

Binding and Wiring in Electrodes for Li Insertion Batteries

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Performance, efficiency and stability of electrodes in electrochemical energy and storage devices, such as batteries, fuel cells, supercapacitors etc., crucially depends on binding and wiring of electroactive particles. As the particles size decreases from micro- to nano-scales, both features become more and more important because, at smaller dimensions, efficient binding and wiring is not possible without introducing appropriate interaction between active particles and binders (or conducting additives).

In the case of insertion Li insertion batteries, binding in electrodes is usually achieved by addition of polymeric binders, such as teflon, poly(vinylidene fluoride) or different kinds of resins. Despite the obvious practical importance of these additives, very little is known about the mechanisms through which the matter is held together in the presence of binders. For example, no clear answer has been given to basic questions, such as: Is the binder only a »passive« phase which holds the particles together by forming networks into which particles are caught (Fig. 1, on left) or does the binder interact with the particles forming bridges as sketched in Fig. 1 (on right)? Similarly: What are the binding forces of various kinds of binders? Even less fundamental, but very important questions from the energy density point of view, have been hardly tackled, e.g.: What is the minimum binder content which yields acceptable electrode performance?

The present paper tries to give answers to this kind of questions. For this purpose, beside the conventional binders, other binder types (e.g. gelatin, cellulose, gummi arabica etc.) are also discussed. Particular attention is devoted to binder distribution in the composite material and to forces between binder and active particles (see, e.g., Figure 2). It is shown that some binders (gelatin) do not serve merely as binding substances, but also as surface modifiers. Such substances have a decisive influence on particle arrangement within the final composite material. In other words, introduction of, e.g., gelatin leads to a considerable degree of particle self-arrangement.

The crucial importance of particle self-arrangement, governed by a binder/surface modifier, on electrode performance is shown on two examples:

- anode: if gelatin (binder/surface modifier) is present on graphite particles, it dictates the arrangement of crystallites during the initiation and growth process; this has a significant impact on both irreversible losses and reversible capacity of graphite anodes
- cathode: if gelatin is present on cathodic active particles, it dictates the arrangement of additives, such as carbon black. The arrangement of carbon black, however, is crucial for efficient wiring of active particles. Wiring of active particles, in turn, affects crucially the electrode kinetics. We show that this holds true not only for the well-known example of LiFePO_4 , but also for other cathode materials, such as LiMn_2O_4 and, even, LiCoO_2 .

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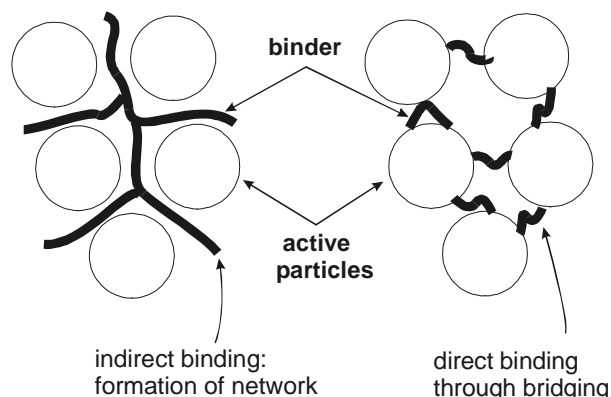


Fig.1. Two possible mechanisms of binding. It can be suggested that conventional binders (teflon, PVDF) bind mainly by mechanism on the left, while some other binders (gelatin) bind according to the mechanism on the right. Miscellaneous effects are expected with some polyelectrolyte binders (e.g. cellulose).

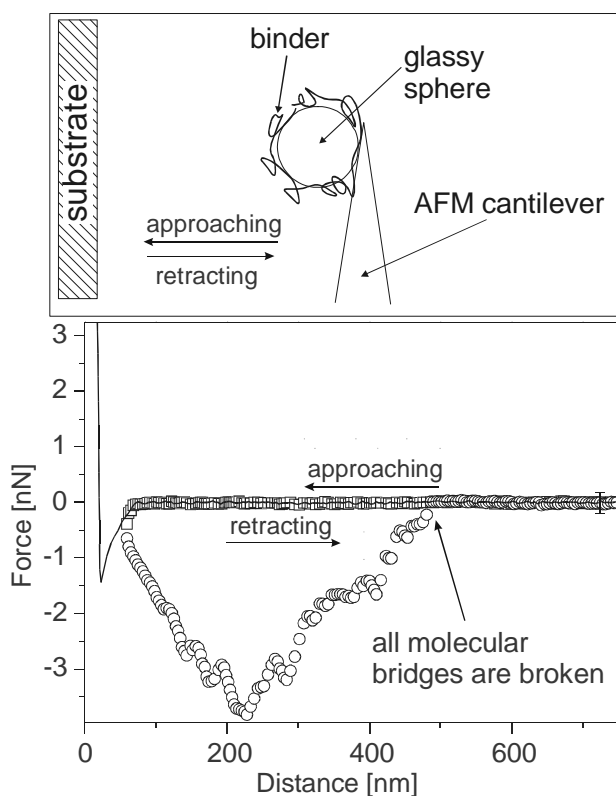


Fig.2. Principle of measurements of binding forces of a selected binder (above) and a typical graph of force vs. distance from the substrate (below) for gelatin as a binder.