1.1 Comparison of Applications Overview

Secondary (rechargeable) battery chemistries in use today include Sealed Lead Acid (Pb Acid), Nickel Cadmium (NiCd), Nickel Metal Hydride (NiMH), Lithium ion (Li-ion), and Lithium Polymer (Li-Poly). This section of the handbook explains the key advantages and disadvantages of each of the battery chemistries listed.

1.1.1 Nickel Metal Hydride (NiMH)

The rechargeable sealed NiMH cell absorbs hydrogen in the metal alloy makeup of its negative electrode during charge. As the cell is discharged, the metal alloy releases hydrogen to form water. The use of the metal alloy is the underlying reason for the high energy density of the NiMH cell compared to other chemistries (see Figure 1.1 Energy Density Comparison). For more detail description of the chemical reactions within a NiMH cell, see Section 3.1, Principles of Operation.

As shown in the following table, NiMH batteries have a long cycle life (minimum of 500 cycles) and good storage characteristics. Furthermore, the battery can be recharged at any time without experiencing voltage depression (or memory effect). Most importantly, the NiMH battery is an environmentally friendly product.

Table 1.1.1

Advantages	Disadvantages	Typical Application
High volumetric and gravimetric energy density Long cycle life Good storage characteristics No memory effect/voltage depression Environmentally friendly Slow and rapid charge compatible	Overcharge/ over-discharge protection needed	Cellular phones, camcorders, emergency backup lighting, power tools, laptops, electric vehicles

1.1.2 Nickel Cadmium (NiCd)

The Nickel Cadmium (NiCd) cell chemistry is different from NiMH cell chemistry in that the NiCd cell absorbs cadmium where the NiMH cell stores hydrogen. Cadmium is much larger and heavier than hydrogen, which leads to lower volumetric and gravimetric energy densities of the NiCd cell (see figure 1.1, Energy Density Comparison). The NiCd's cycle life and discharge voltage profile are equivalent to NiMH. Also, NiCds can be placed into storage at any state of charge (SOC). Nevertheless, the NiCd battery needs to be completely discharged before it is charged to avoid the occurrence of voltage depression (or memory effect). Furthermore, the primary disadvantage to the use of the NiCd chemistry is the environmental concerns and health risks associated with the use of cadmium.

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Table 1.1.2

Advantages	Disadvantages	Typical Application
Long cycle life Good storage characteristics Rapid charge compatible	Low volumetric and gravimetric energy density Memory effect/voltage depression Environmental and health concerns (e.g. kidney damage, itai-itai (ouch-ouch) disease in Japan, and Mutagenic)	Calculators, power tools, tape recorders, flashlights, medical devices (e.g., defibrillators), electric vehicles, space applications

1.1.3 Lithium ion (Li-ion)

Rechargeable Lithium Ion (Li-ion) cells have a negative electrode (anode) made from lithium compounds. Lithium is a highly reactive material and is much lighter than the hydrogen-absorbing metal alloy of the NiMH negative electrode. This leads to higher gravimetric energy densities for the Li-ion cell (see Figure 1.1 Energy Density Comparison).

As shown in the following table, one of the advantages of Li-ion cells is that they have a self-discharge rate much lower than NiMH cells. As a result, Li-ion cells can stay in storage for 12 months without requiring maintenance. On the other hand, lithium is a very reactive material and it requires special circuitry to control charging as well as preventing over discharge of the cells. If too high of a voltage is applied during charge, a catastrophic failure (e.g. explosion) will occur which may result in damage to the surrounding environment. In addition, a puncture penetrating the electrodes of the cell will also cause catastrophic failure. Furthermore, if the lithium of the negative electrode is exposed to water the negative electrode will spontaneously combust.

The expected cycle life of a Li-ion cell in an application is about 500+ cycles. Storing them fully charged at high temperature significantly degrades the capacity. This is encountered for example, when using a laptop at full charge while plugged into a wall.

Table 1.1.3

Advantages	Disadvantages	Typical Application
Very high volumetric and gravimetric energy density Good storage characteristics	High cost Costly charge and discharge control required Lower rate capability Low high temperature performance Potential health risks/catastrophic failures	Laptops, cellular phones, electric vehicles, digital cameras, camcorders, DVD players

1.1.4 Lithium-polymer (Li-Poly)

Lithium Polymer Ion batteries provide the performance of the Li-ion in a thin or moldable package. They do not use a volatile liquid electrolyte and can sustain significant abuse without explosion or fire. As with all batteries, they should still be handled with care, as there is significant energy stored in the cell. The lithium-polymer uses a polymer soaked with gelled electrolyte to replace the traditional porous

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separator.

Lithium-polymer is not a mature technology and low manufacturing costs have not yet been realized. Lithium-polymer finds its market niche in wafer-thin geometries, such as batteries for credit cards and other such applications. Expected cycle life is about 500 cycles.

