

BATTERY POWER PRODUCTS & TECHNOLOGY

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Diverse Battery Chemistries Suit a Range of Applications

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Batteries first appeared about 1800, in the form of "voltaic piles" made by Luigi Galvani and Alet di Volta. Those first primary cells consisted of discs of copper and zinc, separated by cardboard discs soaked in brine.

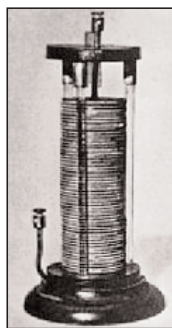


Figure 1. A Ritter Pile consists of copper discs immersed in brine. (Courtesy of Varta-Automotive)

About two years later, Johann Wilhelm Ritter invented the "Ritter Pile," which also consisted of copper discs and brine-soaked cardboard. That device, the first accumulator, could be charged by applying a current and then later discharged into a load. Experimenters quickly noticed that chemical changes in the battery materials limited the amount of charge that could be retained and used later.

Many chemical combinations have been tested in the quest for a fully reversible process for storing electricity. The following discussion reviews the non-rechargeable (primary) cells and rechargeable (secondary) cells

available today, along with their characteristics and relative merits.

Primary Batteries

Zinc Carbon (1.5 V)

The oldest type of primary cell (zinc carbon) was also the first to be manufactured on a large scale. Since then, zinc carbon cells have been largely displaced by the far superior alkaline manganese cells. Zinc carbon types were best suited for intermittent loads, but unfortunately they leaked corrosive chemicals that often destroyed the battery terminals.

Alkaline Manganese (1.5 V)

The most common of all battery types today, alkaline manganese cells directly replace the old zinc carbon types, and provide much higher capacity with a much reduced risk of leakage.

Mercury

Because mercury is poisonous, mercury cells have been almost completely phased out. They once were used primarily in the button cells that powered hearing aids, and in the light-level-measurement circuits for early cameras.

Lithium

Several lithium technologies are available. Lithium-manganese dioxide with a terminal voltage of 3 V, is the most common. Lithium-iron disulphide has a terminal voltage of 1.5 V, and serves as a drop-in replacement for alkaline manganese batteries in high-current applications such as digital cameras.

(Pure) lithium batteries have even greater capacities. Although available in standard sizes, their unpredictable

cell voltages can range from 1.5 V to 3.6 V. On the other hand, the energy density of lithium cells is high enough to be dangerous. The cells can explode when short circuited.

Lithium iodine technology is much better behaved. It uses only solid components, and its self-healing capability repairs any cracks that may occur in the separator. High internal impedance limits the use of lithium iodine cells to low-power applications such as cardiac pacemakers.

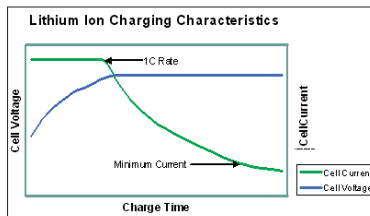


Figure 2. Charging current declines with time after a lithium cell has been fully charged. (Courtesy of Mpower)

Zinc Air (1.4 V)

Zinc air batteries are used in applications that require long shelf life. They are activated when the material is exposed to air by removal of a seal, but their energy density is low, and they suffer from high rates of self-discharge after being activated. They are often used in emergency equipment for which the long shelf life is a benefit.

Silver Oxide (1.55 V)

Silver oxide cells are used mostly in calculators and watches, where their long life under low-load conditions is an advantage.

Rechargeable Batteries

Lead Acid (nominal 2 V per cell)

Lead-acid batteries have high capacity and good recharge characteristics, and developments in plate technology have improved their capacity and useful life. Deep discharge of lead-acid batteries should be avoided, because a low cell voltage allows irreversible chemical reactions to take place. Self-discharge rates are high, but the battery capacity is so large that self-discharge is seldom a problem. The charger should be a constant-voltage type with current limiting and temperature compensation.

Nickel Cadmium (1.2 V)

Still widely used but gradually losing out to nickel metal hydride types, nickel cadmium (NiCad) cells have always suffered from "memory," i.e., a loss of capacity in the absence of periodic charge/discharge cycles. The memory effect is caused by the growth of large cadmium hydroxide crystals on the anode. Large crystals reduce the anode's active surface area, and must therefore be broken up by a deep discharge cycle. If you don't perform a deep discharge periodically, the battery capacity declines as the crystals become progressively more difficult to break down.

Chargers vary in the rate at which they can re-charge

a battery, but they generally apply a constant current to the battery. Low-current chargers, normally defined as one-tenth the capacity (i.e., C/10, which is 100ma for a battery whose C = 1A/h), can be left on for long periods without danger of explosion. When charging is complete, however, they should be turned off to avoid the memory effect described earlier. Chargers that apply rates above C/10 should incorporate an automatic turn-off mechanism. Some monitor temperature for that purpose, and others look for the small reduction in terminal voltage that indicates when charging is complete. NiCad batteries are capable of 500 to 1,000 charge/discharge cycles.

