**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.

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**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.

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**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**

<table>
<thead>
<tr>
<th>Carbon Form</th>
<th>Si Source</th>
<th>CNFs</th>
<th>Graphene</th>
<th>Hierarchical Carbon Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-D</td>
<td>Si NPs</td>
<td>A-Si</td>
<td>Si NPs</td>
<td>Si NPs</td>
</tr>
<tr>
<td>1-D</td>
<td>60%</td>
<td>75%</td>
<td>70%</td>
<td>50%</td>
</tr>
<tr>
<td>2-D</td>
<td>Initial Capacity (mAh/g)</td>
<td>~3000</td>
<td>~2000</td>
<td>~2300</td>
</tr>
<tr>
<td>3-D</td>
<td>Cycling Performance (mAh/g)</td>
<td>~1500</td>
<td>~1500</td>
<td>~1700</td>
</tr>
</tbody>
</table>

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**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.

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**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.

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**Reference**


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