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Lithium upgrades lead revolution

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Miniaturized, feature-rich devices are driving a growing need for reliable and cost-effective power management solutions using lithium battery technology.

Primary lithium batteries are commonly utilized in single-use devices as well as in applications that require exceptionally long battery life without worrying about battery status (i.e. automatic external defibrillators). Lithium chemistry is also preferred for devices that need to be small, lightweight, and ergonomically designed. Certain lithium chemistries are also well adapted to the high temperatures associated with autoclave sterilization cycles as well as the extremely low temperatures required by the medical cold chain.

First utilized in pacemakers during the 1960s, primary lithium batteries now power all types of medical devices, including this wireless blood oxygen meter. (Above)

BioAccess created an alternative version of its single-use, hand-held bone drill using TLM-1550HP lithium metal oxide batteries instead of alkaline cells.

Why lithium?

First utilized in pacemakers during the 1960s, primary lithium batteries now power all types of medical devices, including automatic external defibrillators, surgical saws, drills, robotic inspection systems, RFID asset tracking tags, infusion pumps, bone growth stimulators, glucose monitors, blood oxygen meters, cauterizers, and other medical devices.

Lithium batteries are the preferred choice for many of today's advanced medical devices because they offer the highest specific energy (energy per unit weight) and energy density (energy per unit volume) of any battery type. Lithium cells, all of which use a non-aqueous electrolyte, also have nominal open circuit voltages of between 1.7 and 3.9V. However, the use of non-aqueous electrolytes results in relatively high internal impedance.

Lithium chemistries also offer an extended temperature range, made possible by the absence of water and the chemical and physical stability of the materials. Lithium thionyl chloride cells provide the widest temperature range of all (-55°C to +125°C) and can be specially modified to withstand temperatures as low as -80°C to support the medical cold chain, delivering continuous power even at extremely cold temperatures to permit around-the-clock monitoring of pharmaceuticals, transplant organs and tissue samples that are frozen or packed in dry ice.

Not created equal

Within the category of lithium primary batteries, numerous competing chemistries are available, each offering certain advantages and disadvantages.

Li/MNO2 (lithium manganese dioxide) batteries, originally designed for consumer items such as toys and cameras, are now commonly utilized in glucose monitors. Li/MNO2 cells feature relatively low cost and high current-pulse capabilities, but suffer

LITHIUM BATTERY CHARACTERISTICS

Characteristics	LiSOCL2 bobbin	LiSOCL2 w/hybrid Layer capacitor (PulsesPlus)	TLM Series Lithium metal oxide	LiSO2	LiMnO2
Energy density (Wh/1)	1,420	1,420	680	410	650
Power	Low	High	High	High	Moderate
Voltage	3.6V	3.6V – 3.9V	4.1V	3.0V	3.0V
Pulse amplitude	Small	High	Very high	High	Moderate
Passivation	High	Low	Low	Fair	Moderate
Performance at elevated temperature	Fair	Excellent	Excellent	Moderate	Fair
Performance at low temperature	Fair	Excellent	Excellent	Excellent	Poor
Operating life	Excellent	Excellent	Excellent	Moderate	Fair
Self-discharge rate	Low	Low	Low	Moderate	Moderate
Operating temperature	-80°C to 125°C	-40°C to 85°C	-40°C to 85°C	-55°C to 60°C	0°C to 60°C
Operating life	20+ years	20+ years	20 years	10 years	5 years
Typical applications	Bone healers, oxygen meters, glucose meters, devices that are sterilized, modifiable for the cold chain	Automatic external defibrillators (AED), devices to be sterilized	Automatic external defibrillators (AED), cauterizer, disposable power tools, resuscitation	Automatic external defibrillators (AED)	Glucose monitors

from high self-discharge and low energy density, which makes for bulky devices. Likewise, Li/MNO2 cells have a limited temperature range of -10ºC to 60ºC.

Li/SO2 (lithium sulfur dioxide) batteries, found in certain types of external defibrillators, are capable of delivering high current-pulses at low temperatures, but tend to be larger and heavier than other lithium chemistries. Li/SO2 cells also suffer from higher self-discharge, which limits their potential service life.

Li/SOCL2 (lithium thionyl chloride) cells are ideally suited for low-current applications where a steady low current (micro amps to low milli amps) is applied for an extended period of time. They feature high energy density, high capacity, and low self-discharge rate, and feature an operating life as long as 25+ years. Certain bobbin-type lithium thionyl chloride cells also can operate in extreme temperatures ranging from -80°C to 125°C.

A hybrid version of the lithium thionyl chloride cell, the PulsesPlus battery, combines the advantages of lithium thionyl chloride chemistry with a hybrid layer capacitor to deliver high current-pulses. This hybrid cell is ideal for use in automatic external defibrillators (AEDs) and similar applications that generally operate with a low background current (sleep mode) but require periodic high-current pulses (in the multi-amp range). PulsesPlus cells also offer the potential for an end-of-life indication when the battery has depleted 90 to 95% of its original capacity. This end-of-life feature can be useful for critical applications where the "readiness status" of the device needs to be continually monitored.

