# White Paper: Rechargeable Batteries

Posted 01/22/10 at 02:00:00 PM by Jason Cross

**Li-ions, NiCads, and NiMHs, oh my! What does this alphabet soup mean and how do you get the most from your rechargeable devices?**

Batteries are everywhere. They're in our phones, mice, cars, laptops, game machines, controllers, remotes, cameras—you name it. Battery technology influences the design, capabilities, and feature set of nearly everything portable, from laptops and cell phones to hybrid and electric vehicles.

Most of the batteries in our lives are rechargeable, and our more eco-aware world is quickly replacing standard alkaline AA and AAA batteries with rechargeable equivalents. Still, few people know how all these batteries work or how to best take care of them.

## Battery Basics

We're going to focus on common rechargeable battery types, but before we get into that we should cover a few basics about how batteries work and go over common terms. Every battery has two electrodes: the anode and the cathode. In a standard non-rechargeable chemical battery, a chemical reaction oxidizes the anode (typically zinc metal powder), causing free electrons to flow through the electrolyte (ionizing solution) and out the negative terminal. The process is sustained by closing the circuit to the positive terminal, creating a continuous positive charge to the cathode (typically magnesium dioxide powder). A rechargeable battery is one that can store energy if the electron flow is reversed, because the oxidizing chemical reaction can be reversed by the application of electricity. This is, of course, an oversimplification—a detailed description of the chemistry involved in batteries, especially rechargeables, would vary depending on the type of battery and is well beyond the scope of this article.

There are lots of rechargeable battery types—standard Lead Acid car batteries were some of the first commercialized—but most of what you see in today's electronic devices are either Nickel-Cadmium (NiCad), Nicked-Metal Hydride (NiMH), or Lithium-ion (Li-ion). If you understand these three battery types, you'll understand 99 percent of the rechargeable batteries you're likely to use from day to day.

All rechargeables can be measured by their energy density, the ratio of how much energy they can hold per unit of weight. Different battery types have different energy densities, but density can also be affected by improvements in manufacturing and design.

## Nickel-Cadmium

Nickel-Cadmium, or NiCad, batteries were some of the first commercially produced rechargeables, outside of car batteries. Fifteen years ago, they were everywhere. The anode is a nickel hydroxide and the cathode is the metal cadmium. By today's standards, NiCads have a fairly low energy density, perhaps 50 watt-hours per kilogram. However, NiCads can discharge a large amount of current very rapidly without sustaining any damage, and they can take on charge very quickly, so they're popular in some motor-driven applications like power tools.

Unfortunately, cadmium is poisonous heavy metal and this makes old NiCad batteries hard to dispose of safely. If you have a NiCad battery, you shouldn't store it for long periods of time fully charged. NiCads have a nasty "memory effect," where they don't like to be recharged without being fully drained, nor stored for long periods in a fully charged state. Large crystals can form on the cell plates and prevent the battery from taking on a full charge. Every five charges or so, you should let the battery drain completely and charge it fully.

## Nickel-Metal Hydride

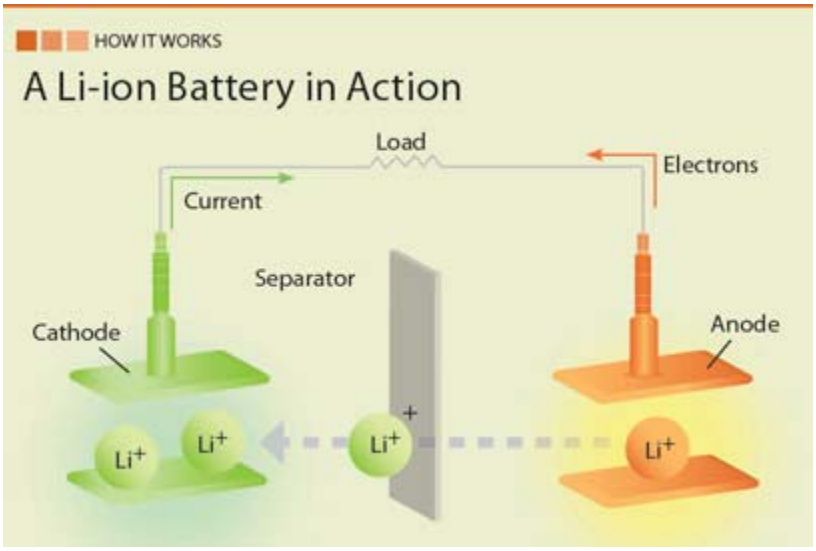
Most similar to Nickel-Cadmium are Nickel-Metal Hydride, or NiMH, batteries. Most of the rechargeable AA and AAA batteries you see on store shelves these days are NiMH, and they're used in a lot of electric vehicles and hybrids, too. They have 30–40 percent higher energy densities than NiCad, and the replacement of cadmium with a hydrogen-absorbing alloy in the cathode makes them more environmentally sound. They don't take well to being charged/discharged very rapidly, so a quality "smart charger" or "trickle charger" may extend the life of your battery and allow it to hold more charge longer.

NiMH batteries used to be limited to around 200 or 300 recharges before ceasing to hold a charge well, but recent advances in manufacturing methods have improved this. You can now get NiMH batteries that recharge up to 1,000 times. Similar improvements have been made in their ability to hold charge when sitting unused. NiMHs suffer from the same "memory effect" as NiCads, although to a much lesser degree, so you'll want to fully discharge/recharge them every now and then.

## Lithium-Ion

In most consumer devices with permanent (or proprietary) batteries like laptops or cell phones, you'll find a Lithium-ion battery. In this battery type, the positive electrode is usually lithium cobalt oxide and the negative is carbon. However, the exact composition of the electrodes has varied in recent years in an attempt to improve performance and safety.

Li-ion batteries are light, giving them energy density much greater than NiMH (more than 100 watt-hours per kg). They also don't suffer from the "memory effect" of NiCads or NiMHs, and don't really lose charge just sitting on a shelf. They do lose their capacity to hold charge over time, whether used or not, so don't buy a "new" Li-ion battery that was manufactured more than a year ago.




**In a li-ion battery, positively charged lithium ions flow in a conducting electrolyte, through a separator, to the cathode. This leaves a negative charge of electrons on the anode. When charging, this flow is reversed.**

With every charge, deposits form inside the electrolyte that inhibit the ability of the lithium ions to move between the anode and cathode, and the total charge capacity goes down. This gets worse if the battery is stored fully charged or in high temperatures. The best practice is to leave your laptop only half-charged if you're not going to use it for a long time.

You may have heard of Lithium Polymer batteries. Technically a type of Lithium-ion battery, Li-Poly holds the electrolyte in a solid or gel polymer composite (polyethylene glycol or polyacrylonitrile). This makes them safer and more stable, and because they are, they don't need to be manufactured in dense, heavy, pressure-tight cylinders. Li-Poly batteries can take almost any shape, and are often lighter because they don't require a dense metal casing. On the other hand, they're also more expensive and carry slightly lower energy densities than standard Li-ion cells.

Though they may be the best of the bunch, Li-ion batteries still have their issues. You've no doubt heard about laptop or cell phone battery fires in recent years. Li-ion batteries

can get very hot, and if there’s a failure in the separator inside the battery and the venting organic electrolyte ignites from a spark or heat, it can quickly catch the cells on fire.

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