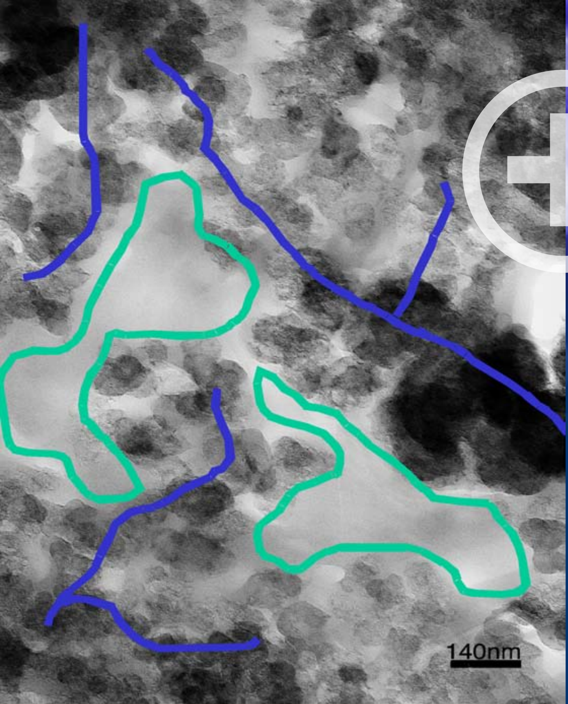

Particles and Binder Interaction in the Lithium-ion Cell Electrodes

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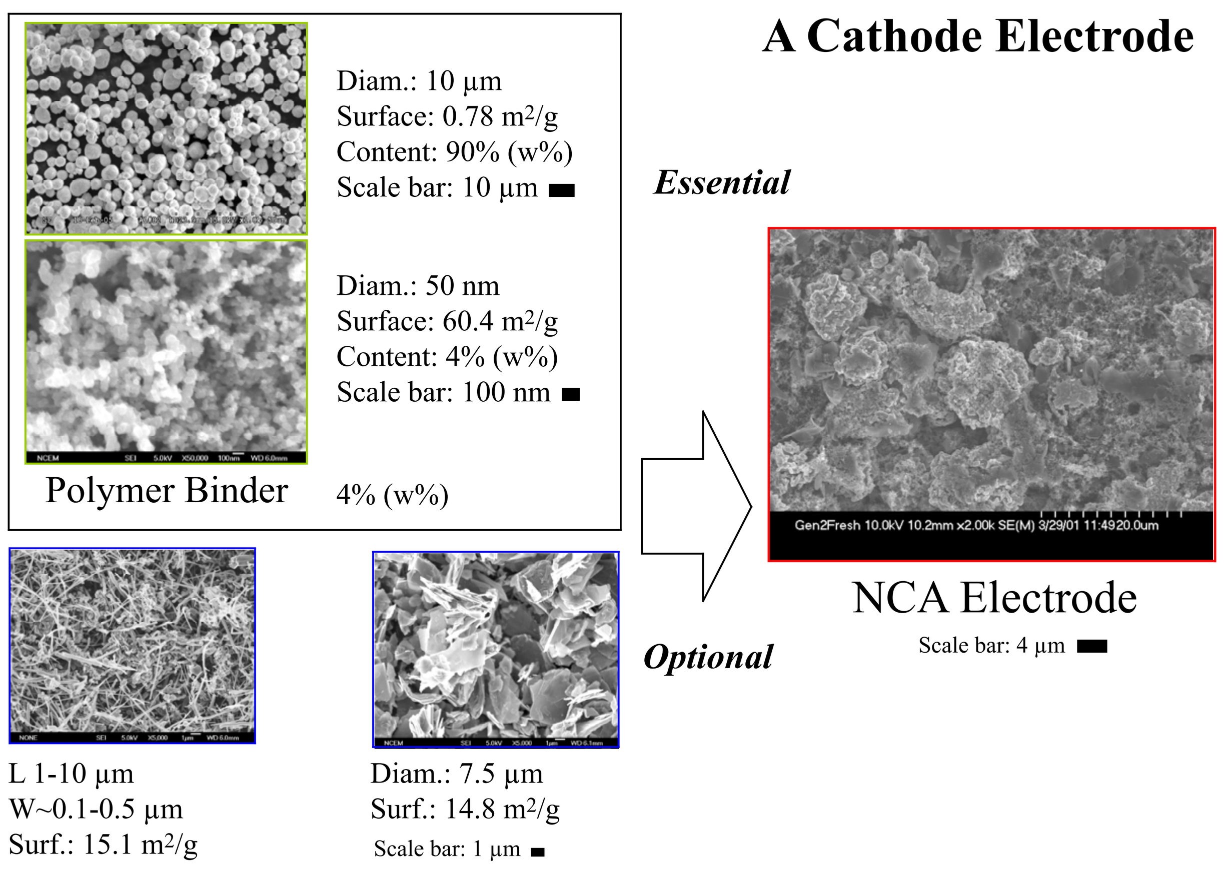
Introduction

