SILICON NANOPARTICLES COATED WITH DNA-DERIVED CARBON AS HIGH-PERFORMANCE ANODE MATERIAL FOR LITHIUM ION BATTERIES

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Recently, silicon has been attracting great interest as an anode material for lithium ion-batteries because of its excellent ability to store lithium ions (Li^+) when compared to the conventionally used carbon materials. However, silicon-based electrode material experiences a drastic volume change (*i.e.*, expansion and contraction) during charge/discharge cycles, leading to a catastrophic failure of the anode. The purpose of this study is to sustain the silicon's high ability to absorb or release Li^+ through the homogeneous coating of DNA-derived amorphous carbon. Silicon nanoparticles coated with double-stranded DNA are thermally treated at 800°C in an argon atmosphere in order to convert the DNA into amorphous carbon. We have observed the homogeneously coated thin, disordered carbons on silicon nanoparticles. Finally, we have verified the effective buffer-like function of DNA-derived carbon by the long-term stable electrochemical behavior of silicon-based anodes in lithium ion batteries.

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Silicon nanoparticles coated with DNA-derived carbon as high-performance anode material for lithium-ion batteries

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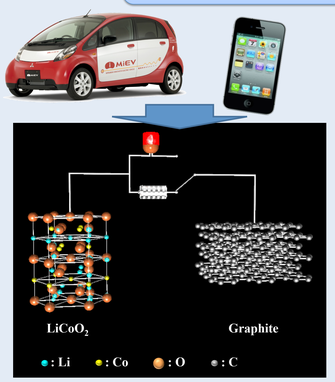
Background

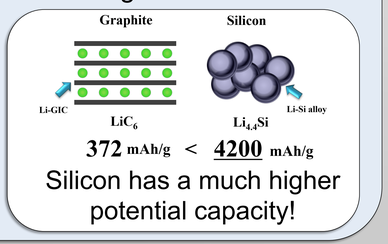


Lithium-Ion Batteries

- The dominant power sources for portable electric devices and EVs.
- Graphite generally used as the anode material.
- However, higher-capacity materials are now being investigated.

Higher Capacity

- More time b/w charges
- Longer-lasting laptops
- Longer-running EVs

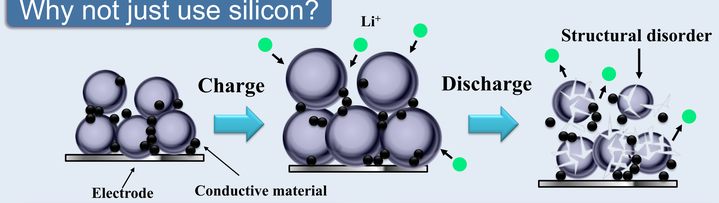


Silicon has a much higher potential capacity!

Purpose

Objective : Increase capacity of a Lithium-ion battery by using carbon-coated silicon instead of graphite as an anode material.

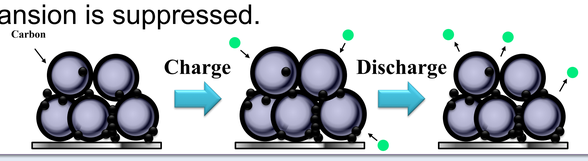
Why not just use silicon?



Silicon anode expands drastically as it absorbs lithium.

Loss of conductivity; Capacity decreases.

Solution: Silicon is coated with DNA-derived carbon and expansion is suppressed.



This material is based upon work supported by the National Science Foundation's Partnerships for International Research & Education Program (OISE-0968405).

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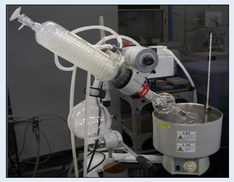
Method

Material creation

1. Si nanoparticles mixed with fish DNA in water (Si:DNA = 2:1).
2. Si-DNA mixture extracted by evaporator.
3. DNA converted into amorphous carbon by heat treatment at 800°C.



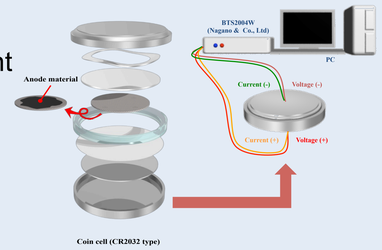
Evaporator

Electric furnace

Analysis

- Raman
- TEM
- Battery Measurement

TEM

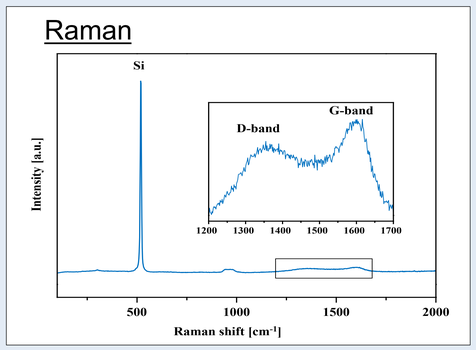


Battery measurement

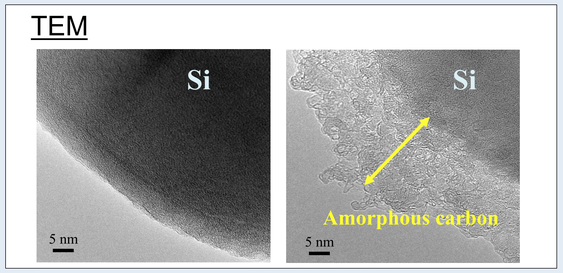
Results - Materials

Before

After

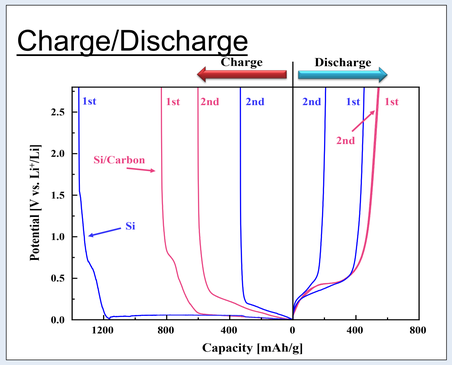


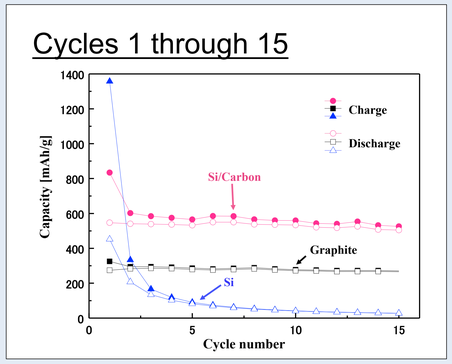
- Both silicon and carbon were detected.



- Silicon was firmly coated with amorphous carbon.

Results - Batteries





Si-Carbon anodes

Capacity

- Exhibit the highest discharge capacity.
- Irreversible capacity lower than that of Si batteries.

Cycle Life

- An overall capacity of around 600 mAh/g.
- About the same cycle life as graphite anodes.

Conclusion

Expansion and contraction during charge/discharge suppressed by carbon coating. The resulting Si-Carbon anodes:

1. Are more stable-cycling than silicon-based batteries.
2. Have twice the capacity of graphite-based batteries.

Future Projects

- Alter temperature of heat treatment: 600 or 1000 °C
- Add double-walled carbon nanotubes to improve anode conductivity and structural integrity.
- Reduce the size of the silicon nanoparticles.

Acknowledgements

Research conducted at Shinshu University's Endo-Hayashi-Kim Laboratory as a participant of the 2012 NanoJapan program, sponsored by NSF-PIRE and Rice University.