Silicon/Graphene as a high capacity anode for Lithium-Ion Batteries

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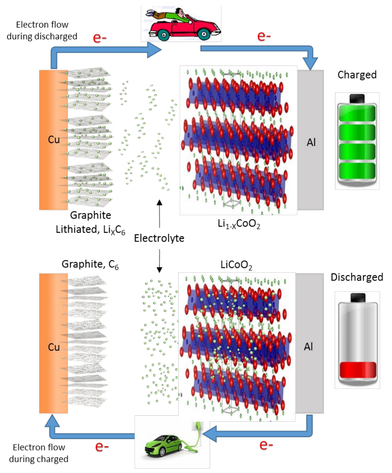
Summary. Silicon is recognized as one of the most promising candidates for next generation lithium-ion battery anode to replace the conventional carbon-based anode due to its high theoretical capacity, proper discharge potential and reliable operation safety. However, the high volume change (>300%) during lithiation/delithiation processes leads a poor cycle life. In the last 20 years a lot of research has been done to solve this problem and Si/Graphene-based materials have been found to perform best in terms of energy density and cost for EV applications. Currently, a rechargeable batteries contains around 140 Wh Kg^{-1} and 200 Wh l^{-1} at pack level. With the incorporation of SiOx/graphene-based materials in the anode is expected to overcome this energy in order to achieve a driving range beyond 500 km.

Li ion Battery operation



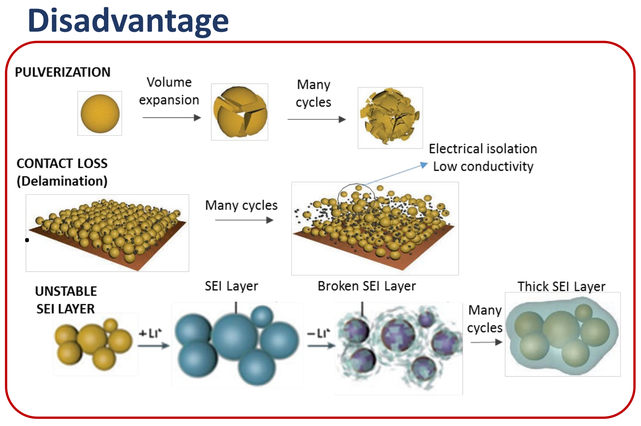
Due to demand of high energy for electric vehicles (EVs), LIB´s need new anode materials with high energy/power capacities to replace the graphite.

Silicon as alternative anode active material for LIBs

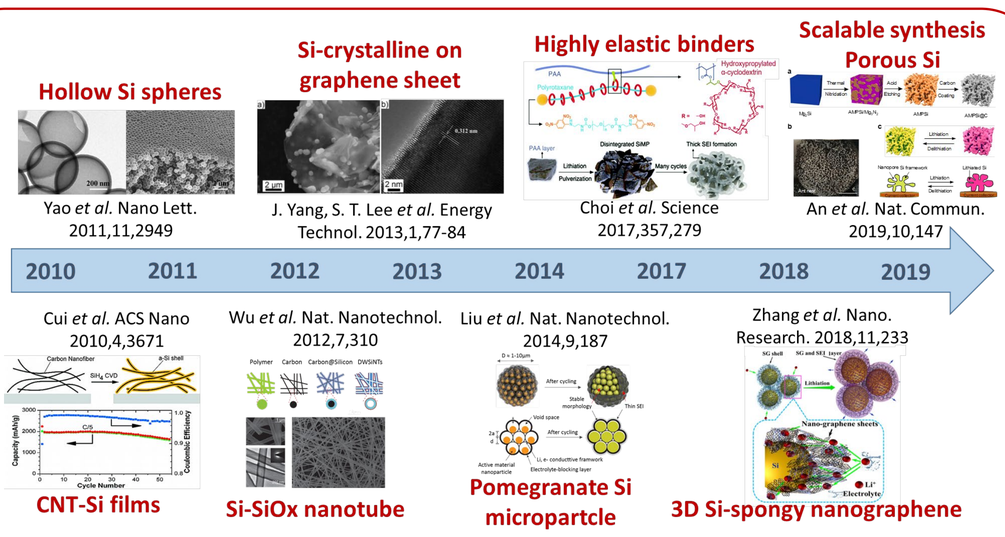
Advantage

- theoretical capacity (>4,000 mAh g^{-1})
- attractive operating voltage (~0.3 V versus Li/Li+)
- Si is abundant, potentially low cost, environment friendly, and non-toxic.

