Bioengineering Applications of Lithium Batteries

S. R. Alavi-Soltani and T.S. Ravi

Department of Mechanical Engineering, Wichita State University, Wichita, Kansas 67260, U.S.A.

1. Introduction

This paper surveys bioengineering applications of lithium batteries. Batteries fall into two main categories: primary or single use and secondary or rechargeable cells. Lithium ion batteries used in bioengineering devices belong to the second group of batteries while cells containing lithium-metal anodes used in bioengineering devices belong to the first group [1].

2. Applications of lithium batteries and lithium ion batteries in bioengineering devices

Several kinds of lithium batteries have been developed for powering implantable bioengineering devices. These batteries which use lithium as anode include [1] lithium iodine polyvinylpyridine, lithium silver chromate, lithium cupric sulfide [2], lithium thionyl chloride, lithium CF_x, lithium silver vanadium oxide, lithium MnO_2 and lithium ion batteries which are used in different implantable bioengineering devices.

Lithium iodine polyvinylpyridine (PVP), lithium silver chromate (Li/SC) and lithium cupric sulfide (Li/CS) batteries are mainly used in heart pacemakers which needs power in microwatt range. Figure 1 shows discharge curve of a lithium iodine polyvinylpyridine battery under a 100 kohm load at 37^oC. Lithium thionyl chloride (Li/TC) batteries are mainly used in implantable devices which consume higher power in milliwatt range such as drug pumps and neurostimulators. These batteries are also used in advanced pacemakers capable of doing other therapies like multisite pacing. Figure 2 shows discharge of a lithium thionyl chloride battery under a 49.9 kohm load at 37^oC. Lithium CF_x batteries are used in implantable devices like previously mentioned advanced pacemakers. These devices need a higher current in micro ampere range compared to lithium iodine batteries. Lithium silver vanadium oxide (SVO) batteries are used in implantable cardiac defibrillators (ICD) which provide a high energy shock directly to the heart to stop fibrillation. Lithium MnO_2 batteries are also used in implantable cardiac defibrillators. Lithium MnO_2 batteries with high output currents in the 13 amperes range have already been produced.

Lithium ion batteries are used in implantable devices, like left ventricular assist devices (LVAD) and total artificial heart (TAH), which need high power and therefore cannot deploy primary lithium batteries. The power requirements of these devices are too high to be satisfied by rechargeable implantable batteries. For example the battery should be capable of cycling at high rates for several years in the range of 0.5 to 3 A of current with an average current of 1 A and working voltage of 20 to 30 V. Therefore external lithium ion batteries are the main source of energy in these devices. The power is transferred to the device by telemetry. However a tiny implantable battery pack is also used in some of these devices to provide backup energy in case of failure of external battery. These batteries are capable of providing power of the device for about one hour per day independently. Moreover lithium ion batteries are used in implantable hearing assist devices like implantable cochlear stimulation devices. The batteries which are used in implantable hearing assist devices are small coin type cells and can be implanted with the device and recharged through the skin. Besides some neurostimulators may need lithium ion batteries to get enough longevity in a device which is of acceptable size for implantation. More recently efforts have been made to charge the batteries implanted with pacemakers using wireless near-infrared power transmission.

3. Conclusion

The specification and application of primary and secondary lithium batteries used in bioengineering were explained in this paper. In general lithium batteries are more attractive option than any other battery for bioengineering applications specially powering implantable devices due to their favorable characteristics like high specific energy and energy density, High discharge rate capability at 37^oC, high capacity, long operating time at 37^oC, long cycle life at 37^oC, low self-discharge at 37^oC, low internal resistance and surface temperature at high discharge rates, state of charge detection capability, quick charging capability with good full charge detection point, high quality, uniform cells (in terms of capacity, internal resistance, etc) and forewarning of premature cell failure. It is notable that recently efforts have been made to expand the applications of lithium ion batteries so that they can be implanted inside human body. Thanks to their high power density and recharging capability, the prospect of extending applications of lithium ion batteries in bioengineering applications in near future is much more promising than primary lithium batteries.

[1] Takeuchi, E., Leising, R., “Lithium Batteries for Biomedical Application” MRS bulletin, August 2002, pp 624-627
[2] Holmes, C. “The Role of lithium batteries in modern health care” Journal of Power sources, No 97-98 (2001), pp 739-741
[3] Nazri, G., Pistoia, G. “Lithium Batteries Science and Technology” Kluwer Academic Publishers, 2004

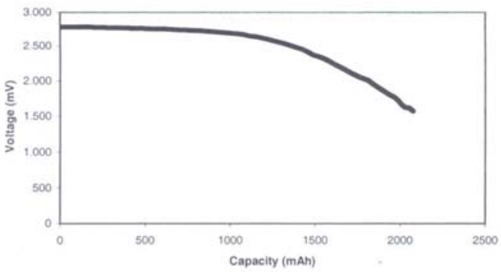

Fig.1. discharge of a lithium iodine Polyvinylpyridine battery under a 100 kohm load at 37°C [3]

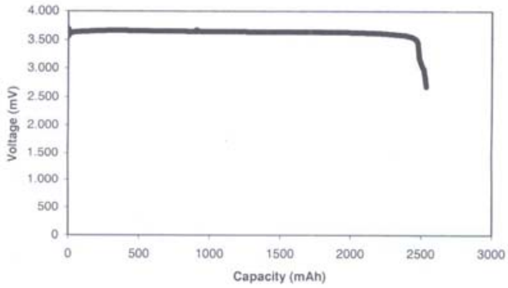

Fig.2. discharge of a lithium thionyl chloride battery under a 49.9 kohm load at 37°C [3]