

## Supplementary Information

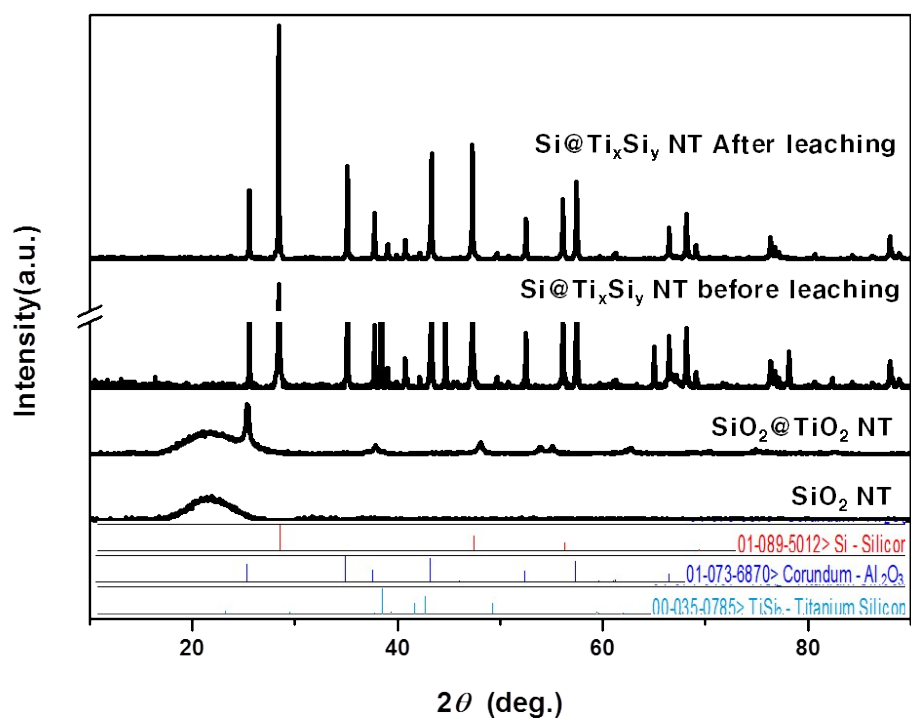
# **Nanotubular structured Si-based multicomponent anodes for high-performance lithium-ion batteries with controllable pore size via coaxial electrospinning**

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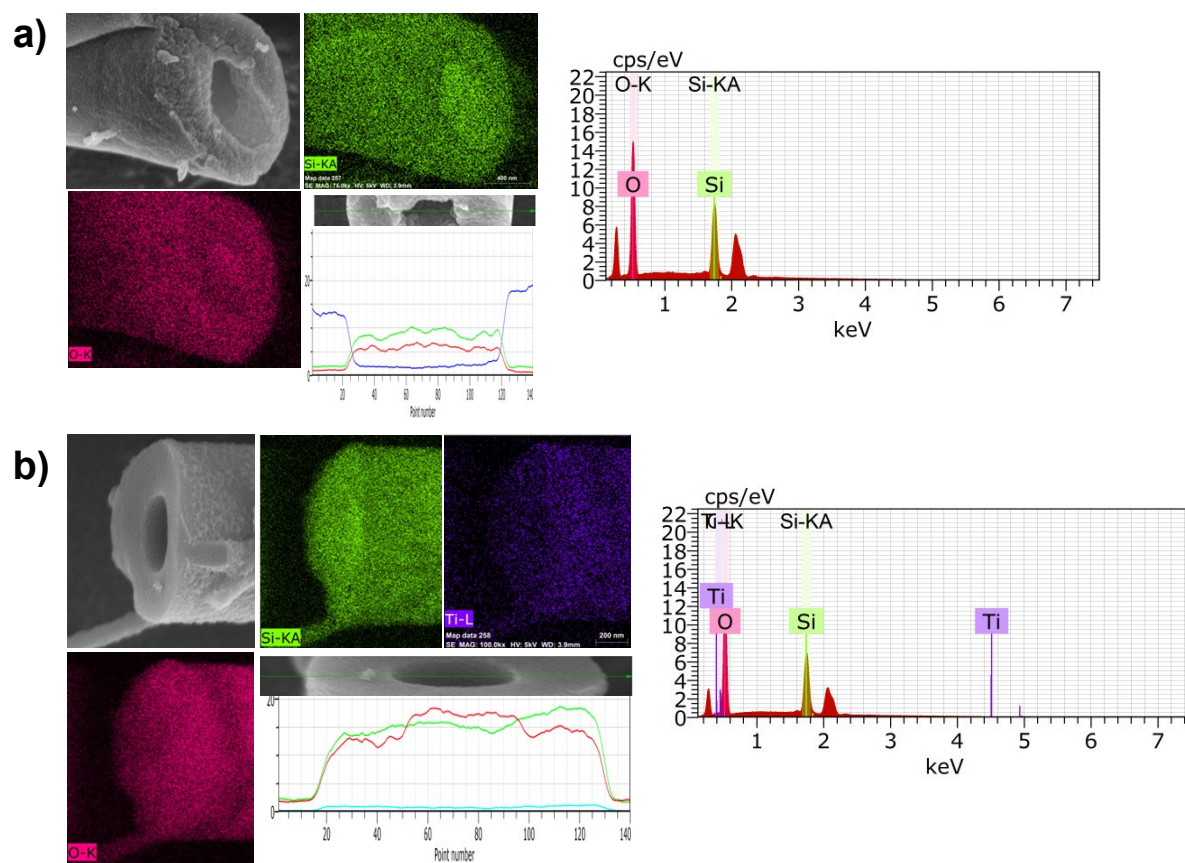
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**Table S1.** Electrochemical properties of Si-based anode materials

