Electrochemical Power Sources for Implantable Medical Devices in Treatment of Disease

Curtis F. Holmes
Greatbatch-Hittman, Inc.
9190 Red Branch Road
Columbia, MD 21045

Paul Skarstad
Medtronic Energy and Component Center
6700 Shingle Creek Parkway
Brooklyn Center, MN 55430

Boone B. Owens
Corrosion Research Center
University of Minnesota
Minneapolis, MN

Whereas experimental battery-powered devices for medical use have been reported in the literature as far back as the late nineteenth century, the modern era of treatment of disease by implantable battery-powered devices began with the development of the implantable pacemaker in the late 1950's. Since the implantation of the first successful pacemaker in 1960, a large variety of implantable devices using electrochemical power sources have been developed and used to treat a variety of diseases, and many millions of battery-powered devices have been implanted in the last forty years. In addition to implantable devices, batteries power external devices such as external pacemakers, defibrillators, Holter monitors, external drug delivery systems, and motorized wheelchairs.

The first successful implantable pacemaker was powered by zinc/mercuric oxide batteries. This technology remained the standard until the introduction of lithium batteries. The first lithium-powered pacemaker was implanted in Italy in 1972, and today over 900,000 pacemakers are implanted annually. The lithium/iodine system remains the most frequently used battery at this writing. Some advanced pacemakers with higher current-delivery requirements are powered by solid cathode-liquid electrolyte systems. . The use of this type of power source for pacemakers is likely to increase in the future.

The introduction of the implantable defibrillator/cardioverter (ICD) in the early 1980's made it possible to treat ventricular fibrillation with an implantable device. Whereas the first such units simply provided a high-energy shock directly to the heart to stop ventricular fibrillation, units today provide antitachycardia pacing to slow down a fast-beating heart before fibrillation occurs. A variety of monitoring functions also is provided by today's devices. Most ICD's today are powered by the lithium/silver vanadium oxide system, although some employ the lithium/manganese dioxide system.

More recent developments include the use of biventricular pacing to treat congestive heart failure. Recent clinical results have provided promising indications that this treatment can effectively reduce symptoms associated with this deadly disease.

Whereas cardiac rhythm management was the first application of battery-powered implantable devices, many other devices have been developed in the last thirty years to treat a variety of other human diseases. Implantable neurostimulators were first introduced to treat relief from pain. By stimulating various nerves within the body, these units have proven effective in pain management. New applications have emerged in the last fifteen years, and neurostimulators are used today to treat a variety of diseases, including urinary incontinence, epilepsy, depression, Parkinson's disease, and obesity.

These devices are similar to cardiac pacemakers in their basic function, but the higher current drains required by this application demand batteries such as solid cathode-liquid electrolyte or soluble cathode (oxyhalide) batteries.

Several implantable devices have been developed to treat hearing defects. Such devices can treat acute hearing loss or less serious hearing problems. Lithium ion rechargeable batteries power several of these devices, and one such device uses a lithium/iodine cell.

Implantable drug delivery devices contain a pumping mechanism, a refillable reservoir, electronic circuitry, and a battery. The device administers drugs such as painkillers, chemotherapy, and insulin. Medium powered lithium batteries power these devices.

Among the most dramatic devices in use today are the left ventricular assist device (LVAD) and the totally artificial heart. LVAD's are attached to the heart and assist in performing the pumping function. Such devices, originally intended as a "bridge" to a transplanted human heart, are now providing permanent treatment to patients.

Several totally artificial hearts were implanted in 2001, and much publicity was given to this event. These devices completely replace the patient's natural heart and provide the complete cardiac function. They are in the very earliest stages of clinical devaluation.

Both the LVAD and the totally artificial heart have such high current demands that no implantable battery can adequately power them. The primary power source is a rechargeable battery pack usually worn as a vest by the patient. The power is transmitted into the body via telemetry. Some such devices also employ an implantable rechargeable battery that provides an hour or so of independent power.

The last forty years have seen remarkable advances in both the development of new implantable devices and development of batteries to power them. Both primary and secondary batteries fulfill an important role in the treatment of disease and in providing comfort and increased quality of life to patients suffering from a variety of medical conditions.

Looking ahead, scientist, engineers, and physicians are working to develop even more devices. Artificial vision is being investigated. Artificial limbs are under development. Gait assist devices to provide hope for paraplegics are being considered. All of these devices will require electrochemical power sources for their successful operation, and electrochemists specializing in battery research and development are working on advanced power sources for such devices today.