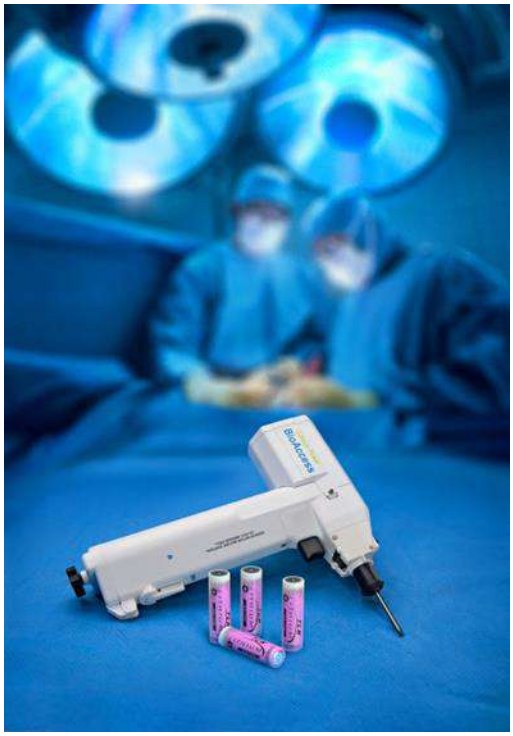
Lithium Batteries for Medical Devices



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Empowering Medical Technology

Louis Adams, Regional Sales Manager, Tadiran Batteries

Advanced lithium battery technology is powering the development of a new generation of medical devices. These products are becoming increasingly sophisticated, feature-rich, and miniaturized, necessitating the use of the lithium options. This article highlights a number of battery solutions and offers the outcome of a real world case application.

Advancements in technology have led to a new generation of lithium battery-powered medical devices, ranging from surgical drills and power tools to automatic external defibrillators (AEDs), robotic inspection systems, RFID asset tracking tags, infusion pumps, bone growth stimulators and other wearable devices, glucose monitors, blood oxygen meters, cauterizers, and remote sensors.

Primary lithium batteries are preferred for medical applications because they offer the highest specific energy (energy per unit weight) and energy density (energy per unit volume) of any battery chemistry. Lithium cells have a nominal open circuit voltage of between 1.7 and 3.9V. Their electrolyte is also non-aqueous, permitting certain cells to operate in temperatures ranging from -55 to 125°C. In addition, specially modified bobbin-type $LiSOCl_2$ batteries are used to monitor the transport of frozen tissue samples, pharmaceuticals, and transplant organs throughout the medical cold chain, where temperatures as low as -80°C must be maintained.

A Wide Selection of Chemistries

Among lithium primary batteries, there are numerous chemistries to choose from, each offering unique performance characteristics (Table).

For example, hand-held glucose monitors are often powered by $LiMNO_2$ (lithium manganese dioxide) batteries that have certain limitations, including high self-discharge, low energy density, and a narrow temperature range (-10 to 60°C).

$LiSO_2$ (lithium sulfur dioxide) batteries deliver high pulses, especially at low temperatures. They also have drawbacks, including high annual self-discharge and added bulk due to their low energy density.

Bobbin-type $LiSOCl_2$ (lithium thionyl chloride) cells feature high energy density, high capacity, and very low self-discharge rate, permitting up to 40-year operating life for certain low power applications, including RFID asset tracking devices. Certain brands of bobbin-type $LiSOCl_2$ cells can operate at extreme temperatures (-80 to 125°C) making them ideal for use in applications that require autoclave sterilization. A patented version of this battery, the PulsesPlus, combines a standard bobbin-type

$LiSOCl_2$ cell with a hybrid layer capacitor to deliver low background current along with periodic high pulses, which is ideal for AEDs and for powering advanced two-way communications.

Applications that require short bursts of very high power from a miniaturized power supply, such as surgical drills and power tools, can be powered by a unique type of lithium metal oxide battery, the TLM Series, which delivers high voltage, high energy density, instant activation, and exceptionally long operational life even in extreme temperatures. TLM batteries feature an open circuit voltage of 4.0V, along with the ability to deliver up to 15A pulses (5A continuous current at 3.2V). These cells can operate in -40 to 85°C temperatures.

Requirements Dictate Choice
The specific application requirements of a device are going to dictate the choice of battery technology used. A bone growth stimulator, for example, requires low continuous current to emit low-intensity, high frequency sonic pressure waves that stimulate bone growth and healing. Use of a standard $LiSOCl_2$ battery pack, with its high energy density, enables this wearable device to be lighter and more compact, resulting in greater user comfort.

On the opposite side of the spectrum, an AED can go for years without requiring any background current but needs to deliver high pulses during a cardiac arrest. These application requirements are well suited to hybrid bobbin-type $LiSOCl_2$ batteries, which can deliver pulses of up to 15A, feature a very low annual self-discharge rate (under 1% per year), and operate reliably in extreme temperatures.

Surgical Drills Present a Unique Challenge
Surgical suites are highly controlled environments, so introducing any new

technology requires a careful vetting process to ensure product safety and efficacy. A prime example involves the development of new, battery-powered automatic torque limiting surgical screwdrivers.