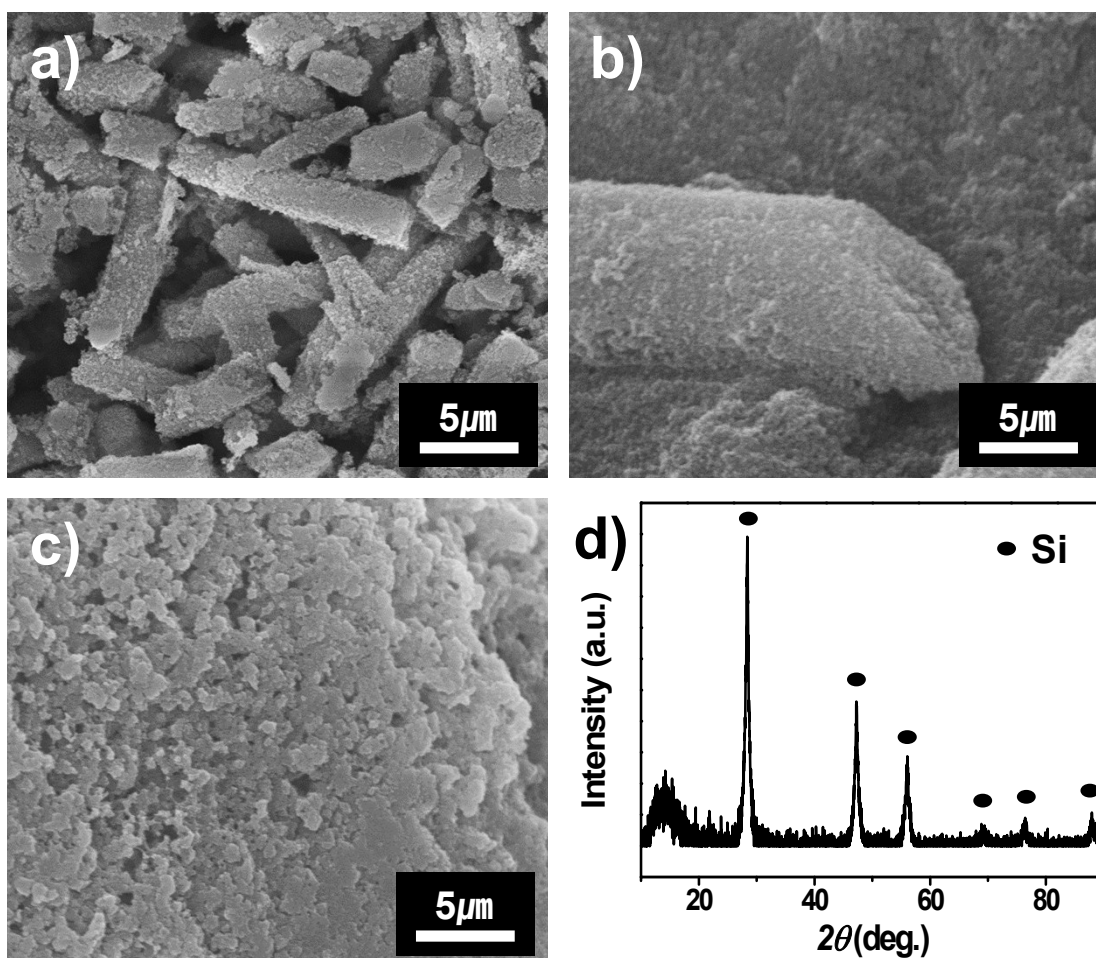
| Structure                                                                          | Synthetic methods                                            | First charge capacity (mAh/g) | Capacity retention (%) | C-rate | Loading mass of active material (mg/cm <sup>2</sup> ) | Ref.                                             |
|------------------------------------------------------------------------------------|--------------------------------------------------------------|-------------------------------|------------------------|--------|-------------------------------------------------------|--------------------------------------------------|
| Si nanoparticle                                                                    | Commercial                                                   | ~2500                         | 65 (400 cycles)        | 0.5 C  | 0.2-0.3                                               | <i>Adv. Mater.</i> , 2013, <b>25</b> , 1571.     |
| Porous Si                                                                          | Mg reduction                                                 | ~1650                         | 62.6 (1000 cycles)     | 0.5 C  | 0.5-1.0                                               | <i>Sci. Rep.</i> , 2014, <b>4</b> , 5623.        |
| Si hollow sphere                                                                   | Template etching                                             | ~2720                         | 52.1 (700 cycles)      | 0.5 C  | 0.1-0.2                                               | <i>Nano Lett.</i> , 2011, <b>11</b> , 2949.      |
| Si-C yolk-shell                                                                    | Carbon coating on Si-SiO <sub>2</sub> core-shell and etching | 1180                          | 98.3 (1000 cycles)     | 0.5 C  | 0.2                                                   | <i>Nat. Nanotechnol.</i> , 2014, <b>9</b> , 187. |
|                                                                                    | Air inflation                                                | 1650                          | 65 (40 cycles)         | 0.5 C  | N/A                                                   | <i>RSC Adv.</i> , 2014, <b>4</b> , 36218.        |
| Si nanowire                                                                        | Template-based impregnation                                  | ~3000                         | 33.5 (1000 cycles)     | 0.5 C  | 0.03-0.04                                             | <i>Nano Lett.</i> , 2013, <b>13</b> , 5740.      |
| Si nanotube                                                                        | Mg reduction of SiO <sub>2</sub> nanotubes                   | ~1850                         | 48.6 (90 cycles)       | 0.1 C  | N/A                                                   | <i>Adv. Mater.</i> , 2012, <b>24</b> , 5452.     |
| Ti <sub>x</sub> Si <sub>y</sub> -coated Si/Al <sub>2</sub> O <sub>3</sub> nanotube | Coaxial-electrospinning and Al reduction                     | 1540                          | 75 (280 cycles)        | 0.5 C  | 1.59                                                  | This work                                        |