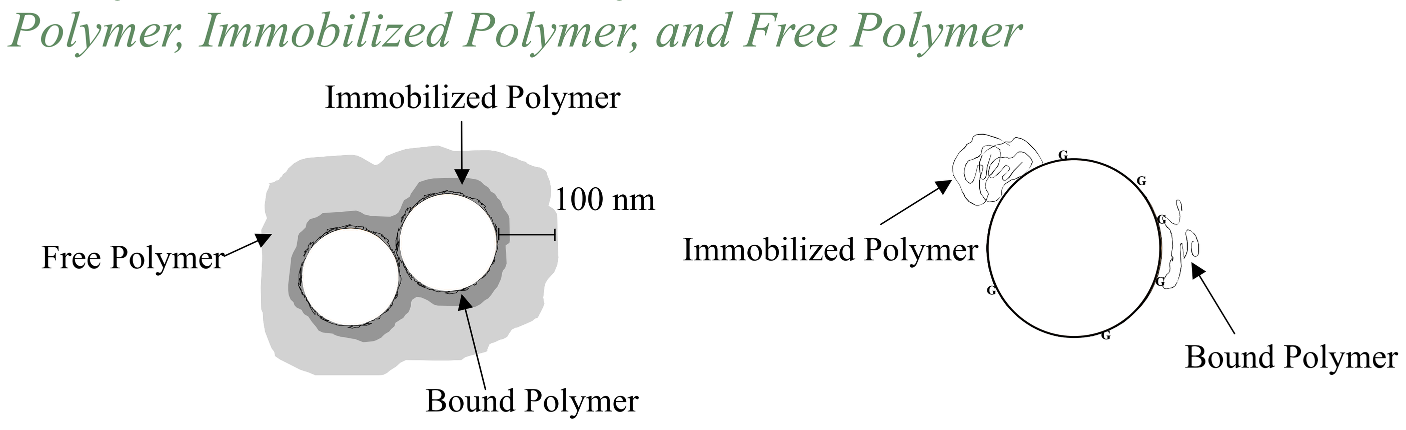
Proper electrode design is critical to meet high power performance requirements for lithium-ion rechargeable battery applications. Binders and conductive additives, although not electrochemically active, are essential components in the electrodes. In a simple three component cathode system where polyvinylidene difluoride (PVDF) is used as a binder, along with active material and acetylene black (AB) conductive additive, the dominant interaction between polymer and active material or polymer with AB changes proportionately with particle surface area. The PVDF binder interaction with the active material and AB on the micro or nano-scale plays an important role in determining the battery performance.