Table 1.1.4

Advantages	Disadvantages	Typical Application
Very thin profile Flexible form factor Lightweight Improved safety	Expensive No standard sizes High cost-to-energy	Calculators, digital cameras, pagers, lap tops, phones, PDAs

1.1.5 Sealed Lead Acid (Pb Acid or SLA)

The main attraction for Sealed Lead Acid (Pb Acid) cells is the low cost of lead. This makes the Pb Acid cell very inexpensive per watt-hour. Lead is relatively heavy resulting in low volumetric and gravimetric energy densities (see figure 1.1, Energy Density Comparison). Also, the cycle life of a Pb Acid battery is directly proportional to the amount of energy removed from the battery during discharge. To obtain an equivalent cycle life of a NiMH system, only 30% of the Pb Acids capacity can be used. Another disadvantage to the Pb Acid chemistry is they need to be charged before being placed into storage or they will lose cycle life. Furthermore, there are some environmental concerns regarding the use of lead.

Table 1.1.5

Advantages	Disadvantages	Typical Application
Low cost High rate capabilities	Low volumetric and gravimetric energy density Fair cycle life Must be charged to be stored Environmental and health concerns (e.g. mental retardation, interference with kidney and neurological function, hearing loss, blood disorders, hypertension)	Wheelchairs scooters, golf carts, people movers and UPS

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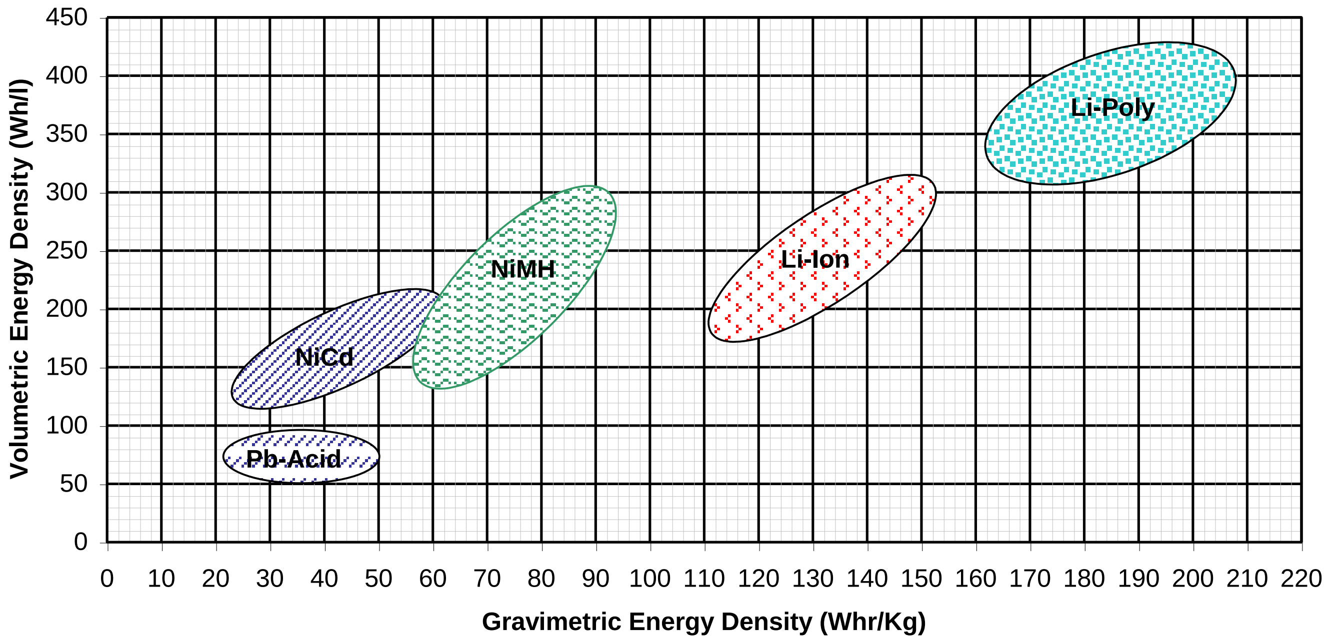
Figure 1.1 Energy Density Comparisons



Note: *Characteristics change according to improvements in chemistry or special niche requirements.*

Figure 1.2 Over All Comparison

Chemistry	Relative Cost	Weight	Temp (ºC)	Cycle Life	Shelf Life (Months)	Volts Per cell
Lead Acid	X	Very Heavy	-15 to 50	180+	6	2.0
Nickel Cadmium	2X	Heavy	-20 to 65	500+	6	1.2
Nickel Metal Hydride	2.5X	Moderate	-10 to 60	500+	12	1.2
Lithium Ion	4X	Light	-10 to 60	500+	12	3.7
Lithium Polymer	5X	Light	-10 to 60	500+	12	3.7

Note: *Characteristics change according to improvements in chemistry or special niche requirements.*

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