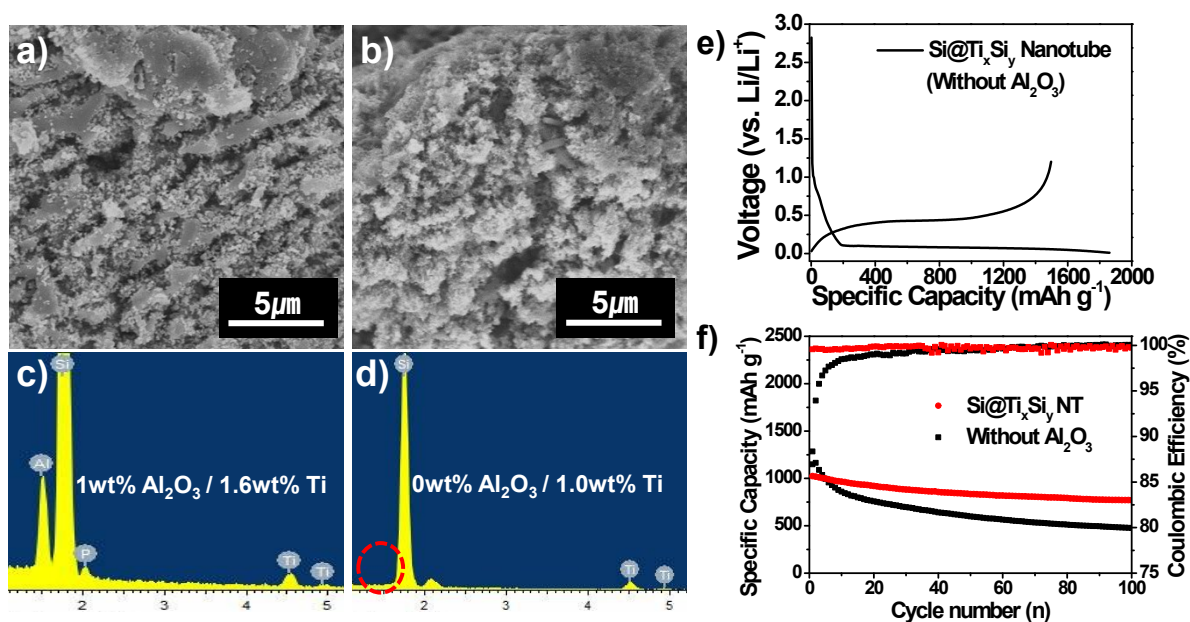
**Fig. S1.** XRD patterns of four types of tubular structures fabricated by co-axial electrospinning and/or aluminothermic reaction.



