

# Carbon and Alternative Materials for Negative Electrodes for Li-Ion Batteries

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## Introduction

The active materials in commercial Li-ion batteries are usually graphitized carbons for the negative electrode and LiCoO<sub>2</sub> for the positive electrode. The electrolyte contains LiPF<sub>6</sub> and solvents that consist of mixtures of cyclic and linear carbonates. Electrochemical intercalation is difficult with graphitized carbon in LiClO<sub>4</sub>/propylene carbonate (PC) because of rapid electrolyte decomposition and exfoliation of the crystallite structure. On the other hand, LiClO<sub>4</sub> in PC is an acceptable electrolyte for intercalation of Li<sup>+</sup> ions in nongraphitized carbons (e.g., petroleum coke), but the electrochemical Li capacity is less, amounting to about 180 mAh/g C. Other amorphous carbons have been investigated, and some have electrochemical capacities that exceed 372 mAh/g C, which is the capacity of graphite.

The discussion in this paper is directed at analyzing the electrochemical performance of negative electrodes for Li-ion batteries. The physicochemical properties and the electrochemical performance of active materials in the negative electrodes are intimately connected, therefore both must be considered in selecting an alternative material to graphite in negative electrodes for Li-ion batteries. An analysis of this relationship is discussed in this paper.

## Results and Discussion

Some of the typical characteristics of negative electrodes containing graphite and an alternative material are summarized in Table 1. The results of the analysis using this data from Table 1, and assuming the capacity of the positive electrode is fixed, are plotted in Figure 1. When the irreversible capacity loss ( $Q_{irr}$ ) increases, a greater fraction of the capacity of the positive electrode is consumed in  $Q_{irr}$ , and a lesser amount is available to contribute to the reversible capacity of the negative electrode. The consequence is that the alternative anode must be made thinner because of the limited capacity of the positive electrode. Furthermore, the electrode thickness of the alternative anodes is much less than that of graphite, which is assumed to be 100- $\mu$ m thick. These observations suggest that any gain in reversible capacity that is attained with alternative anodes must be balanced with the minimum electrode thickness than can be readily fabricated. A more sophisticated analysis and improved model would be helpful to determine the optimum combination of positive electrode and alternative anode for Li-ion batteries.

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Table 1. Characteristics of negative electrodes.

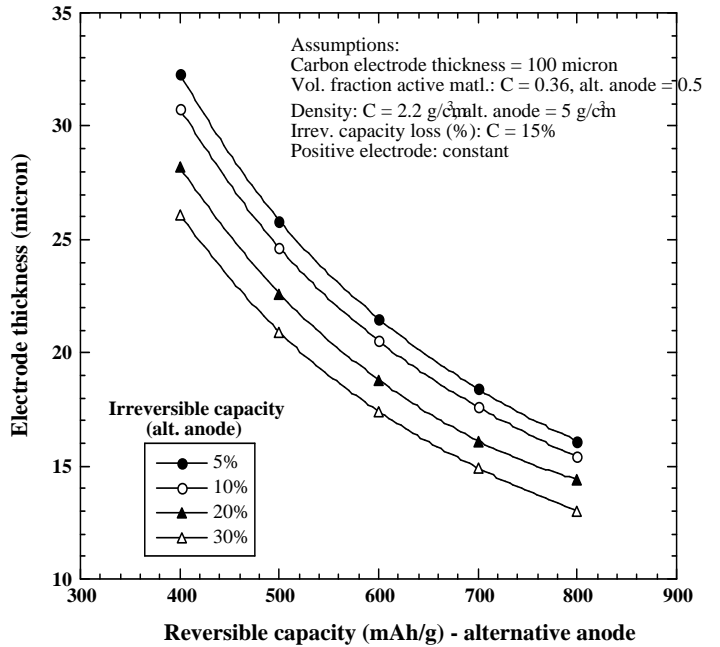


Fig. 1. Comparison of the thickness of graphite and alternative anode for negative electrodes in Li-ion batteries.

Parameter	Graphite	Alternative Anode
Electrode thickness (cm)	0.01	variable
Volume fraction	0.36	0.50
Density (g/cm <sup>3</sup> )	2.2	5.0
C (mAh/g)	372	400-800
Dimension parameter (i)	0.15	0.05-0.30
x, y	1	1