Disadvantage

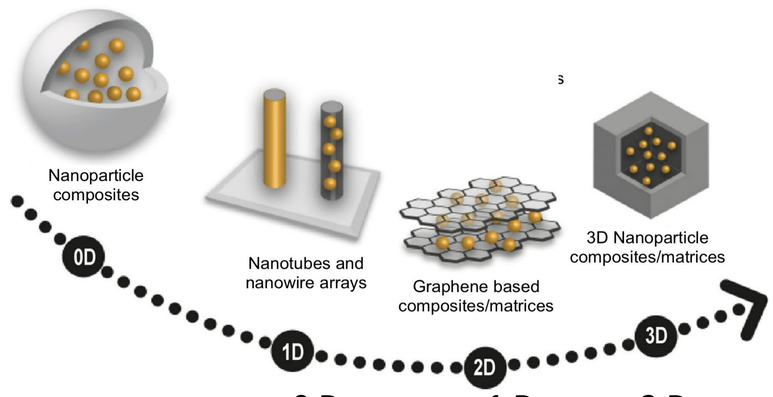


Timeline of selected important breakthroughs in the silicon-based anode



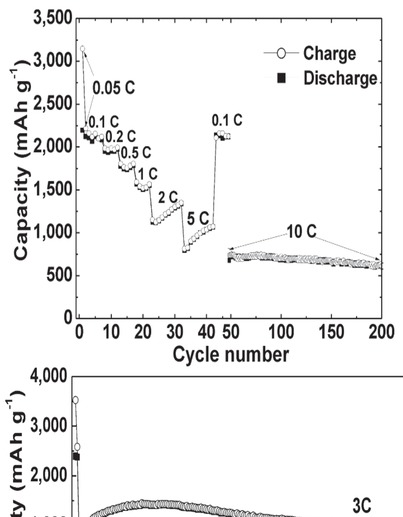
- Despite the significantly improved cyclability based on these structural designs, the industry has adopted the silicon monoxide phase (SiOx, x ≈ 1) as the first Si-based commercial anode material, because these materials can be produced in massive quantities by different process.

Representative Si anode with different carbon forms

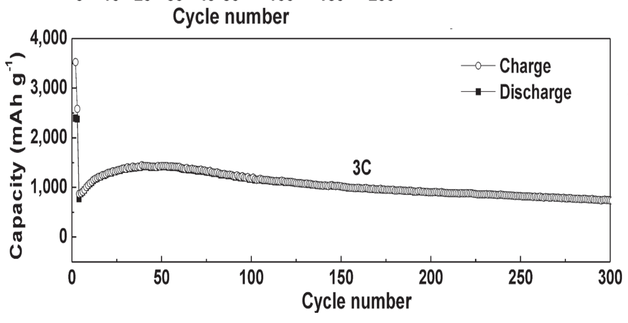


Carbon Form	0-D Carbon Black	1-D CNFs	2-D Graphene	3-D Hierarchical Carbon Frame
Si Source	Si NPs	A-Si	Si NPs	Si NPs
Si Loading	60%	75%	70%	50%
Initial Capacity (mAh/g)	~3000	~2000	~2300	~2000
Cycling Performance (mAh/g)	~1500 22 cycles	~1500 55 cycles	~1700 120 cycles	~1600 100 cycles

The cyclic stability of Si/Graphene based anode at high C-rate



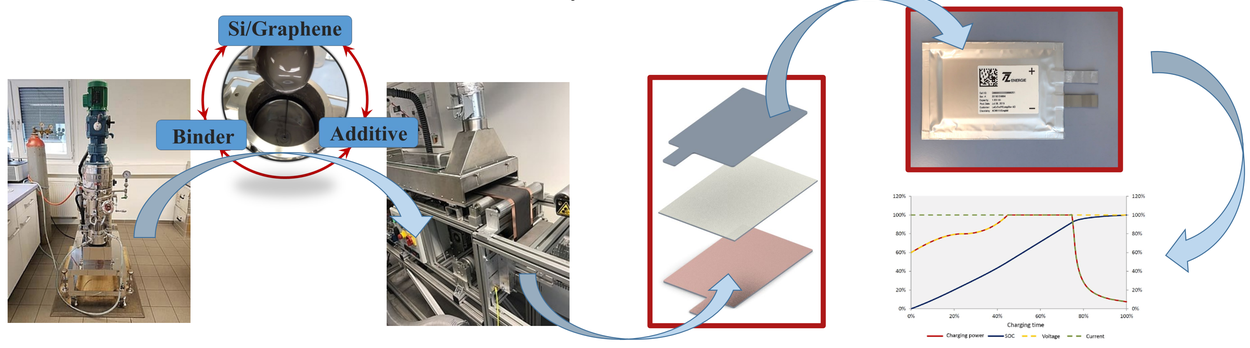
- The nanostructured Silicon/ Reduced Graphene Oxide (Si/RGO) electrode remains high charge/discharge capacities even at high C-rate (87% at 10 C).



- The capacity stability also remains at 3 C for 300 cycles.

TZE-Project COATEMO II

- Development of novel, high-energy, fast charging and durable ***silicon/graphene*** anode materials for electromobility.



- The incorporation of Si or SiOx leads to the development of a new matrix with new additives and binders that interact properly with the new active material and at the same time allow a good performance at a low cost.

Reference

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