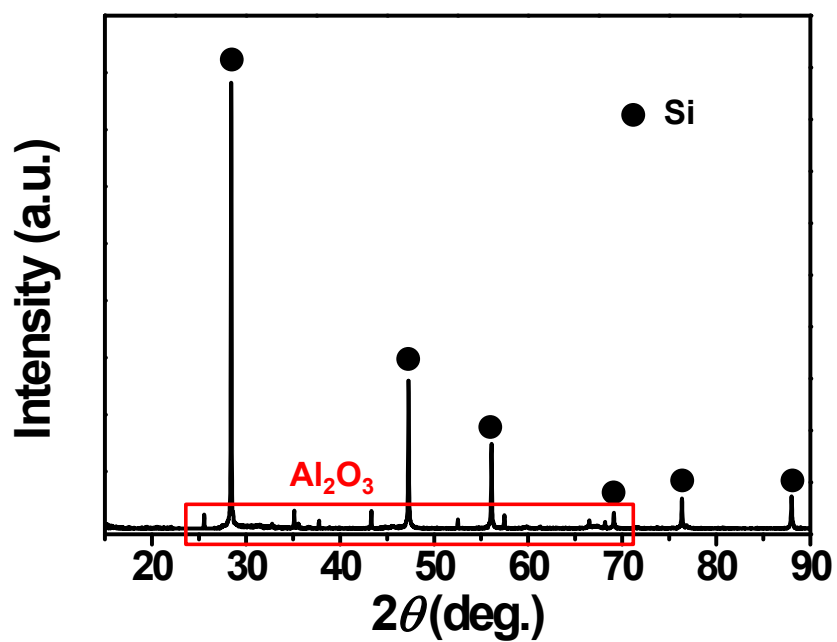
**Fig. S2.** EDS mapping and line scan spectrum of (a)  $\text{SiO}_2$  nanotubes and (b)  $\text{SiO}_2@\text{TiO}_2$  nanotubes.



