Storage Characteristics of Li-Ion Batteries for NASA's Exploration of the Outer Planets

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INTRODUCTION

NASA's planetary explorations are aimed at understanding the geological and environmental conditions, and at examining the evidence of water, as a precursor to life, on different planets and their moons in our solar system. These studies would in turn help us understand the conditions that led to our planet. One planetary object of immense scientific interest is Europa, the fourth largest satellite of Jupiter, with the most likelihood of supporting life outside Earth and possibly Mars. Images from NASA's Galileo spacecraft show evidence of a deep ocean of melted water under an icy crust on Europa. NASA is planning to launch a relatively large mission, termed as Jupiter Ice Moon Tour (JIMO), where each of the moons would be explored using surface probes.

One of the challenges for Jovian missions is the hostile, high intensity gamma radiation prevailing on Jupiter and its moons. In order to address this, preliminary experimental studies have been carried out both on super Ni-Cd and lithium ion cells. Both systems showed good tolerance to radiation up to a cumulative intensity of about 20 Mrad.[1]

Another challenging aspect of such missions to the outer planets is the long calendar life of about 10-12 years for batteries. Lithium ion chemistry, being relative new and still evolving, is yet to exhibit such a long demonstrated life. Thus far, few studies are available on the storage/shelf life characteristics of lithium-ion cells/batteries.[2-4] Nickel-cadmium or nickel-hydrogen batteries, on the other hand, show a demonstrated calendar life of over 10 years, but there is a four-fold penalty on mass and eight-fold penalty on volume with these systems, compared to lithium batteries. The objective of this study is, therefore, to assess the storage characteristics of aerospace prototype lithium ion cells for the benefit of NASA's future missions to the outer planets, such as JIMO and Pluto Fly-by.

The studies reported here involve 7 ah prismatic cells from Yarndey Technical Products, or Lithion from Pawcatuck, CT, and 9 Ah cylindrical DD cells from SAFT America, Inc., Cockesville, MD. These cells have been on storage for the last three years, at a floating charge voltage of 3.65 V corresponding to ~50% state of charge, and at five different temperatures of 55°C, 40°C, 23°C, 10°C, 0°C, and -20°C. These cells have been subjected to capacity checks, both at ambient and low temperatures, as well as AC impedance (EIS) measurements, after each three months. Additionally, three of each of these cells were stored uninterrupted, without capacity or impedance checks, at 10°C, 0°C, and -20°C for the last three years. In this paper, we will provide updates of the capacity retention and electrochemical impedance characteristics as function of storage. In addition, we will report the storage characteristics of various other lithium ion prototypes from different generations and different manufacturers to demonstrate the readiness of this technology for future NASA/JPL missions that require prolonged storage life.

There exist two different models to address the capacity losses sustained by lithium ion cells during storage and/or cycling. One model involves a growth of the solid electrolyte interphase (SEI) on the carbon anode[4] and the other relates to the loss of electronic conductivity on the cathode,[5] due to morphological arrangements prompted by the volume changes upon intercalation/deintercalation. The detailed storage data generated from our studies will be examined in the context of these two models.

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