Manufactured by Pro-Dex (www.pro-dex.com), these screwdrivers are used by neurosurgeons to firmly set titanium screws into thin titanium plates that cover portions of the skull removed during surgery. The drivers are equipped with an automatic torque limiting sensor to ensure that the titanium screws are properly driven to the right depth — completely flush with the top surface of the titanium plate — thus eliminating the risk of an unsightly bump that could cause unnecessary patient discomfort.

The new technology drivers combine a special high-rel motor with advanced microelectronics, proprietary algorithms, and state-of-the-art sensor technology to automatically limit the torque. Other key performance features include reversible variable speed control and touch sensors that enable left- or right-handed surgeons to experience tactile feel during screw insertion or extraction.

Since the device is completely reusable (except for the battery pack, which is discarded after a single use), all electro-mechanical components have been ruggedized to withstand the excessive heat and humidity associated with multiple autoclave sterilization cycles. To achieve such rigorous performance standards, virtually all components, except the batteries, are being manufactured at the company’s production facility in Irvine, CA.

According to Stu Gallant, vice president of product and business development at Pro-Dex, “Creating a truly surgeon-friendly power tool requires the ideal power supply, as selecting the right battery can result in a dramatic reduction in size and weight without sacrificing power or performance. Several primary lithium chemistries were considered, but we selected lithium metal oxide (TLM Series) batteries for their ability to deliver high continuous power, high pulse amplitude, and up to 4.1V continuous current per cell during active drilling cycles. Use of these small but powerful batteries helps make the new drivers handy and ergonomic tools that save time and reduce operator fatigue.”

Currently, two models have been developed — one powered by two TLM 1,550HP batteries, which delivers up to 8V of variable current to permit speeds of up to 2,200RPM; and another version powered by four TLM 1,550HP batteries, which delivers up to 16V of variable current to permit speeds of up to 4,000RPM.

Characteristics	$LiSOCL_2$ bobbin	$LiSOCL_2$ w/hybrid Layer capacitor (PulsesPlus)	TLM Series Lithium metal oxide	$LiSO_2$	$LiMnO_2$
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	Fair	Fair	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

A Future Option

The battery pack used to power these drivers is discarded after a single use. However, in the future, it could be possible to develop a reusable battery pack powered by TLI Series medical-grade rechargeable Lithium-ion (Li-ion) batteries.

Consumer-grade Li-ion rechargeable batteries are not manufactured to medical-grade standards, as they deliver only five years of maximum operating life, 1,000

recharge cycles, and are constructed with crimped seals that are prone to breakage and corrosion. Consumer-grade Li-ion batteries are also not designed to handle the high temperature and humidity associated with autoclave sterilization procedures.

By contrast, medical grade rechargeable TLI Series Li-ion batteries can deliver up to a 20-year operating life and 5,000 full recharge cycles, and can draw up to 15A of continuous current. These robust batteries also feature a hermetic seal for added protection against leakage and corrosion, and provide an extended temperature range to handle multiple autoclave sterilization cycles.

Exciting possibilities exist for next generation medical technology being powered by primary and rechargeable lithium batteries.

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Electronic PRODUCTS

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Powering miniaturized medical devices

Advanced lithium battery chemistries enable self-powered medical devices to become smaller while delivering uncompromised performance

By LOUIS ADAMS,
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As self-powered medical devices become increasingly sophisticated and miniaturized, the choice of power supply becomes more critical for applications ranging from surgical drills and medical power tools to automatic external defibrillators (AEDs), infusion pumps, bone growth stimulators and other wearable devices, glucose monitors, blood oxygen meters, cauterizers, RFID asset tracking tags, and other remote wireless devices.

Self-powered medical devices increasingly require the use of industrial grade primary lithium batteries instead of consumer grade batteries for various reasons, including:

- Reliability – patient wellness depends on procedure outcome
- High power-to-size ratio – enables the medical device to be smaller, lighter, and more accurate
- Small physical size – allows the device to be ergonomically designed for comfort and ease-of-use
- Long shelf life – ensuring that the device will operate reliably after long storage periods without needing to recharge or replace the battery
- High temperature survivability – if sterilization is required
- Cold temperature operability – for items transported through the cold chain
- Ability to supply high pulses –to run motors and communications circuits.

A choice among primary lithium chemistries

Primary lithium batteries deliver the highest specific energy (energy per unit weight) and energy density (energy per unit volume) of any battery chemistry, with a non-aqueous electrolyte, and a nominal open circuit voltage of 1.7 to 3.9V. Table A summarizes the various chemistries that are available.

