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Organic Radical Battery: Transition-metal free Lithium-ion Battery

Kentaro Nakahara, Jiro Iriyama, Shigeyuki Iwasa, Masahiro Suguro and Masaharu Satoh

Fundamental & Environmental Research Laboratories
NEC Corporation

34 Miyukigaoka, Tsukuba, Ibaraki
305-8501, Japan

Introduction

The organic radical battery is a new type of lithium-ion battery which is attractive as an environmentally friendly, high power, high energy density rechargeable battery. In this battery, polyradicals are used as an active material in cathodes instead of a transition-metal oxide. So far, we have reported on the synthesis and electrochemical properties of a stable nitroxyl polyradical, poly (2,2,6,6-tetramethylpiperidinoxyl-4-yl methacrylate) (PTMA) (Fig.1) [1][2]. Here we describe the battery performance characteristics of organic radical batteries.

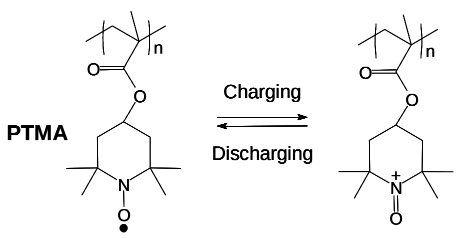

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Fig.1 PTMA charge & discharge mechanism

Experimental

Organic radical batteries were fabricated through modification of the method used to make a lithium-ion battery (Fig.2). Both lithium metal and a graphite intercalation compound were applied as anode active materials for the organic radical battery. Carbonate into which lithium salt had been dissolved was used as the electrolyte solution.

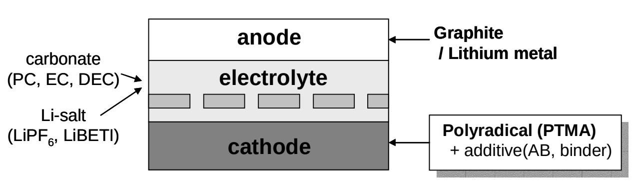

Fig.2 Schematic image of an organic radical battery

Result and discussion

We charged the fabricated battery at a constant current until its voltage reached 4.0 V vs. lithium and 3.8 V vs. graphite. In the charge-discharge curves, there was an obvious voltage plateau. Average voltage was 3.53 V vs. lithium and 3.44 V vs. graphite, slightly lower than those of normal lithium-ion batteries. The initial specific capacity of the PTMA was 60-100 mAh/g (Fig.3). This value was correlated with the radical density (radical/unit) of the polyradical (PTMA).

Improving the PTMA dispersion in the cathode, enabled improved flatness of the voltage plateau. For a 250-μm-thick electrode, no capacity deterioration was observed until the current density reached a few mA/cm^2 of the current density (Fig.4). Furthermore, we could apply this battery at a discharge current density of 10-100 mA/cm^2 when the thickness was below 100 μm.

We previously reported that the cycle ability of a PTMA electrode is quite good (92% after 1000 cycles). So, the cycle ability of an organic radical battery is determined by that of the anode material. Using a graphite electrode as an anode instead of a lithium metal thin film significantly improved the cycle ability (Fig.5).

In conclusion, the organic radical battery has the potential to become a practical rechargeable battery, especially for high-power applications.

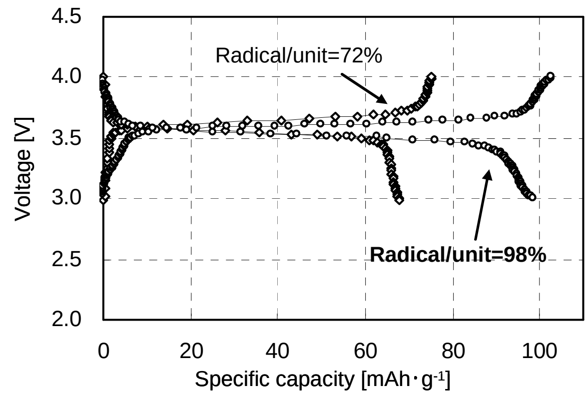

Fig.3 Charge & discharge curves for PTMA/Li cells

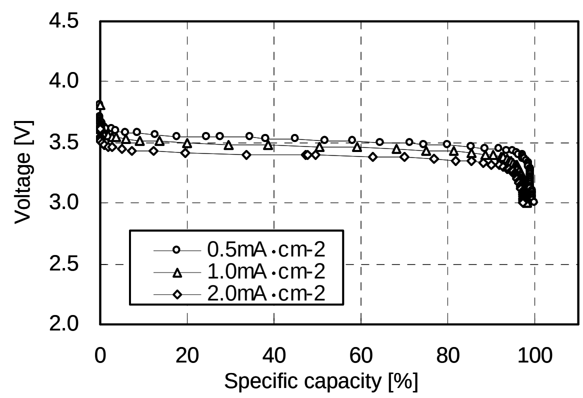

Fig.4 Discharge curves at various current densities for a PTMA/Li cell with good dispersion

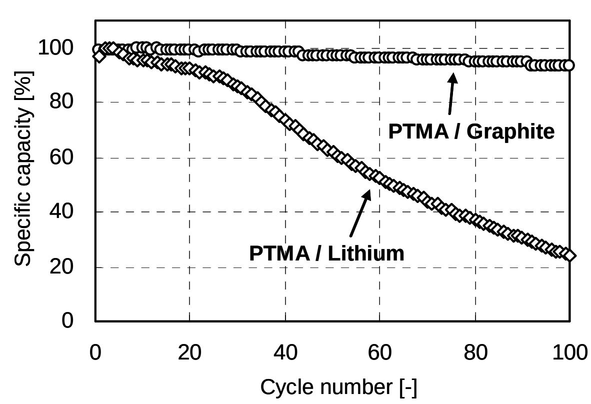

Fig.5 Cycle ability for an organic radical battery

Acknowledgments

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References

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[2] J. Iriyama, K. Nakahara, S. Iwasa, Y. Morioka, M. Suguro and M. Satoh, *11ht IMLB.* Monterey, 148 (2002).