Particles Binder Interaction



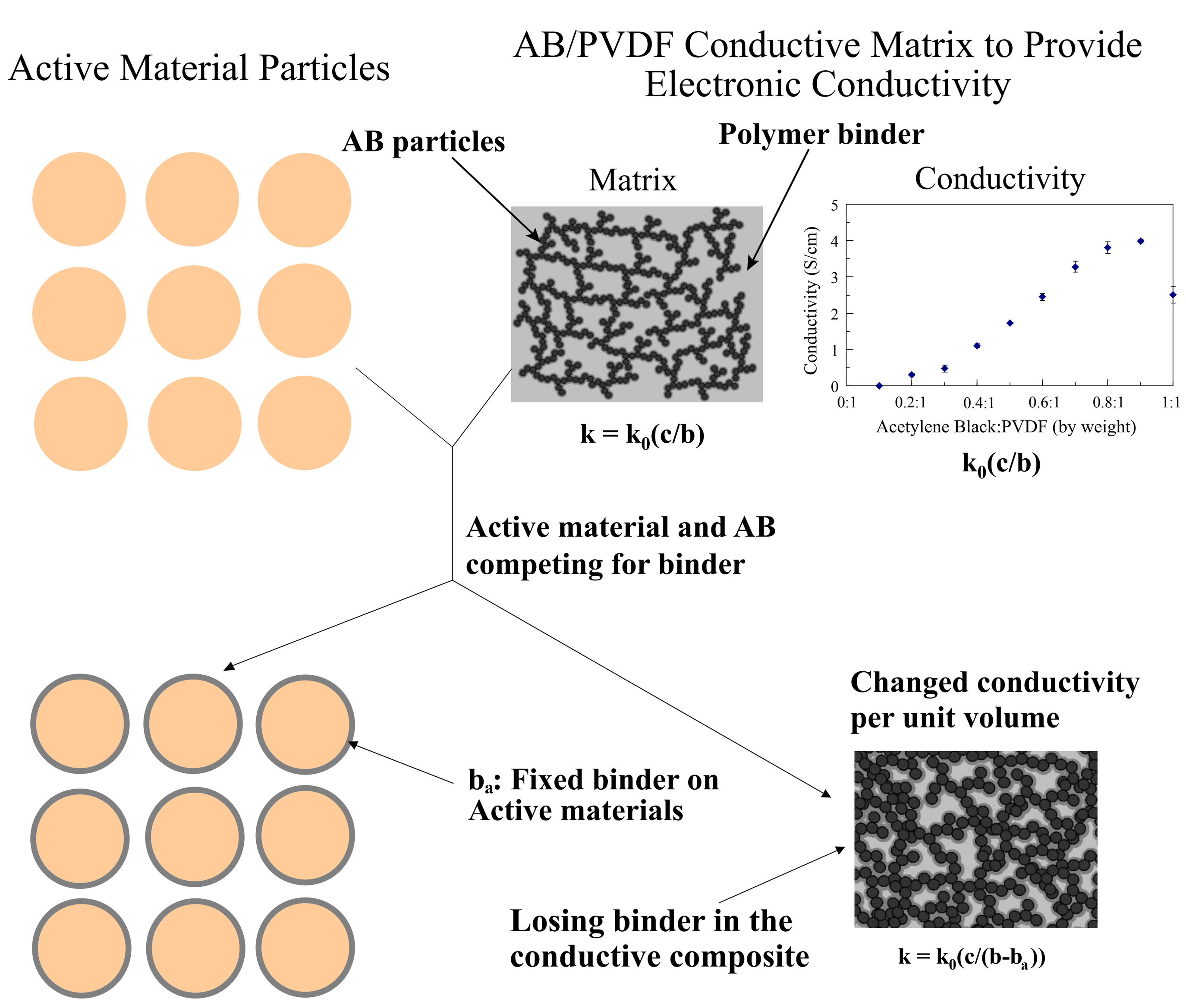
Three Physical States of Polymer in Contact with Particles