In addition, Tadiran developed the TLM Series lithium metal oxide batteries designed to deliver high cell voltage, high energy density, instant activation, and exceptionally long operational life even in extreme temperatures, TLM Series batteries deliver an open circuit voltage of 4.0 volts with high current pulses of up to 15A and 5A continuous current at 3.2V. Often used in disposable devices such as hand-held surgical drills, power tools and cautherizers, TLM Series batteries provide ergonomic solutions by allowing hand-held and strapped-on devices to be as small and as lightweight as possible.

Real-life examples

The following case studies illustrate

how lithium chemistry can be ideal for certain types of applications:

• **Bone growth stimulator requiring low continuous current.** Five to 10% of the nearly 6 million bone fractures that occur annually in the United States show delayed or impaired healing. Bone growth stimulators use high frequency sonic pressure waves to stimulate bone growth and healing. These devices are usually strapped on over the fracture site or fitted into a cast and emit low-intensity, pulsed ultrasound.

This application typically utilizes a battery pack made up of AA-size Li/SOCL2 cells to deliver long-term continuous power. The battery's high energy density reduces size and weight, which is a critical requirement since the device is worn by the patient.

• **Automatic external defibrillators (AEDs) requiring low background current, periodic low current-pulses, and very high current pulses when in use.** AEDs are portable devices used to restore normal heart rhythm to patients in cardiac arrest, a sudden and potentially fatal condition. The AED automatically analyzes the patient's heart rhythm and advises the rescuer as to whether or not a shock is needed to restore a normal heart beat.

AEDs are often located in public places, such as schools, restaurants, airports, and office buildings (public access AEDs) where hardwired AC power may not be available to ensure continual battery recharging. These remote locations also may be exposed to extreme temperature that could compromise battery performance. As a result, these devices often rely on primary lithium batteries for long-term reliability, enabling them to deliver high current-pulses even after extended periods of inactivity.

For example, a leading manufacturer of automatic external defibrillators utilizes PulsesPlus hybrid Li/SOCL2 batteries to deliver the high-current pulses required to stimulate the human heart. The PulsesPlus battery was also chosen for its extremely long shelf life (self-discharge of less than 1% per year) and its ability to withstand extreme temperatures, which translates into greater system reliability, since battery failure can result in a patient fatality.

Awarepoint developed an RFID asset tracking tag for medical applications that uses lithium thionyl chloride batteries capable of withstanding the high temperatures associated with autoclave and chemical sterilization cycles.

• **Hand-held surgical drill requiring no background current with very high current-pulses.** The manufacturer of a single-use hand-held bone saw previously designed the device using a strapped-on battery pack consisting of 8 LMNO2 cells, which was then wire harnessed to the bone saw and discarded after one use.

To deliver a more ergonomic solution, the device was redesigned utilizing 3 TLM high-energy lithium batteries located within the saw's handle, thus eliminating the need for the wire harness and the external battery pack, permitting greater mobility for the surgeon. TLM high-energy batteries were chosen for this high rate application because they can deliver high current-pulses of up to 15 Amps.

Similarly, BioAccess, a Baltimore-based manufacturer of a single-use, handheld bone drill, created an alternative version of its device using TLM-1550HP batteries instead of alkaline cells. The lithium metal oxide cells delivered an open circuit voltage of 4.1 V along with the ability to handle high current-pulses of 15A with a 5A continuous load. An equivalent alkaline battery pack would require 3X the weight and 2X the volume (requiring 15 AA-size alkaline batteries versus 6 AA-size TLM-1550-HP batteries). Use of the lithium metal oxide cell also enabled faster drilling speeds, extended drilling time, and increased torque for more efficient drilling cycles.

Looking to the future

Lithium batteries have dynamic potential for use in portable and hand-held medical devices, as well as in more exotic applications such as spider-like robotic capsules that are swallowed and crawl through the GI tract to perform diagnostic and surgical procedures. In addition, a new generation of medical devices is emerging that combine telematics, GPS, and RFID tracking capabilities. These devices can be coupled with heart rate, temperature, and other advanced sensors that enable healthcare providers to monitor a patient's vital signs and precise whereabouts in hospitals, nursing homes, assisted living quarters, or remote locations via satellite.

For example, Awarepoint, San Diego, recently introduced a RFID asset tracking tag for medical applications that uses lithium thionyl chloride batteries capable of withstanding the high temperatures associated with autoclave and chemical sterilization cycles. Previously, medical asset tracking devices had to be removed from medical equipment prior to sterilization in order to protect the battery from heat-related damage. Medical devices and equipment equipped with Awarepoint asset tags can now remain online during sterilization cycles, thus enabling continuous real-time tracking and reporting.

Examples such as this demonstrate how recent advancements in lithium battery technology are playing a critical role in an industry undergoing revolutionary change. As medical technology continues to evolve, exciting possibilities and challenges will emerge involving long-term power management solutions that enhance the performance and reliability of next generation medical devices.