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Introduction and Foreword to Focus Issue on Intercalation Compounds for Rechargeable Batteries

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JES Focus Issue on Intercalation Compounds for Rechargeable Batteries

Introduction and Foreword to Focus Issue on Intercalation Compounds for Rechargeable Batteries

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This issue is a first for the *Journal of The Electrochemical Society*; an issue devoted to a single topic, in this case Battery Intercalation Electrodes. Many of these papers were presented at the 222nd meeting of The Electrochemical Society in Honolulu, Hawaii, in October 2012.

This issue is very timely, as 2013 represents 40 years of research on intercalation compounds for battery electrodes. Some of the precursor research that generated interest in solid-state electrochemistry, mixed conductors, "insertion" compounds, and rechargeable batteries came out of the research group of Prof. Bob Huggins at Stanford University. We are very pleased that Bob has contributed to this issue. Out of Bob's lab in 1972 came a very predictive article "*Beta Alumina, Prelude to a Revolution in Solid State Electrochemistry*,"[1] and several future pioneers in the field. Without the resulting breakthroughs leading to today's lithium-ion batteries, the portable electronics revolution would not have been enabled.[2]

In 1972, both Exxon and Bell Laboratories mounted major, but fairly quiet, efforts on lithium battery research. These studies resulted in the discovery of the key role of intercalation reactions[3] and the first commercial lithium batteries, and recently showed the longevity of such cells. Figure 1 shows a solar-recharged Li/TiS_2 cell clock, built in the mid-1970s and still operating today. Ongoing testing of such cells at Rutgers University have shown that they still retain the majority of their capacity,[4] demonstrating the remarkable lifetime of lithium cells.

Around 1991, a second breakthrough occurred when SONY embarked on the very successful commercialization of the Li-ion battery[5] based on a carbon anode and a $LiCoO_2$ cathode.[6] This cell configuration led to lithium-ion batteries becoming the dominant power source for portable devices, driving out NiMH. However, the high cost of cobalt, which is driven by its use in batteries, has resulted in that material being partially replaced by a combination of nickel and manganese, leading to the NMC class of materials such as $LiNi_{0.6}Mn_{0.4}Co_{0.2}O_2$. In addition to lower costs, these compounds are also more thermally stable.

Another breakthrough occurred in 1997 with the discovery of the electrochemical activity of the olivine $LiFePO_4$.[7] This discovery enabled the construction of safer large batteries, with a minimal risk of oxygen evolution on charging. Such batteries have found application in all-electric drive HEV buses, where an 11 kWh battery system is used, and over 25 million miles have been driven in the United States. Olivine batteries are also in use in 8 – 32 MW size grid systems; one such system is used in West Virginia for smoothing and load leveling (Fig. 2).

Spinel LiM_2O_4 intercalation compounds remain one of the key players in both positive and negative electrodes of lithium ion batteries since $LiMn_2O_4$ was found to be electrochemically active in 1983.[8] Today, 4V Spinel is used in electric vehicles such as the Nissan Leaf, and major research efforts are being carried out on both the high voltage 5V cathode and on the $Li_4Ti_5O_{12}$ anode spinels across the world.

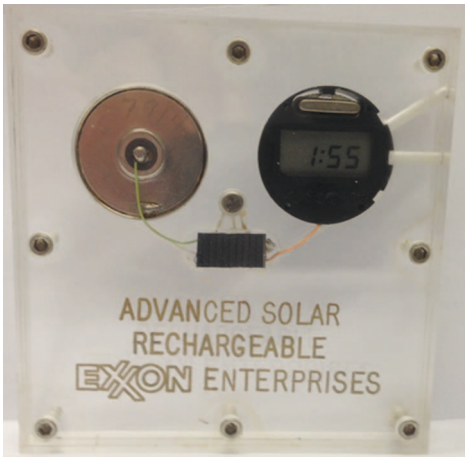

Figure 1. A $LiTiS_2$ cell solar rechargeable clock, built in the mid 1970s, operating in 2013.

Even with all of this advancement, today's lithium-ion batteries are still far from reaching their ultimate targets, with cells such as Li/MO_2 still attaining only 20% of their theoretical capacities. Extensive research is underway to move the frontiers forward, and this special issue of the Journal of The Electrochemical Society presents 29 papers reporting some of the latest results in this field of research.

Figure 2. A 32 MW $LiFePO_4$ battery at a wind power farm in West Virginia. (Photo courtesy of AES Energy Storage.)

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