Bound Polymer, Immobilized Polymer, and Free Polymer

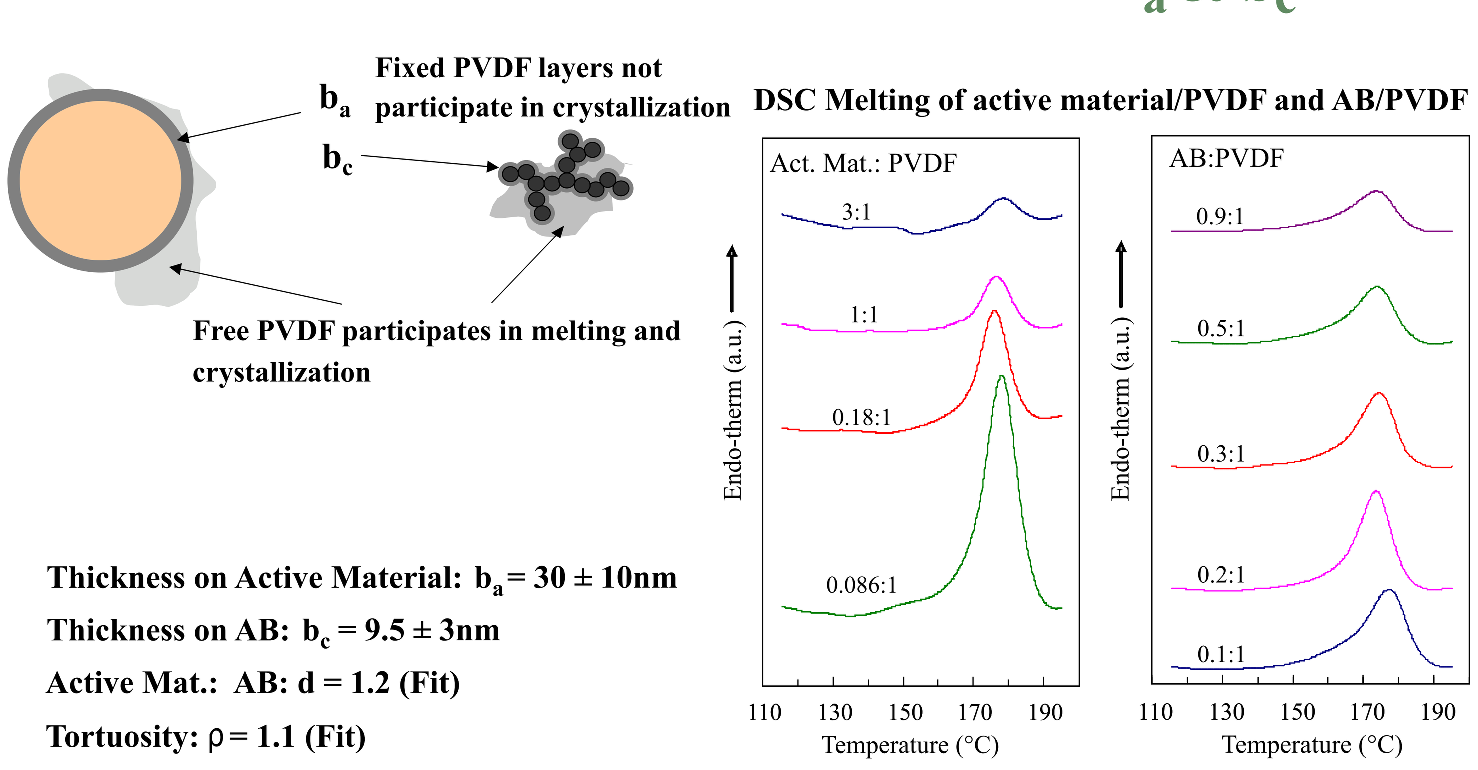


Bound and immobilized polymer are fixed layer on particles!