Nickel Metal Hydride (1.2 V)

Nickel metal hydride (NiMH) batteries, which serve as direct replacements for the closely related NiCad batteries, offer higher capacity and a minimal memory effect. They provide fewer charge/discharge cycles than do NiCads, but NiMH batteries are preferred in all applications because they don't require regular charge/discharge cycling to prevent the memory effect. Nickel metal hydride batteries are environmentally more friendly than Nicad equivalents, because they contain smaller amounts of the heavy metals. Charging requirements are the same as for Nicads.

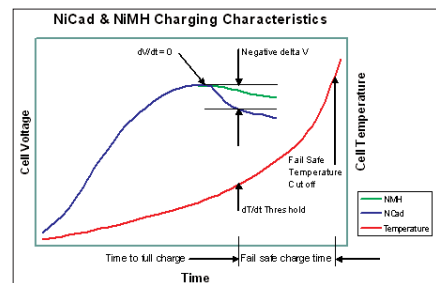


Figure 3. When charging NiCad or NiMH batteries, the terminal voltage and cell temperature are both usable as indicators of the fully charged condition. (Courtesy of Mpower)

Nickel Zinc

Available as both primary and secondary cells, nickel zinc cells are more environmentally friendly. They include almost no heavy metals, they are cheaper than NiMH types, and they offer almost the capacity of lead acid batteries with half the weight. You might ask, what has happened to this technology, why are we not using it more?

Lithium

Lithium has proven to be an excellent chemistry for secondary cells, and several lithium technologies have been developed for that use. Lithium itself is a light-weight metal that reacts violently with water. Most lithium technologies address this issue for the sake of safety, but all lithium cells are easily damaged (sometimes explosively) by uncontrolled charging. Their high terminal voltage (3.6 V) allows use of a single cell for many applications such as mobile phones. They also have up to four times the capacity of an equivalent lead acid

Battery Technology

cell. Other advantages include the ability to withstand deep discharges, absence of the memory effect, and a capability for fast charging under the proper conditions.

Lithium cells are charged with constant current initially, then with constant voltage as their terminal voltage reaches the level indicating a full charge. Lithium-cell chargers usually incorporate both temperature monitoring and charge monitoring (coulomb counting).

Rechargeable Alkaline Manganese

Rechargeable alkaline-manganese cells are reported to provide up to 250 charge/discharge cycles. Their capacity is slightly less than that of single-use alkaline manganese cells, but equivalent to that of nickel metal hydride cells.

Charging

There is a growing need for secondary cells that recharge in less time. Charging time is usually lengthened by the need to absorb gasses generated by the charging process. Though gasses in a sealed cell are absorbed, they can cause the internal pressure to rise as high as 10 bar (almost 10 standard atmospheres). Several charging strategies are available:

Constant Voltage

Constant-voltage charging is typically used for lead acid batteries, and must include an initial current limit when applied to fully discharged batteries. Lead acid batteries exhibit a negative temperature coefficient, so to prevent overcharging, the temperature should be monitored as well.

Constant Current

Constant-current charging is used for NiCad and NiMH batteries. NiCads tolerate overcharging at the "trickle charge" rate ($C/10$ or less) for reasonable periods, and the charge termination can be determined by monitoring for the small reduction in terminal voltage that indicates a full charge. When fully charged, these batteries also exhibit an increase in their rate of temperature rise. Both of these characteristics can be used to terminate charging at higher charge rates ($C/2$ to $2C$).

Burst Charging

Burst charging is a variation on the constant-current method. Once per second (typically) the high charging current is switched off for 20 to 30 milliseconds. The brief respites allow the battery chemicals to stabilize before charging recommences.

Burp Charging

Burp charging is similar to burst charging, but during the off periods it includes an even shorter period (typically 5 milliseconds) for discharge of the battery. Short discharges help to reduce the formation of gas bubbles. (Exact time intervals depend on the battery chemistry.)

Special integrated circuits are available to ease the design of most battery chargers. Maxim, for instance, produces devices like the MAX1647 and DS2711 for general-purpose chargers, and other devices for chemistry-specific systems such as lithium battery chargers. All provide fast and safe battery charging.

Hazardous Materials

In general, nearly all the chemical reactions in batteries rely on heavy metals such as mercury, cadmium, and lead, which are known to cause health and environmental problems. Recycling of lead acid batteries has been partly addressed, mostly because of the relatively high value of lead and the ease of recycling it, but similar provisions for the disposal of other battery types have yet to be established.

Contact Maxim at www.maxim-ic.com.

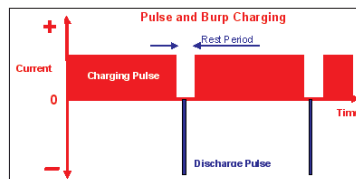


Figure 4. Pulse charging allows a rest interval between charge-current pulses, which allows the battery chemicals to stabilize, and burp charging adds a brief discharge pulse within each rest interval, which minimizes the internal formation of gas bubbles.