

Supporting information

High performance of the Ge@C nanocables as the anode for lithium ion batteries

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Growth mechanism of the Ge NWs

In our experiment, there without any catalysis, and there are many nanoparticles can be seen from the SEM images. The EDS spectrum indicated that the particles are Ge nanoparticles (Figure S1 & Fig. 2(a)). If we shorter the reaction time, the tadpole-looking products can be detected. And as the reaction time longer, the Ge NWs can be obtained. So, the growth mechanism should be speculated as the following:

First, the Ge gas had been absorbed with the substrate and rapid nucleation and growth. And then the Ge nanoparticles stop growing as it grows up to some dimension scope. Then the Ge nanoparticles with absorbing over-saturated Ge gas and begin to separate out Ge element to forming the Ge NWs.

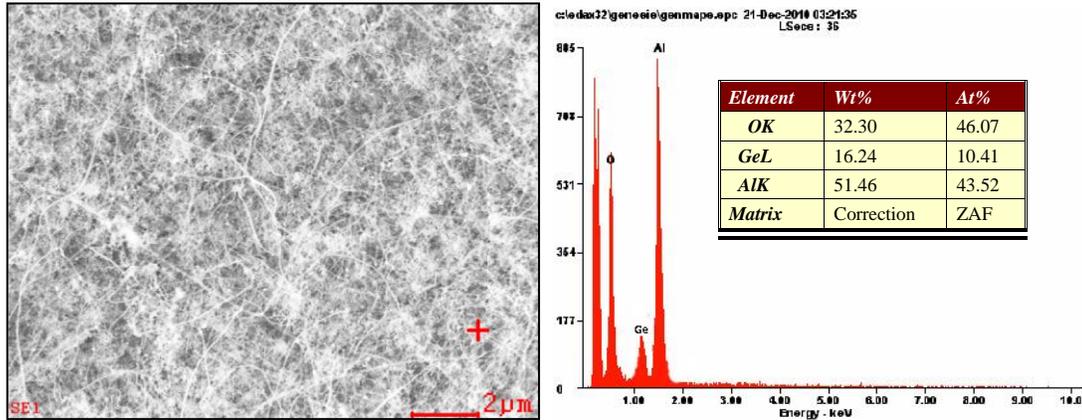


Figure S1. The SEM images of the as prepared Ge NWs on the sapphire substrate, the right side is the EDS image of the red mark in the SEM image and the insert is the element analysis of the EDS image.

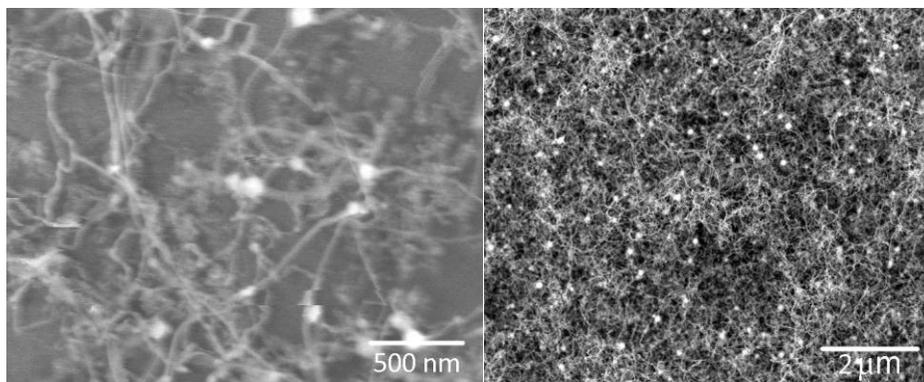


Figure S2. The Ge NWs growth on the sapphire substrate with different growth time, the left is 10 min and the right is 60 min.

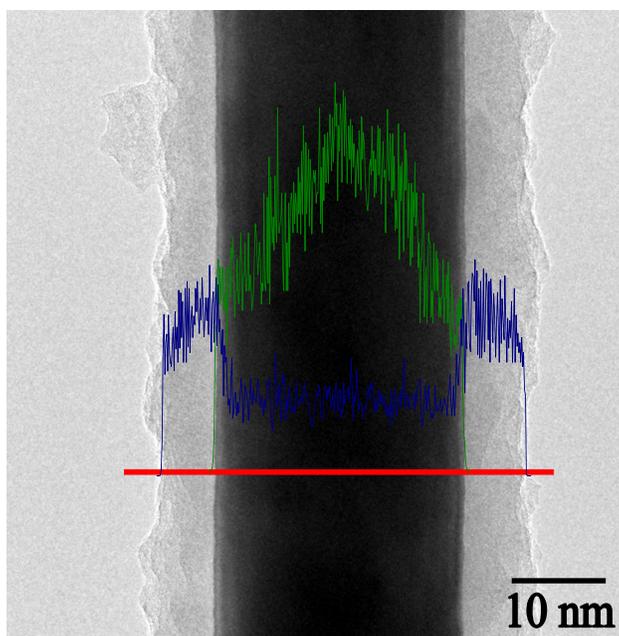


Figure S3. TEM image of Ge@C NW and EDS line profiles of Ge (Green) and C (Blue) along the red line.

Thermogravimetric analysis (TGA), carried out in air at a heating rate of $10\text{ }^{\circ}\text{C min}^{-1}$, was used to determine the chemical composition of the Ge@C composite NWs.