Characteristics	$LiSOCL_2$ bobbin-type	$LiSOCL_2$ w/hybrid Layer capacitor (PulsesPlus)	Lithium metal oxide	$LiSO_2$	$LiMnO_2$
Energy density (Wh/1)	1,420	1,420	680	410	650
Power Voltage Pulse amplitude	Low 3.6V Small	High 3.6V – 3.9V High	High 4.1V Very high	High 3.0V High	Moderate 3.0V Moderate
Passivation	High	Fair	Fair	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 Typical applications	20 years + Bone healers, oxygen meters, TAKE OUT, devices that are sterilized, modifiable for the cold chain	20 years + Automatic external defibrillators (AED), devices to be sterilized	20 years Automatic external defibrillators (AED), cauterizer, disposable power tools, resuscitation	10 years Automatic external defibrillators (AED)	5 years Glucose monitors

Table A: Primary lithium battery characteristics

Lithium manganese dioxide ($LiMNO_2$) cells power hand-held devices such as glucose monitors, but suffer from a narrow temperature range and a high annual self-discharge rate.

Lithium sulfur dioxide ($LiSO_2$) batteries deliver high pulses, especially at low temperatures, but add bulk due to their low energy density, and have a high annual self-discharge rate.

Bobbin-type lithium thionyl chloride ($LiSOCL_2$) cells feature very high energy density and high capacity, along with a very low annual self-discharge rate, enabling low power devices to operate for up to 40 years. These cells feature a wide temperature range (-80°C to 125°C), making them ideal for autoclave sterilization and for use in the medical cold chain.

Due to their low rate design, standard bobbin-type $LiSOCL_2$ batteries cannot deliver high pulses. One solution is to combine a standard bobbin-type $LiSOCL_2$ battery with a patented hybrid layer capacitor (HLC) that stores energy and delivers periodic high pulses. Another option is to combine a standard $LiSOCL_2$ battery with a supercapacitor, which is a bulkier, more complex, and more costly solution.

Specialized batteries deliver high rate current

A lithium metal oxide battery, the TLM Series, was developed for applications requiring continuous high rate power, such as surgical drills and power tools.

Constructed with a carbon-based anode, a multi metal oxide cathode, and an organic electrolyte, TLM Series cells feature a nominal voltage of 4V and up to 2 Wh of energy, with a discharge capacity of 135 mAh to 500 mAh, capable of handling 5A continuous loads and 15A maximum pulses. These powerful little cells offer up to 20-year shelf life due to a low annual self-discharge rate (less than 1% per year), along with a wide temperature range (-40° to 85°C) and a hermetic seal.

Some real-life examples

Bone growth stimulator (low continuous current)

Stimulating bone growth and healing requires low-intensity, high frequency sonic pressure waves. Use of a standard bobbin-type $LiSOCL_2$ battery pack enables this wearable device to be compact and lightweight.

AED (long shelf life, high pulses)

Automatic external defibrillators (AEDs) require extremely long battery shelf life, often remaining idle for extended periods, but then must operate reliably in an emergency. Combining a standard $LiSOCL_2$ battery with an HLC delivers both a low annual self-discharge rate (less than 1% per year) along with pulses of up to 15 A to stimulate a heartbeat.

Hand-held surgical drills (high rate, high pulse)

Pro-Dex automatic torque limiting surgical screwdrivers permit neurosurgeons to insert titanium screws into titanium plates at just the right depth to cover portions of the skull removed during surgery (see Fig. 1), thus eliminating the risk of unsightly bumps or additional patient discomfort.

Fig. 1: A portable, automatic torque limiting surgical screwdriver permits neurosurgeons to insert titanium screws into titanium plates at just the right depth in the skull.

According to Stu Gallant, vice president of product and business development at Pro-Dex, “Creating a truly surgeon-friendly power tool requires the ideal power supply, as selecting the ideal battery can result in a dramatic reduction in size and weight without sacrificing power or performance.”

After reviewing several primary lithium chemistries, Pro-Dex selected TLM Series lithium metal oxide batteries for their ability to deliver high pulse amplitude and up to 4.1 V continuous current per cell during active drilling cycles. Two models are currently available: one that uses two TLM 1550HP batteries to deliver 8 V of variable current for drilling speeds up to 2,200 rpm; and another model that uses four TLM 1550HP batteries to deliver 16 V of variable current for drilling speeds up to 4,000 rpm.

Pro-Dex surgical screwdrivers are reusable, except for the battery pack. In the future, these devices could be made fully re-usable by using an industrial grade Lithium-ion (Li-ion) battery, the TLI Series, which can deliver up to 15 A of continuous current (AA size cell), able to operate for 20 years and 5,000 full recharge cycles, while offering an extended temperature range and a hermetic seal.

Hand-held surgical drill (a smaller alternative to alkaline batteries)

BioAccess, a surgical device manufacturer, now offers lithium metal oxide batteries as an optional power supply upgrade for a surgical drill that was previously powered by alkaline battery packs. The alkaline batteries performed well and offered excellent reliability, but added unnecessary weight. Use of the optional lithium metal oxide battery pack enables faster drilling speeds, more active drill time (30 to 40 seconds at a time for up to 20 to 30 cycles), more instantaneous power, and greater stall torque for more efficient drilling cycles with less operator fatigue.

