storage time between use, or where it is difficult or inconvenient to charge the battery. Secondary batteries are primarily used when there is a need for high levels of energy or large load currents, at low temperature and where it is convenient to charge the batteries.

There is a wide range of primary and secondary batteries. The most common primary systems are alkaline, lithium and metal/air batteries. Among secondary batteries, lead acid, nickel/cadmium (NiCd), nickel/metal hybrid (NiMH) and Lithium-ion (Li-ion)/Lithium-polymer (Li-polymer) batteries dominate, but efforts are being made continuously to find new systems that can match or exceed the performance of existing systems, improve their safety and reduce their cost.



Primary systems

The most popular primary battery used in portable consumer products is the alkaline battery. There are many different types of primary lithium batteries. Lithium/manganese dioxide batteries (Li/MnO₂) are the best sellers by far, and are primarily used for memory backup and in consumer products such as cameras and toys. Despite their better performance, Li/MnO₂ batteries have great difficulty in competing with alkaline batteries in many consumer products because of their price.

Metal/air batteries exploit the oxygen in the air as an active cathode material, which means that the air electrode, on which the oxygen will react, makes up only a marginal part of the volume of the battery. The metal anode occupies a far greater space than in a conventional primary battery, which consequently results in a very high energy content. A number of different metal/air systems have been the subject of research, but only the zinc/air battery has achieved extensive use, and then only in the button cell design.

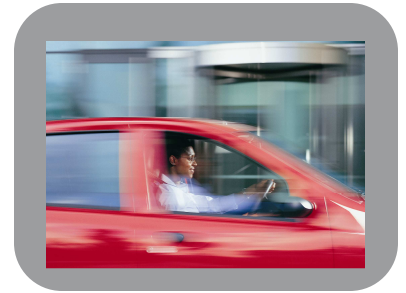
Stricter Environmental Legislation Will Phase Out Some Battery Technologies

The use of lead-acid batteries began in the nineteenth century. Because of low manufacturing costs, good performance and long life, the lead-acid battery is, in spite of its respectable age, still the most common battery in the entire world, with a market share of as much as 40 – 45 %. New manufacturing methods, cell designs and application areas are still introduced. The lead-acid battery has a wide field of applications. The most common use is as a starter battery in cars, with additional applications in industrial trucks and as reserve power.

NiCd batteries are a mature and thoroughly tested battery technology that was patented in 1899 by Waldemar Jungner. NiCd batteries are used in a huge variety of stationary, mobile and portable applications, ranging from large-scale backup power and start batteries for aircraft to handheld power tools and toys. NiCd batteries have no future in Europe, due to strict EU environmental legislation. Over the next twenty years, NiCd batteries are expected to be phased out in Europe and the rest of the industrialized world, at least in consumer electronics applications.

The NiMH battery exploits relatively new battery technology, which began to be used more at the beginning of the 1990s. NiMH batteries offer the same cell voltage as NiCd batteries, and can therefore replace them in many applications without special modifications being necessary. The cell voltage, combined with higher energy density and better environmental properties, are the driving forces that enabled NiMH batteries

to win market share from NiCd during the 1990s in consumer electronic products, such as computers and mobile phones. Currently, NiMH batteries are being replaced in turn by the significantly more energy-dense Li-ion batteries. The portable NiMH batteries are, however, still expected to remain on the market in the near future as a low-cost alternative to lithium batteries. With their relatively high energy density, and their good cyclic properties, NiMH batteries have also found applications in electric and hybrid vehicles.



Energy-dense Lithium-ion Batteries

Li-ion batteries were introduced onto the market in the mid 1990s and then began, as previously stated, to replace the NiMH batteries in mobile phones and other portable electronic items. At the present time, use of lithium batteries has spread to other and cheaper consumer products. It is important to remember that Li-ion batteries are a generic name for a large number of different battery chemistries with varying properties and performance. At present, their low weight, coupled with excellent power delivery, means that the automotive industry is in the driver's seat for the development of lithium-ion batteries.

Manufacture of lithium-ion batteries is primarily dominated by Japanese companies, and a few manufacturers in Europe and North America, with Korea and China gaining momentum. Li-ion batteries are still in an early phase of development, seen in terms of the battery industry, and have only been available for 15 years in the commercial market. This means that there is a potential for both comprehensive technical development and price reductions.

Selecting the Most Suitable Battery for the Application

There are a number of factors that must be considered in selecting the most suitable battery for a particular application. The characteristics of available battery types must be weighted against the equipment requirements. The most important considerations include:

- Operating voltage level
- Load current and profile
- Duty cycle – continuous or intermittent
- Service life

- Physical requirement
 - Size
 - Shape
 - Weight
- Environmental conditions
 - Temperature
 - Pressure
 - Humidity
 - Vibration
 - Shock
 - Pressure
- Safety and reliability
- Shelf life
- Maintenance and replacement
- Environmental impact and recycling capability
- Cost

The ideal battery is obviously one that is inexpensive, has infinite energy, can handle all power levels, can operate over the full range of environmental conditions, has unlimited shelf life and is completely safe.

In summary, lithium batteries are expected, over the next 20 years, to dominate the market for rechargeable batteries, while NiCd batteries will have been phased out in the industrialized countries. NiMH batteries will still be used in some niche applications.

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