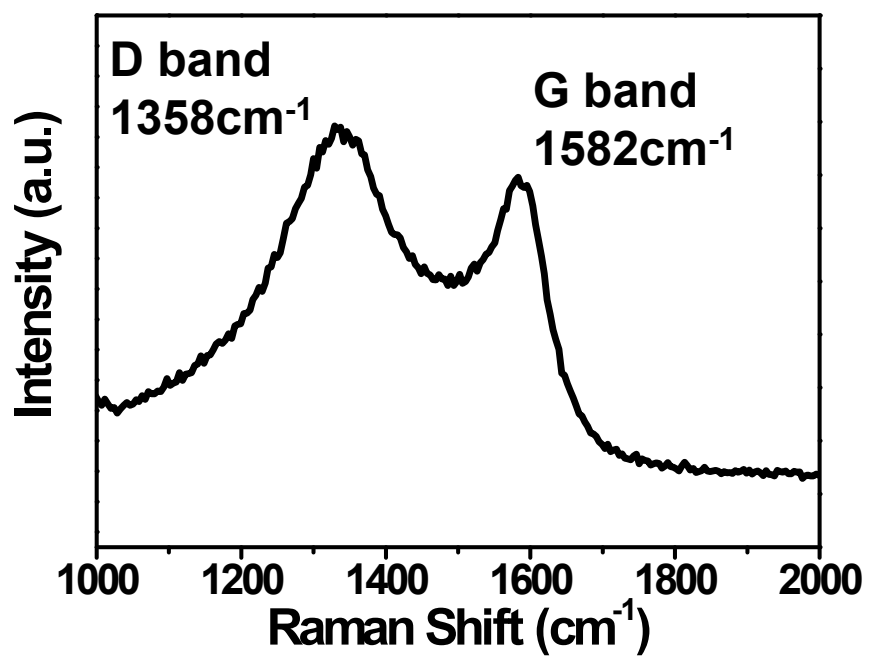
**Fig. S3.** Si nanotubes prepared by Mg reduction of  $\text{SiO}_2$  nanotubes. (a-c) SEM images showing collapsed Si nanotube. (d) XRD pattern of collapsed Si nanotube obtained by magnesiothermic reaction.



**Fig. S4.** SEM images of  $\text{Ti}_x\text{Si}_y$ -coated Si nanotubes after etching process with concentrated phosphoric acid at  $150\text{ }^\circ\text{C}$  for (a) 2 h (b) 3 h. (c) and (d) are EDS spectra of the corresponding SEM images of (a) and (b), respectively. (e) Voltage profile of formation cycle and (f) cycling retention of  $\text{Si@Ti}_x\text{Si}_y$  nanotubes without  $\text{Al}_2\text{O}_3$  layer obtained at  $0.5\text{ C}$  rate.