Fig. 2: A surgical drill provides variable speeds to 4,000 rpm with four lithium metal oxide batteries

Substituting 6 AA-size TLM-1550HP batteries for alkaline battery pack also enabled BioAccess to achieve a 36% weight reduction with only 40% of the volume. An equivalent alkaline battery pack would have required 3X the weight and 2.5 times the volume (15 AA-size alkaline batteries vs. 6 AA-size TLM-1550-HP batteries).

Recent advancements in lithium battery technology have enabled medical devices to become increasingly miniaturized without sacrificing performance.

By By LOUIS ADAMS, Southwest Regional Manager, Tadiran Batteries, www.tadiranbat.com

Cutting the Size and Weight of Surgical Devices

The Project: Replace the previously used alkaline battery packs to power a surgical bone drill with a more efficient alternative.

The Solution: Utilize high power lithium batteries to make cordless bone drills lighter, more powerful, and more ergonomically designed.

By Sol Jacobs

Orthopedic surgeons are continually looking to increase productivity and improve efficiency by choosing medical devices that are lightweight and ergonomically designed.

This fact was clearly on the minds of the product development engineers at BioAccess as they began designing their latest generation of cordless, single-use surgical bone drills. Teaming up with Tadiran, a leading manufacturer of long-life lithium batteries, they recently unveiled a new higher power device that is significantly lighter and more ergonomically beneficial than previous models, yet capable of delivering high energy density and capacity required to produce greater torque and faster drilling speeds, which saves valuable OR time and cost.

Formerly powered by alkaline packs, BioAccess bone drills now use TLM-1550-HP lithium packs to produce greater torque and faster drilling speeds while reducing weight by 36%.

After carefully reviewing available battery chemistries, BioAccess specified a custom battery pack made from six TLM-1550-HP AA-size high power lithium batteries from Tadiran. Introduced to the market approximately two years ago, these high power lithium batteries enable BioAccess portable bone drills to deliver excellent performance characteristics, that have been quickly validated based upon positive feedback from OR surgeons and through input received by BioAccess' field sales representatives. BioAccess is currently ramping up production of its newest generation bone drills based on strong demand from surgeons who appreciate the drill's increased power and better ergonomic comfort during surgical procedures, which minimizes fatigue and leads to more efficient drilling cycles.

BioAccess powered earlier generations of its portable small bone drills with alkaline battery packs. While these products performed well and offered excellent reliability, BioAccess' goal of continuous improvement called for ongoing refinements that would ultimately reduce overall weight and extend the power ceiling of the device.

"With the Tadiran cells, we get much more power than a standard alkaline pack, while trimming 36% off the weight," says Bob Chapolini, MD, president of BioAcess. "This noticeable weight reduction makes the product more ergonomic by reducing user fatigue. If we had used a AA alkaline pack giving the same power as the Tadiran pack, the drill would have been three times heavier and twice the volume (requiring 15 AA-size alkaline batteries versus six AA-size TLM-1550-HP batteries). That would have turned a compact, lightweight design into a heavy, bulky instrument. That is not what the surgeon wants."

TLM-1550-HP cells feature an open circuit voltage of 4.1 V along with the ability to handle pulses of up to 15 A, with 5 A maximum continuous load. The battery also operates across a wide temperature range (-40°C to 85°C) and can withstand pre-surgical sterilization temperatures as high as 125°C. While the BioAccess bone drill is specifically designed for single use, the extended temperature range of the cell makes it extremely well-suited

	Previous Alkaline Pack	TLM-1550-HP Pack	Alkaline Equivalent to TLM-1550-HP Pack
Weight (Oz)	6.3	4.0	12.4
Volume (Cu. In.)	3.3	3.3	7.13
# of Batteries	15 AAA	6 AA	15 AA

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for autoclave cycles.

"We're seeing a remarkable efficiency gain from these new batteries," Chapolini adds. "TLM-1550-HP battery packs enable more active drill time and a much longer shelf life, as well as more instantaneous power when the device is activated. Surgeons also do not want to experience power delays when utilizing our device in the OR. Use of a TLM-1550-HP battery pack ensures a more positive and reliable experience, as our latest generation of cordless drills are capable of delivering more power compared to alkaline cells, along with more stall torque, 30 to 40 seconds at a time, with 20 to 30 cycles."

A former surgeon himself, Chapolini speaks from experience, which helps establish credibility with surgeons as he demonstrates the newer drill model in physician offices, and at medical conferences and symposiums. "Any time we go to a symposium or conference, we've usually kept our demo units in storage for weeks or months at a time without testing system reliability." he says. "Fortunately, every time that we have pulled a bone drill out of the box it has operated powerfully and reliably, which provides greater reassurance to the prospective customer. What's more, the power provided for these small bone procedures is such that it may give us an opportunity to sell the drills into other classes of surgery that involve larger or heavier power tool classifications, which opens additional doors of opportunity for our product," Chapolini adds.

Recognizing that extended storage life coupled with high reliability would be important product attributes for BioAccess, Tadiran's quality assurance department conducted extensive testing on the TLM-1550-HP to ensure that the cell could offer an extremely long service life of up to 20 years, as certain emergency medical devices can go unused for extended periods of time yet must work reliably in life threatening situations. To accomplish this, the batteries feature very low annual self-discharge, resulting in a potential service life of up to 20 years.

