Secondary Cells for Robotic Motor Function

Introduction

As mobile robots become increasingly complex, a mobile power supply becomes a more pertinent concern. While development in battery cell technology has been progressing slowly, an increase in the capabilities of sensor, processor, and actuator has led to a rapidly escalating power demand. This technical review examines commercially available secondary cells (rechargeable batteries) currently used in robotics, potential advances in that field, and its implementations.

Commercially Available Secondary Cells

Energy and power density, efficiency, depth of discharge, self-discharge rate, and maintenance are some of the chief considerations when selecting a battery power supply. Due to issues such as low energy density, high self-discharge, and thermal runaway, lead acid, NiMH, and NiCd batteries have been largely phased out of use for mobile robotics [1]. As a result, lithium ion batteries, which have high energy density and relatively low maintenance requirements [1], have become the most attractive option for most robotic applications, especially when battery cost is not to the principle consideration in projects involving mobile robots. The most economic and common form of the battery is a cylindrical 18650 cell[2]. A typical example such a product would be Samsung's INR18650-35EA Lithium-ion rechargeable cell, which has a standard discharge capacity of 3,350mAh, nominal voltage of 3.60V, dimensions of 65.25 x 18.55 mm [3]. Currently, the market price of this product is $4.99[4]. For a device such as a quadcopter, a 3700mAhr battery may correspond to slightly more than 10 minutes of function, so multiple cells would likely be required for operation in robotics [5]. In the case of higher end batteries with increased nominal voltage, the size and cost of the battery increase steeply. For example, the 6 Ahr MLS 12/80 model from Mastervolt, which has a nominal voltage of 12V, dimensions of 90 x 70 x 109 mm, and a weight of 0.8 kg is at $208.06[6].

For instances where an ultra-slim design is desired, such as with drones, lithium polymer(lipo) batteries are the preferred choice [2]. The low width of these cells is achieved by replacing the traditional porous electrolyte with a thin polymer. In addition to their higher prices, these cells suffer from poor conductivity, which hinders their ability to provide high currents. The PL-7250115-2C model, which is a 5000mAh with dimensions of 117mm x 50mm x 7.2mm costs $16.00 per cell [7].

Underlying Concepts of Secondary Cells

Rechargeable batteries function similarly to regular batteries. All batteries share basic components: an anode, a cathode, an ionic conductor (electrolyte), and usually a separator. At steady state, ions in the electrolyte react with the anode and cathode, causing an accumulation of electrons on the anode and a depletion of electrons on the cathode. When a path is provided from the anode to the cathode, electrons will naturally flow from the higher potential anode (which is thus oxidized) to the lower potential cathode (which is reduced). During the charging process, the presence of an independent voltage causes the anode to undergo reduction and the cathode to undergo oxidation [8].

For the battery to function as a secondary cell, the chemical reaction the electrochemical oxidation- reduction reactions must be reversible. In addition, the electrodes must maintain their physical state throughout the process. Should this not be satisfied, such as in the case of older lithium metal cells, the moving lithium atoms tended to form dendrite filaments on the electrode surfaces, causing a short between the electrodes and potentially igniting the flammable electrolyte [9].

Advancements in Secondary Cell Technology

Despite its complications with dendrite formation, lithium metal cells are being investigated for their potential as next-generation, high-energy-density rechargeable cells. Lithium metals cells are particularly attractive, with its theoretical specific capacity (3,860 mAh/g) which far exceeds that of lithium-ion batteries (372 mAh/g). To address the dendrite formation, efforts have been made to develop new non-aqueous liquid electrolytes. For instance, when 50 ppm water (H2O) was added into 1 M LiPF6/PC electrolyte, the moving lithium formed well-aligned nanocolumns [10]. While the process did not eliminate the formation of filaments, these nanocolumns are easier to control and predict than dendrites.

For lithium ion cells, research seems to indicate that nanostructure carbons can be utilized to construct composite electrodes. These structures can form conducting networks which allow the lithium ions to migrate more rapidly [11], improving the lifetime of the battery.

Implementation of Power Supply

While the battery itself is relatively simple structurally, the power structure of the mobile robotic system involves greater complexity. The capacity of the power supply will be determined mostly by the power requirements of the individual components of the robot, including the motor, actuator for control, and sensors. Along with the power electronics of the system, identifying the appropriate power supply will help realize proper function of the mobile robot.

[1] Morris, Melissa & Tosunoglu, Sabri. "Survey of Rechargeable Batteries for Robotic Applications." presented at 2012 Florida Conference on Recent Advances in Robotics, Boca Raton, Florida, May 10-11, 2012

[2] Battery University, "Advantages and limitations of the Different Types of Batteries - Battery University" *batteryuniversity.com*, Mar. 21, 2017.[Online] Available: https://batteryuniversity.com/learn/archive/whats_the_best_battery. [Accessed Jun. 16, 2019].

[3] SAMSUNG SDI, "SPECIFICATION OF PRODUCT for Lithium-ion rechargeable cell," INR18650-35E datasheet, Mar. 10,2015 [Revised July 9, 2015].

[4] 18650batterystore, "Samsung 35E 18650 3500mAh 8A Battery - INR18650-35E," [Online] Available: https://www.18650batterystore.com/Samsung-18650-p/samsung-35e.htm [Accessed Jun. 16, 2019].

[5] R. Jarema, "Batteries - choose the right power source for your robot", Apr. 12, 2018 https://medium.com/husarion-blog/batteries-choose-the-right-power-source-for-your-robot-5417a3ec19ca [Accessed Jun. 16, 2019].

[6] Mastervolt BV, "MLS 12/80 | Mastervolt," [Online] Available: https://www.mastervolt.com/products/li-ion/mls-12-80/ [Accessed Jun. 16, 2019].

[7] BatterySpace.com, "Polymer Li-Ion Cell: 3.7V 5000 mAh (7250115-2C, 18.5Wh, 10.0A rate) --- UN38.3 Passed (NDGR)," [Online] Available: https://www.batteryspace.com/polymer-li-ion-cell-3-7v-5000-mah-7250115-2c-18-5wh-10-0a-rate-----un38-3-passedndgr.aspx?gclid=CjwKCAjw0ZfoBRB4EiwASUMdYbZTg9_Q9gDfAw41xNzuXF0AGvEycScjRxXY3PX1D3hS0zMLNyB_khoC79cQAvD_BwE [Accessed Jun. 16, 2019].

[8] Scientific American, "Sega Ends Production of Dreamcast," *Scientific American,* [Online]. Available: https://www.scientificamerican.com/article/how-do-rechargeable-that/. [Accessed Jun. 16, 2019].

[9] Jim Lynch-Michigan, "New lithium batteries last longer and don't burst into flames," *Futurity*, Aug. 21, 2018, [Online]. Available: https://www.futurity.org/ceramic-lithium-ion-batteries-1841362/ [Accessed Jun. 16, 2019].

[10] B. Liu, J. Zhang, and W. Xu, "Advancing Lithium Metal Batteries" Joule, 16 May, p. 833, 2018.

[11] S. Xin, Y. Guo, L. Wan , "Nanocarbon Networks for Advanced Rechargeable Lithium Batteries," Accounts of Chemical Research, vol. 45, no. 10, pp. 1759–1769, 2012