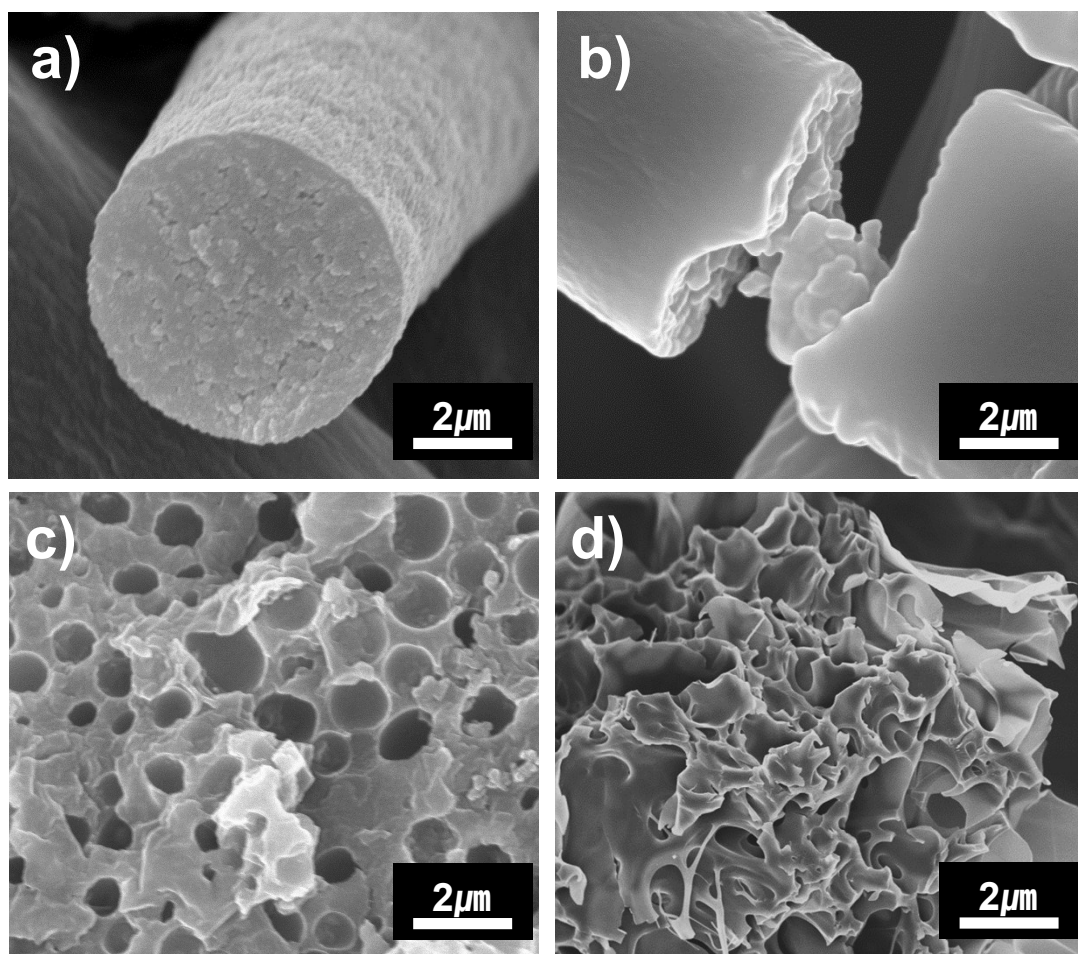


**Fig. S5.** XRD pattern of bare Si nanotubes prepared by aluminothermic reduction of SiO<sub>2</sub> nanotubes (without TiO<sub>2</sub> coating). During the aluminothermic reaction, both Si and Al<sub>2</sub>O<sub>3</sub> were simultaneously formed after phosphoric acid leaching process