"Simply put, the TLM-1550-HP battery is an optimum power source for a great many single-use devices," says Sol Jacobs, VP and general manager of Tadiran. "With unique attributes such as extraordinarily high capacity and energy density, extremely long life, and extended temperature range, TLM-1550-HP cells are particularly well-suited for a wide range of medical applications," Jacobs says. "This includes automatic external defibrillators (AED), cauterizers, CPR resuscitation equipment, and other handheld power devices used in hospitals, clinics, or by field responders. The positive results achieved as a result of our partnership with BioAccess demonstrate the importance of OEM design engineers working in close partnership with the right battery manufacturer to achieve the optimum power management solution."

ONLINE

For additional information on the products and technologies discussed in this article, see *MDT* online at **www.mdtmag.com** and the following websites:

- www.bioaccess.com
- www.tadiranbat.com

Medical Design & OUTSOURCING
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Prescribing the right power supply: Important considerations for using batteries to power medical devices

July 27, 2015 By MDO Editor 0 Comments

Sol Jacobs, VP and General Manager, Tadiran Batteries

Medical technology is advancing rapidly, requiring increasingly sophisticated power management solutions, especially when then the device needs to be self-powered.

Battery-powered medical devices encompass a wide range of applications, including surgical drills, power tools, automatic external defibrillators (AEDs), infusion pumps, bone growth stimulators and other wearable devices, such as glucose monitors, blood oxygen meters, cauterizers, RFID asset tracking tags, as well as other remote wireless devices utilized to monitor patients, procedures, medications and equipment. Each device has unique power requirements; therefore, the choice of power supply requires careful consideration based on application-specific requirements.

Consumer versus industrial grade batteries?
Many wearable medical devices and certain equipment designed for in-home can be powered by consumer grade alkaline and rechargeable batteries, which are reasonably inexpensive and readily available. However, certain applications require the use of industrial grade lithium primary batteries, as lithium offers the highest specific energy (energy per unit weight) and energy density (energy per unit volume) of any battery chemistry. Lithium cells have a nominal open circuit voltage of between 1.7 and 3.9 V. Their electrolyte is also non-aqueous, permitting certain cells to operate in extreme temperatures.

The choice between a consumer battery and an industrial grade lithium battery often hinges on the following factors:

1. Reliability – patient wellness depends on procedure outcome
2. High power-to-size ratio – enables the medical device to be smaller, lighter and ergonomically designed for ease-of-use, comfort and accuracy
3. Long shelf life – ensures that the device is ready to operate even after long periods of storage without needing to recharge or replace the battery
4. High temperature survivability – if sterilization is required
5. Cold temperature operability – for items transported through the cold chain
6. Ability to supply high pulses –to run motors and communications circuits.

A wide choice of primary lithium chemistries

Numerous primary lithium battery chemistries are available for medical applications.

Lithium manganese dioxide (LiMNO2) batteries are often used to power hand-held glucose monitors. LiMNO2 cells are inexpensive, easily replaced and usually sufficient for in-home use, but suffer from a narrow temperature range and a high annual self-discharge rate.

Lithium sulfur dioxide (LiSO2) batteries can deliver high pulses, especially at low temperatures, but add bulk due to their low energy density. LiSO2 batteries also have a high annual self-discharge rate.

Bobbin-type lithium thionyl chloride (LiSOCL2) cells feature the highest energy density, highest capacity and lowest self-discharge rate of any lithium chemistry, making them ideal for use in applications that draw small amounts of current over extended periods, with certain cells able to operate maintenance-free up to 40 years.

Characteristics	$LiSOCL_2$ bobbin-type	$LiSOCL_2$ w/hybrid Layer capacitor (PulsesPlus)	Lithium metal oxide	$LiSO_2$	$LiMnO_2$
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	Fair	Fair	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, TAKE OUT, devices that are sterilized 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

Primary Lithium Battery Characteristics

Bobbin-type LiSOCL2 cells are also well suited to extreme temperatures (-80o° to 125o° C), including autoclave sterilization. Bobbin-type LiSOCL2 batteries can also be specially modified to withstand cold chain temperatures as low as -80° C for transporting frozen tissue samples, pharmaceuticals and transplant organs. Certain of these specially modified batteries have survived prolonged testing at -100° C.

However, due to their low rate design, standard bobbin-type LiSOCL2 batteries are not well suited for delivering the high pulses required to initiate data sampling or wireless communications. An economical solution is to combine a standard bobbin-type LiSOCL2 battery with a patented hybrid layer capacitor (HLC) that stores the energy and delivers the periodic high pulses required for applications such as AEDs. Another option is to combine a standard LiSOCL2 battery with a supercapacitor, which is a bulkier, more complex and more costly solution.

Powering devices that draw high rate current

Certain medical equipment, such as surgical drills and power tools, require continuous high rate power. To address this specialized requirement, lithium metal oxide chemistry was developed, the “TLM Series,” an innovative chemistry that delivers high voltage, instant activation and exceptionally long shelf life, even in extreme temperatures.