Nano-scale Interaction in the Electrode Composites

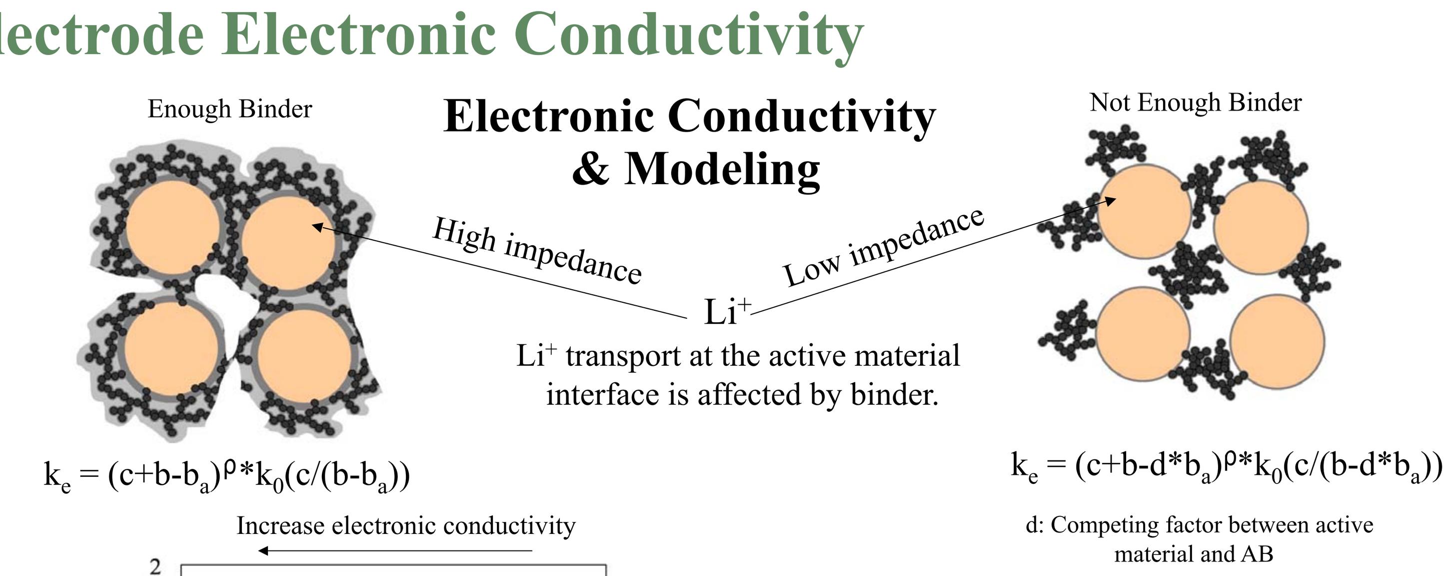


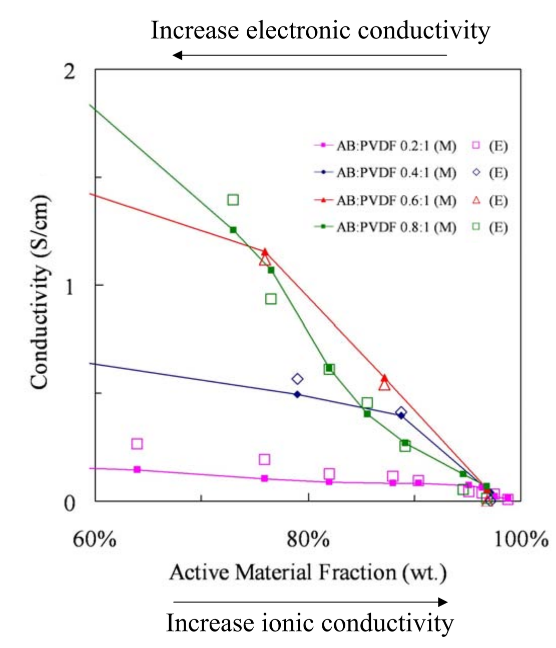
DSC Method to Determine Parameters: b_a & b_c



Thickness on Active Material: $b_a = 30 \pm 10$nm
Thickness on AB: $b_c = 9.5 \pm 3$nm
Active Mat.: AB: d = 1.2 (Fit)
Tortuosity: $\rho = 1.1$ (Fit)

Electrode Electronic Conductivity



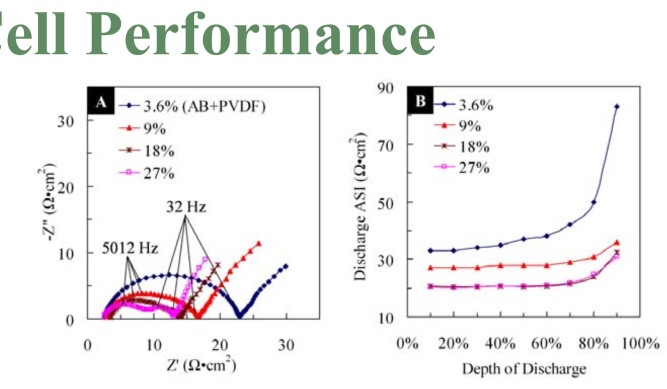


Modeling and Experimental Results of the Electronic Conductivity of the Composite Electrode.