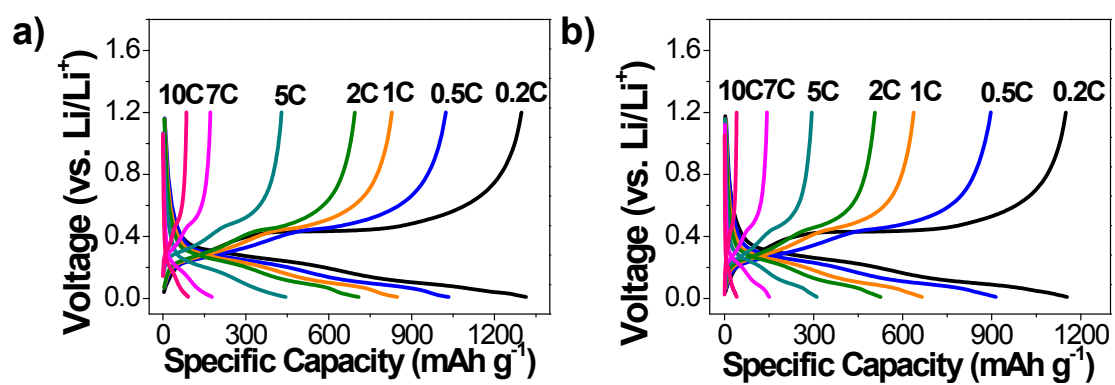


**Fig. S6.** Raman spectrum of carbon-coated Si nanotubes

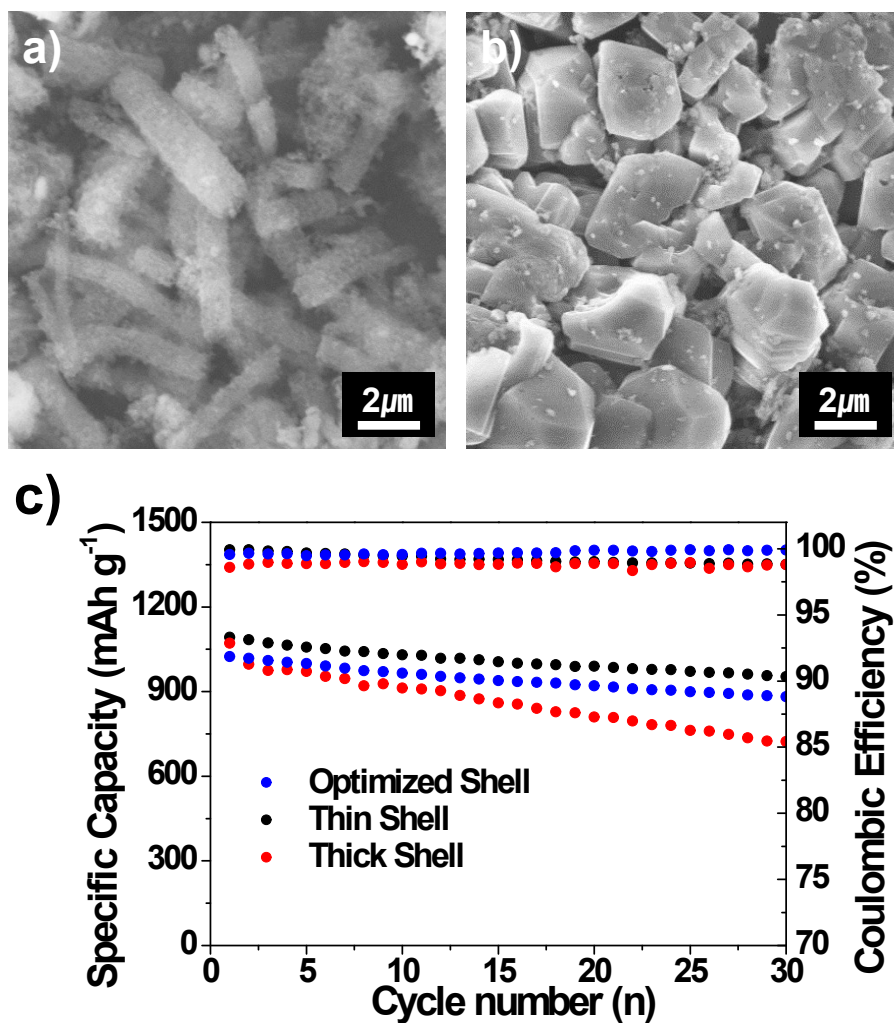




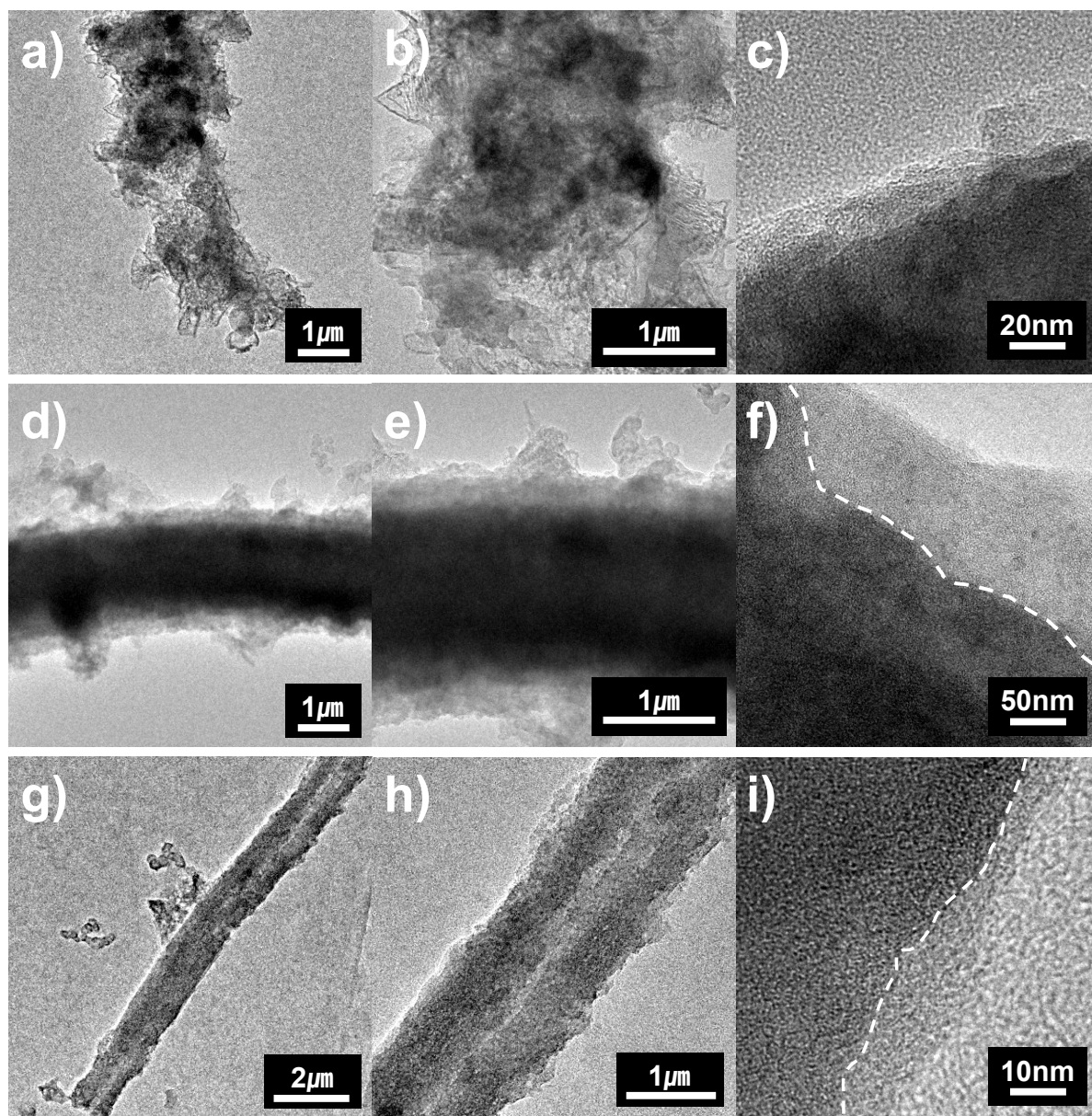
**Fig. S7.** SEM images of SiO<sub>2</sub> tubes fabricated by co-axial electrospinning process. (a) SiO<sub>2</sub> fiber fabricated at oil feeding rate of 0.01  $\mu\text{L min}^{-1}$ . (b) SiO<sub>2</sub> fiber with residual heavy oil in the central region of broken fibers. (c-d) SEM images showing collapsed SiO<sub>2</sub> fibers prepared at oil feeding rate of 10  $\mu\text{L min}^{-1}$ .



**Fig. S8** Rate capabilities of (a) bare and (b) carbon-coated Si nanotubes at various C rates. The discharge and charge rates are the same.



**Fig. S9** SEM images of TixSi-y-coated Si nanotubes with (a) thin-shell (100-200 nm) and (b) thick-shell (700-800 nm). (c) Cycling retention of three different Si-based electrodes obtained in the range of 0.01-1.2 V at 0.5 C rate.



**Fig. S10.** TEM images of (a-c) bare, (d-f) carbon-coated, and (g-i)  $\text{Ti}_x\text{Si}_y$ -coated Si nanotubes at 0.5 C rate after 100 cycles.