Constructed with a carbon-based anode, a multi metal oxide cathode and an organic electrolyte, TLM Series batteries can deliver up to 20-year operating life with an annual self-discharge rate of less than 1% per year. These powerful little cells feature a

Constructed with a carbon-based anode, a multi metal oxide cathode and an organic electrolyte, TLM Series batteries can deliver up to 20-year operating life with an annual self-discharge rate of less than 1% per year.

nominal voltage of 4V and up to 2 Wh of energy, with a discharge capacity of 135 to 500 mAh, capable of handling 5A continuous loads and 15A maximum pulses. These batteries also offer a reasonably wide operating temperature range (-40° to 85 °C.), and a hermetic seal to help prevent battery leakage.

Medical grade rechargeable lithium-ion chemistries

Certain medical devices, especially those designed or in-home use, can operate consumer grade Lithium-ion (Li-ion) rechargeable batteries, which are inexpensive and readily available, but have certain drawbacks, including high self-discharge rates that can result in low battery availability if the cell is not properly recharged before the procedure. Consumer grade rechargeable batteries also have a low power-to-size ratio, so large battery packs are required to deliver the high pulses and continuous energy required by surgical drills and power tools. Consumer grade Li-ion batteries also have crimped seals that may leak, and are not designed to handle high temperature autoclave sterilization.
To address these problems, an industrial grade rechargeable Li-ion battery was developed, the "TLI Series," which can draw up to 15A of continuous current in a small AA size cell, enabling surgical power tools to be smaller, lighter and more ergonomic. Industrial grade Li-ion batteries also feature an extremely low self-discharge rate, enabling medical devices to sit on the shelf for extended periods but still provide instantaneous activation. These ruggedized rechargeable batteries also feature a hermetic seal and an extended temperature range.

Some real-life examples

- Bone growth stimulator (low continuous current): To stimulate bone growth and healing, a bone growth stimulator requires low continuous current to emit low-intensity, high frequency sonic pressure waves. Use of a standard bobbin-type LiSOCL2 battery pack makes this wearable device more compact and lightweight, resulting in greater user comfort and convenience.
- AED (long shelf life, high pulses): AEDs require a power supply that delivers extremely long shelf life, as the AED can remain idle for extended periods, but then must be able to deliver high pulses in the event of a heart attack. Combining a standard LiSOCL2 battery with an HLC provides the combined benefits of a low annual self-discharge rate (less than 1% per year) along with the ability to deliver high pulses of up to 15 A.
- Hand-held surgical drills (high rate, high pulse): Pro-Dex recently developed battery-powered automatic torque limiting surgical screwdrivers, which neurosurgeons use to insert titanium screws that secure in place titanium plates that cover portions of the skull removed during surgery. These precision screwdrivers are equipped with an automatic torque limiting sensor to ensure that the titanium screws are properly driven to the right depth—completely flush with the top surface of the titanium plate—thus eliminating the risk of an unsightly bump that could cause patient discomfort.

The screwdrivers are completely reusable (except for the battery pack, which is discarded), featuring a special high-rel motor with advanced microelectronics, proprietary algorithms, state-of-the-art sensor technology to automatically limit the torque, reversible variable speed control and touch sensors that enable left- or right-handed surgeons to experience tactile feel during screw insertion or extraction. All electro-mechanical components had to be ruggedized to withstand the excessive heat and humidity associated with multiple autoclave sterilization cycles.
"Creating a truly surgeon-friendly power tool requires the ideal power supply, as selecting the ideal battery can result in a dramatic reduction in size and weight without sacrificing power or performance," said Stu Gallant, VP of product and business development at Pro-Dex. "Several primary lithium chemistries were reviewed, and we selected lithium metal oxide (TLM Series) batteries due to their ability to deliver high continuous power, high pulse amplitude and up to 4.1V

continuous current per cell during active drilling cycles. Use of these small but incredibly powerful batteries helps make the new drivers handy and ergonomic tools that saves time and reduce operator fatigue."

Two Pro-Driver models are currently available: one model that uses two TLM 1550HP batteries to deliver up to 8V of variable current to permit drilling speeds of up to 2,200 RPM; and a second model powered by four TLM 1550HP Lithium metal batteries, which delivers up to 16V of variable current to permit drilling speeds of up to 4,000 RPM. While the Pro-Dex battery packs are discarded after a single use, similar devices could be designed to be completely re-usable using industrial grade rechargeable Li-ion batteries.

