Study on the carbon nanostructures for nanosized Si electrodes

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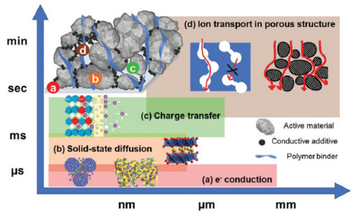
Motivation of the research

Electrode architecture

– Transport behavior of electron/ion



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Charge storage steps

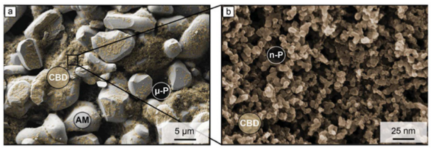
1) Electron conduction from current collector to active site
2) Ion transport in bulk electrolyte to active site
} **Electrode level**

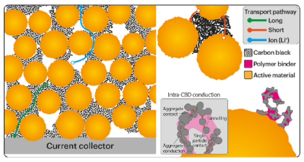
3) Charge transfer at the interface
4) Ion diffusion inside solid materials
} **Material level**

Conventional electrodes

– Micrometer-sized active material

- Sufficient electrolyte pathway from micropores
- Carbon binder domain (CBD) for electrical conductivity





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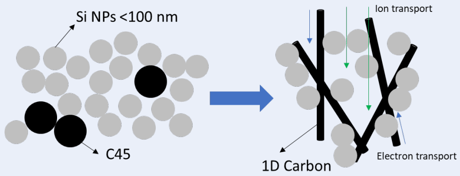
Overall Hypothesis & Goal

Si based electrodes

– Nanometer-sized active material

- The densely packed electrodes impedes the ion transport.
- More conductive additives are required for electrical connectivity

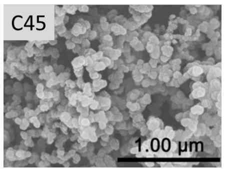


Goal of the research

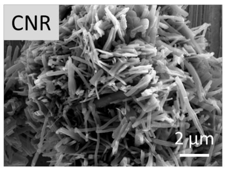
- Study on 1D carbon nanostructures
- Optimize the electrode porosity for ion transport
- Build electrically conductive network
- Achieve higher mass loading electrodes

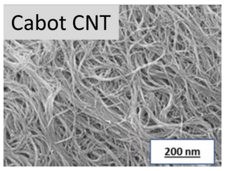
Carbon-binder (C:B) electrode study

Pristine carbon nanostructure



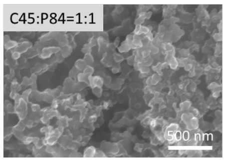
MSE Supplies

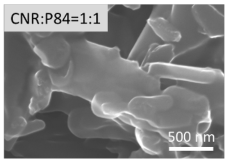


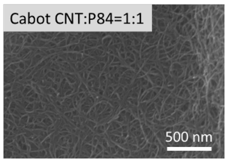


CABOT Datasheet

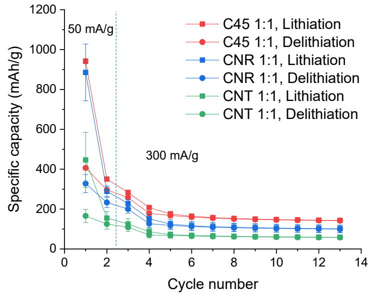
C:B electrode

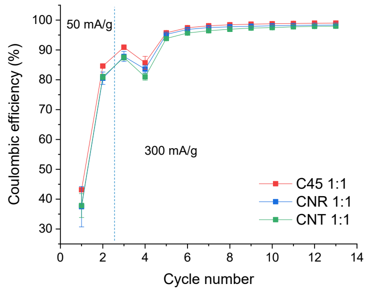






Half-cell test





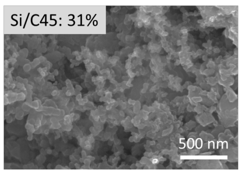
- As CNR piled up sloppily, micropores can be formed between them.
- CNT mat aggregated with binder resulting in dense electrodes.
- CNT electrode showed the lowest irreversible Li^+ consumption and reversible capacity.

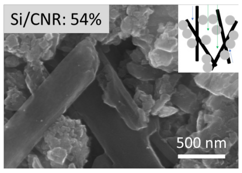
Si electrodes with different carbon nanostructures

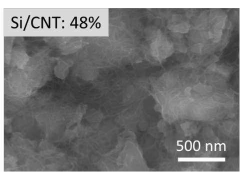
Porosity measurement

- Electrode volume (V_f) = Film thickness × area
- Material volume (V_m) = ∑ (Mass × Density of each solid component)

$$Porosity\ (\%) = \frac{V_f - V_m}{V_f} \times 100$$

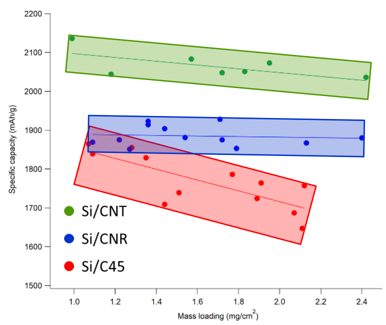


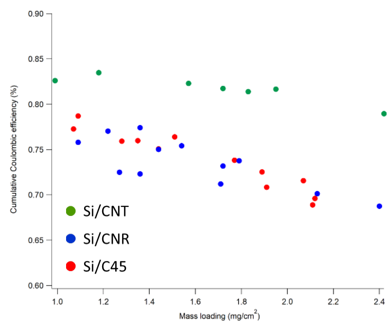




- CNR acted like pillars to create micropores in the electrode .
- CNT mat formed aggregation with Si and binder. These aggregations might increase porosity of the electrode.

Half-cell test





- 3rd delithiation capacity (C/20) is plotted versus mass loading.
- Si/CNR electrode maintained specific capacity even at higher mass loading due to porosity.
- The highest specific capacity of CNT can be attributed to better connectivity between Si and CNT.
- The highest cumulative coulombic efficiency of CNT is consistent with C:B=1:1 electrode results.

Summary and further work

C:B electrodes

- The C:B electrodes were tested to investigate the electrochemical behavior of carbon.
- Micropores can be formed in CNR electrode while CNT formed dense aggregation.
- CNT electrode showed the lowest irreversible Li^+ consumption during the first lithiation.

Si electrodes with different carbon nanostructure

- The Si electrodes with 1D carbon showed better electrochemical performances.
- The improvement can be attributed to CNR: pore structure, CNT: electrical connectivity.

Further work

- Hybrid conductive carbon – Different ratio between CNR and CNT
- Study on PECVD-based Si NPs (Diameter ~6.9 nm)
- SWCNT – The effect of aspect ratio on the electrode structure and performances

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