DC-conductivity measured by 4-probe. Modeling was taken consideration of porosity and tortuosity factors of the AB/PVDF conductive matrix.

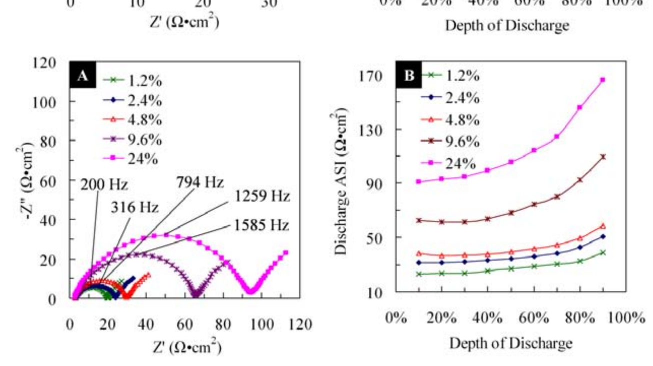
The electronic conductivity is higher with AB:PVDF = 0.4:1; 0.6:1 compare to 0.8:1 with high loading of active materials.

Cell Performance



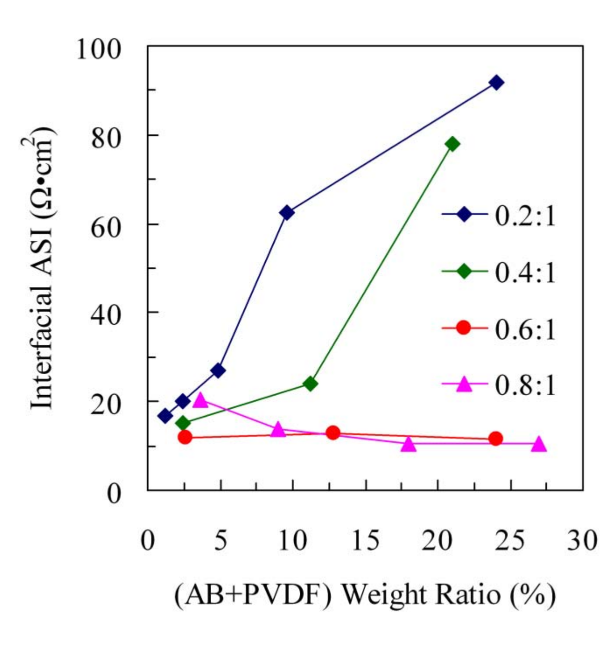
AB:PVDF = 0.8:1

- Charge transfer impedance is represented by the semi-circle of the EIS curve.
- Charge transfer impedance increase as (AB+PVDF) conductive composite decrease.
- The HPPC test results agree well with the EIS test results.



AB:PVDF = 0.2:1

- Charge transfer impedance decrease as (AB+PVDF) conductive composite decrease.
- Li ion blocking effect is dominant in the binder rich composition.
- The HPPC test results agree well with the EIS test results.



Charge Transfer Impedances of the Lithium-ion Cell at Different AB:PVDF Ratios.

At higher PVDF contents such as 0.2:1 AB:PVDF, the active material particles are encapsulated by the (AB+PVDF) composite leading to an ion-blocking effect that dominants the cell resistant. This effect can be reduced by decreasing the total amount of (AB+PVDF) in the electrode. At high AB contents such as 0.8:1 AB:PVDF ratio, AB aggregation caused cell resistant growth is dominant at low (AB+PVDF) loading. An increase of the overall amount of (AB+PVDF) will significantly reduces the impedance. At 0.6:1 AB:PVDF ratio, the cell resistance is stabilized regardless of the (AB+PVDF) content.

Conclusions

- Binder plays critical roles in the composite electrode for providing not only mechanical integrity, but also electronic conductivity.
- The competition for binder between the active material and acetylene black is a fundamental factor affects cell performance.
- High acetylene black content such as AB:PVDF = 0.8:1 tends to produce electrode with lower electronic conductivity at high active material loading, but tend to exert minimum Li ion blocking.
- Intermediate acetylene black content such as AB:PVDF = 0.6:1 tends to produce electrode with higher electronic conductivity at high active material loading, with constant low Li ion block effect.

Acknowledgments

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