Hand-held surgical drill (smaller alternative to alkaline batteries)

BioAccess, a surgical device manufacturer, chose lithium metal oxide batteries as an optional power supply upgrade for their surgical drill, which were previously powered exclusively by alkaline battery packs. While the alkaline batteries performed well and offered excellent reliability, they added unnecessary weight. By substituting 6 AA-size TLM-1550HP batteries for the alkaline battery pack, BioAccess achieved a 36% weight reduction with only 40% of the volume. An equivalent alkaline battery pack would have required three times the weight and two and a half times the volume (15 AA-size alkaline batteries versus 6 AA-size TLM-1550-HP batteries).
Use of a lithium metal oxide battery pack also enabled the surgical drill to deliver faster drilling speeds, more active drill time (30 to 40 secs at a time for up to 20 to 30 cycles), more instantaneous power, and greater stall torque, resulting in more efficient drilling cycles with less operator fatigue.
These case histories illustrate how recent advanced lithium battery technology is enabling medical devices to become increasingly miniaturized while still delivering uncompromising power and performance.

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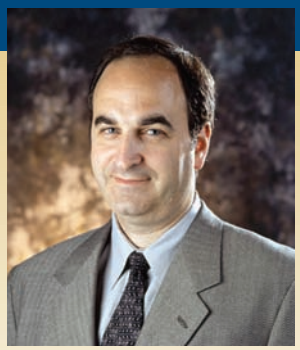

Sol Jacobs
Tadiran Batteries

Lithium-Powered Orthopaedic Bone Drill Features Higher Performance With 36% Less Weight

Replacing alkaline batteries with high power lithium cells enabled BioAccess single-use cordless bone drills to become lighter and more powerful, delivering numerous ergonomic benefits to orthopaedic surgeons.

Faced with overwhelming work schedules, orthopaedic surgeons are continually seeking new ways to manage their time in surgery more effectively and efficiently. One common sense approach involves the early adoption of new technologies that save time and simplify surgical procedures, thus enhancing productivity and reducing possible fatigue.

Farsighted surgical device manufacturers are staying well ahead of the curve by continually enhancing their products and services to deliver productivity-enhancing benefits. An excellent example of this proactive approach to new product design occurred when BioAccess, a surgical device manufacturer, introduced a new power management solution for its cordless small bone drill. (See Exhibit 1.)

The device had been powered previously by alkaline battery packs that performed well and offered excellent reliability. However, recognizing that significant benefits could be achieved by simultaneously increasing drilling power while reducing weight – benefits such as reduced fatigue, greater user comfort and increased power for shorter work cycles – design engineers at BioAccess began to explore alternative power sources for their cordless orthopaedic bone drill.

The engineers' review of available battery chemistries led them to consider the TLM Series high power lithium batteries from Tadiran, a class of batteries designed specifically for applications requiring high current pulses for relatively short intervals of time.

After testing and analysis, BioAccess specified custom battery packs consisting of six TLM-1550-HP AA-size high power lithium batteries, which featured an open circuit voltage of 4.1 V and the ability to handle pulses of up to 15 A, with 5 A maximum continuous load. The ability of TLM Series cells to deliver high energy density and capacity enabled the bone drills to produce greater torque and faster drilling speeds. These batteries were also able to operate across an extremely wide temperature range (-40° C. to +85° C) and withstand pre-surgical sterilization temperatures as high as +125° C. While BioAccess' bone drill is specifically designed for single use, the cell's extended temperature range makes it extremely well suited for sterilization cycles. The increased power achieved by converting from alkaline to

EXHIBIT 1
BIOACCESS ORTHOPAEDIC SMALL BONE DRILL

high power lithium batteries also enabled the cordless bone drill to deliver excellent performance characteristics that have been validated by positive feedback from surgeons.

According to Bob Chapolini, M.D., President of BioAcess, "With the TLM cells we get much more power than a standard alkaline pack, while trimming 36% off the weight. This noticeable weight reduction makes the product more ergonomic by reducing user fatigue. If we had used a AA alkaline pack giving the same power as the Tadiran pack, the drill would have been three times heavier and twice the volume (requiring 15 AA-size alkaline batteries versus 6 AA-size TLM-1550-HP batteries)."

Chapolini adds, "TLM-1550-HP battery packs enable more active drill time and a long shelf life, as well as more instantaneous power when the device is activated. Use of a TLM-1550-HP battery pack ensures a more positive and reliable experience, as our latest generation of cordless drills are capable of delivering more power compared to alkaline cells, along with more stall torque, 30 to 40 seconds at a time, with 20 to 30 cycles."

Chapolini notes that he demonstrates the bone drill in physician offices, medical conferences and symposiums. "Any time we go to a symposium or conference, we've usually kept our demo units in storage for weeks or months at a time without testing system reliability." he says. "Fortunately, every time that we have pulled a bone drill out of the box it has operated powerfully and reliably, which provides greater reassurance to the prospective customer. What's more, the power provided for these small bone procedures is such that it may give us an opportunity to sell the drills into other classes of surgery that involve larger or heavier power tool classifications, which opens additional doors of opportunity for our product," Chapolini adds.

Recognizing that extended storage life coupled with high reliability would be important product attributes for BioAccess' orthopaedic bone drill, Tadiran's quality assurance department conducted extensive testing on the TLM-1550-HP cell to ensure that it would achieve an extremely low annual self-discharge, resulting in exceptionally long shelf life of up to 20 years.