The results showed the Ge@C composite to contain ~80 wt % Ge.

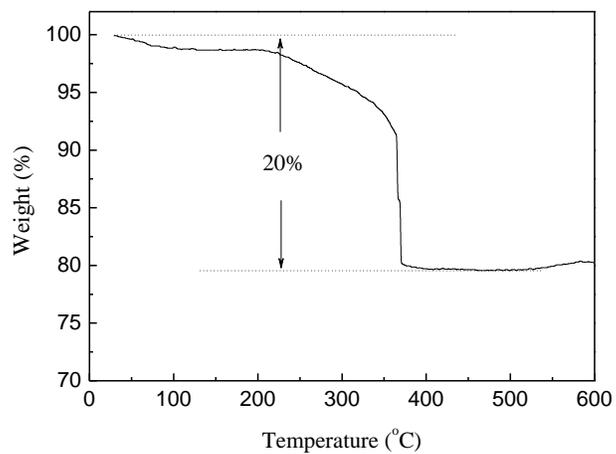


Figure S 4. Thermogravimetric analysis (TGA) of Ge@C NWs in air.

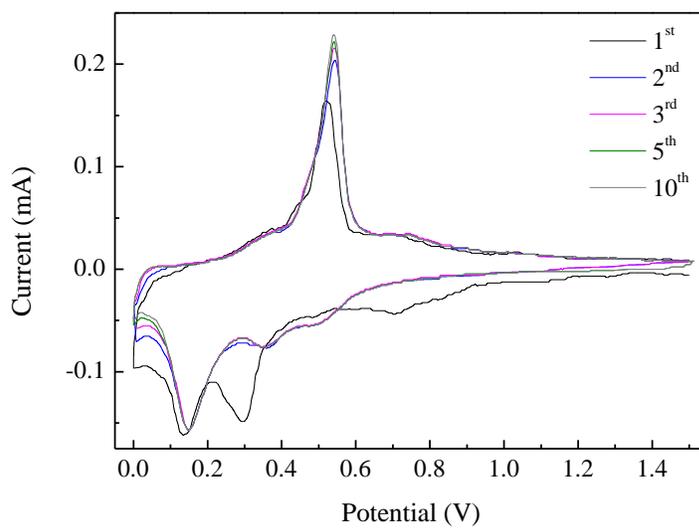


Figure S5. CV profiles of the Ge@C composited NWs electrode at a scan rate of 0.1 mVs^{-1} within the voltage range 0.01–1.5 V versus Li/Li^+ .

Cyclic voltammetry (CV) was performed to understand the redox properties of the

Ge@C composited NWs as an anode material in lithium-ion cells. Two extra reduction peaks at 0.8 and 0.3 V were observed in the first scanning cycle, which could be associated with the formation of a solid electrolyte interphase (SEI) layer. During the subsequent discharge process, the three peaks centered at 0.5, 0.36, and 0.15 V corresponded to multistep reactions between Ge and Li. The reduction of Ge could proceed as $4.4Li^+ + Ge + 4.4e^- \rightarrow Li_{4.4}Ge$, based on complete lithiation. Upon charging, one sharp and symmetrical peak at 0.53 V was observed, which corresponded to the oxidation of Li_xGe into Ge. Moreover, the positions and intensities of the redox peaks remained unchanged during the second cycle, thus suggesting that the Ge@C composited NWs electrode has excellent electrochemical reversibility.

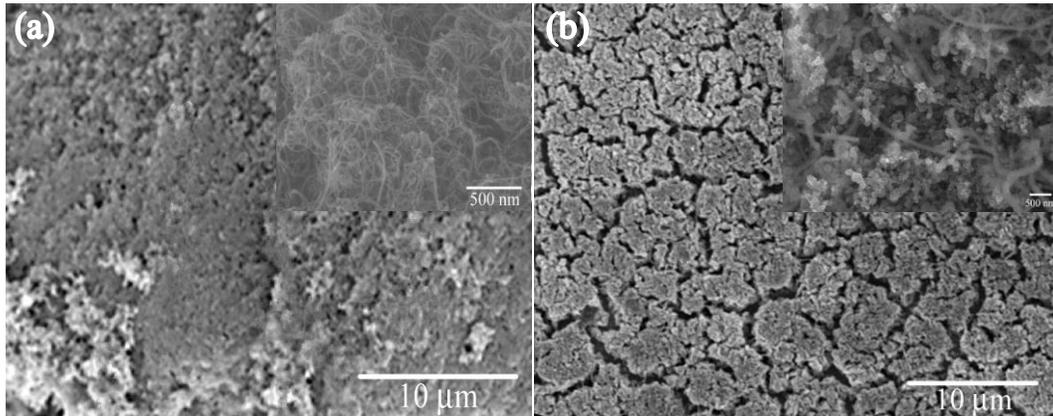


Figure S6. SEM images of the surface of Ge@C composites NWs electrodes before cycles (a) and after (b) 200 cycles at 0.5 C.

In figure S6, it can be found that the Ge@C composite NWs were volume expanded or broken into powder-like after the 200 cycles at 0.5C. And the diameter of the Ge NWs was about 5 times greater than the pristine sample for lithium de/insertion.