CARBON FILAMENTS AS A POROUS REDUCTION ELECTRODE

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INTRODUCTION

For porous electrodes in lithium/oxyhalide primary cells, carbon and graphite materials act both as a current collector and as a catalyst for the reduction of the depolarizer. Extensive studies using carbon and graphite have been conducted, primarily because it is the porous electrode that usually limits the lithium/oxyhalide cell performance [1-16]. The investigations conducted focused on the impact of the carbon material, the carbon treatment, and the porous electrode fabrication process on battery performance. Although other types of carbon have been studied, battery manufacturers, tend to use carbon black because it is carbon black that most closely satisfies performance requirements. Research focused on performance improvement is ongoing. There are still shortcomings in this technology, however. For example, binders are necessary with carbon black to provide shapeability and handleability of the electrode. The binders evaluated to date are all passive and take up space that could be occupied by the catalyzing (or active) carbon. Porous electrode plates using carbon filaments in place of carbon black are manufacturable without the use of a passive binder. The clingy nature of the carbon filaments allows the individual filaments to bind to themselves. In addition, the current carbon black technology precludes fabrication of porous carbon black electrodes of thicknesses less than 0.020. Because thinness is limited by the current technology, the manufacture of porous carbon electrodes with high carbon efficiency and higher surface area is impossible, and therefore, batteries with extended capacity are also impossible. By using carbon filaments in place of carbon black, porous electrodes of less than 0.010 in are possible, which result in significant capacity improvements.

EXPERIMENTAL

A laboratory plate-to-plate discharge test cell was used to evaluate porous carbon reduction electrodes. Electrodes were made by placing the carbon material in a stainless steel cup made by cutting down a AA size battery case and pressing in the case at 21 MPa. An insulative separator was placed on top of the carbon followed by a lithium/nickel screen anode assembly. The layered electrodes were covered with a polymer insulator and a glass slide. The assembly was held together using a metal clip, immersed in BCX electrolyte, a codepolarizer of bromine chloride in thionyl chloride [20], and discharged at a constant current density of 3 mA/cm^2. Data were evaluated at a cut-off of 2V and compared with electrodes fabricated using conventional carbon black.

RESULTS AND DISCUSSION

Porous electrodes made with as-received carbon filaments (Grade ADNH, from Applied Sciences Inc.) yielded higher capacities per g carbon than did those from carbon black. The primary reason for the performance difference is attributed to pore size and structure. As shown in Table 1, the as-received filament (1500 Å diameter) electrode packing densities were substantially less than the as-received carbon black (spherical and of mean diameter 500 Å) electrodes, suggesting higher electrode porosity. After pressing the ADNH electrode to achieve a higher density (and therefore a lower thickness and porosity), the capacity decreased by about 45% compared to as-received filament electrodes due to the partial collapse of the pores, filament breakage and preferential, two-dimensional filament alignment. In addition to packing density, a contribution to performance was made by electrode catholyte absorption capability and rate of absorption. Filament electrodes absorbed more catholyte per g carbon and faster than did the carbon black electrodes. The large aspect ratio of the carbon filaments compared to carbon black was the cause of this difference in absorption properties. In the case of the filaments, the pores were more channel-like, thus producing a wicking action of the catholyte rather than a sponge-like absorption displayed by carbon black. The capacity per g carbon increased with decreasing electrode thickness, when

TABLE 1 - DISCHARGE CHARACTERISTICS OF POROUS REDUCTION CATHODES

Carbon type	Carbon treatment	Electrode thickness (in) ±0.002	Electrode packing density (g/cm^3) ±0.002	Capacity to 2.0 V (mAh/g C) ± 25	Absorptivity (g electrolyte/ g carbon) ± 0.5
ADNH*	As received	0.007	0.233	8729	—
ADNH*	Pressed	0.003	0.651	4877	—
ADNH*	As received	0.022	0.280	3973	99.5
ADNH*	Pressed	0.010	0.610	2068	—
Carbon black‡	As received	0.019	0.473	3140	35.7

* Fabricated without teflon binder
‡ Fabricated with teflon binder

all else was equal. The thinnest possible electrode was thinner for carbon filaments than carbon black, so the capacity per g carbon was extremely high for the as-received filament electrode of thickness 0.007 in.

CONCLUSIONS

Substitution of carbon black with ADNH carbon filaments to fabricate porous reduction electrodes, resulted in higher capacities per g carbon and required no binder for shapeability and handleability. The factors governing the capacity of the porous electrodes were determined to be electrode packing density, electrolyte absorptivity and rate of electrolyte absorption, and electrode thinness.

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