Based on attributes such as high capacity and energy density, long shelf life and an extended temperature range, high power TLM-1550-HP batteries are rapidly gaining acceptance as an optimal power source for single-use medical devices such as handheld power devices used in hospitals, clinics, or by field responders. A comparison of the TLM-1550-HP battery vs. other technologies is visible in Exhibit 2.

The example of the BioAccess orthopaedic bone drill illustrates how design engineers can take a proactive approach to new product design, working closely with battery manufacturers to determine optimum power management solutions as part of a continuous improvement philosophy.

EXHIBIT 2
THE TLP-1550 HP AND OTHER POWER TECHNOLOGIES

	Previous Alkaline Pack	TLM-1550-HP Pack	Alkaline Equivalent to TLM-1550-HP Pack
Weight (Oz.)	6.3	4.0	12.4
Volume (Cu. In.)	3.3	3.3	7.13
# of Batteries	15 AAA	6 AA	15 AA

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Batteries in medical RFID

Withstanding the heat of autoclaves is a must

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The demand for more efficient data capture and seamless information management has spurred a steady growth in wireless radio frequency identification (RFID) real-time location systems (RTLS) well beyond their initial manufacturing and distribution roots. these battery-powered systems are now found in other specialized industries such as the medical industry where cost containment and other dynamics have prompted design engineers into new modes of thought and innovation.

Driven largely by regulations and legal liability concerns, hospitals and other healthcare facilities are embracing new technologies that raise efficiency and improve workflow especially in the area of data capture and asset tracking. Active RFID systems represent an ideal solution to this based upon the flexibility and immediate workability.

Today, many medical staff members are trained in their use of battery-powered RFID asset tracking devices to monitor portable medical equipment. This includes wheelchairs, gurneys, IV pumps, and pulse oximeters. RFID asset tags are also being utilized to monitor the whereabouts of patients and hospital personnel, providing instant access to vital patient information, as well as permanently archived time-stamped records to verify and monitor physical movement and location, visits by attending doctors and nurses. Asset tracking is also used to monitor and record surgical and therapeutic procedures and diagnostic tests, as well as the dispensing of pharmaceutical drugs and medications.

To capitalize on the enormous growth potential for medical RFID applications, designers must understand inherent technical challenges involving power management solutions and the harsh environment to which they will be exposed, such as high temperatures associated with autoclave and liquid sterilization procedures. This was clearly on the minds of the product design engineers at Awarepoint when they created the Awarepoint T2S asset tag, their newest generation of self-contained, battery-operated active RFID asset tags.

Awarepoint surveyed its customers and identified a hot button problem; battery autoclavability, or the inability of the battery cell packs to withstand extreme steam heat used in sterilizing reusable assets.

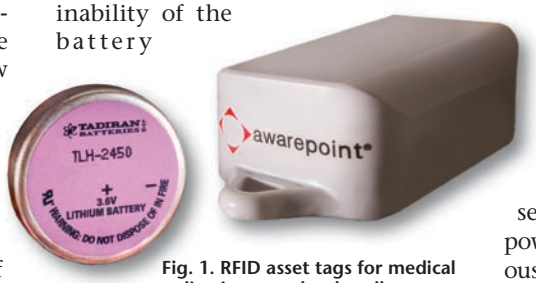

Fig. 1. RFID asset tags for medical applications need to handle power management solutions and harsh environments.

Earlier generations of active RFID asset tags used batteries that could not take the heat, which in many cases is as high as 135°C. As a result, medical equipment that requires steam sterilization was unable to benefit from active RFID technologies. This limitation partially defeats the reason for using RFID technology: to provide fully automated and verifiable real-time 24-hour monitoring and reporting capabilities.

To overcome these major technical challenges, Awarepoint sought out the ideal battery solution as a critical first step in designing a wireless active RFID asset tag that could be sterilized in autoclaves or liquid sterilization cycles.

After conducting a thorough review of all available battery technologies, the design team selected the TLH-2450 coin-size lithium thionyl chloride batteries from Tadiran to provide primary power. It proved in environmental tests that it could withstand the 135°F heat associated with standard autoclave cycles.

The tag is also designed to work continuously for 500 steam-sterilization cycles, or one year on the original battery, which presents added convenience and lower long-term maintenance expense. These compact 3.6-V cells feature 0.55-Ah capacity at 0.5 mA, and maximum service life of up to 20 years. The battery cells are also UL recognized and considered nonhazardous when shipped.

The TLH-2450 cells helped fuel several productivity improvements for those using the asset tags. The batteries provide the power necessary to support continuous remote monitoring throughout the sterilization process. Searching for equipment in a hospital's sterile processing department can be time consuming and often frustrating.

However, since Awarepoint's T2S active RFID asset tags can be sterilized while remaining attached to the medical device, hospital staff can immediately locate equipment in the sterile processing department and determine its clean/dirty status with the click of a button. The tags will also alert medical staff if a device is returned to service without proper sterilization.

The battery and the asset tag exemplify an increasingly popular collaborative mindset among manufacturers today, one that often raises the technological bar to a higher performance standard.

For more on batteries, visit http://www2.electronicproducts.com/Power.aspx.