Supplementary Information: Fabrication of 3D Core-Shell Multiwalled Carbon Nanotube@RuO2 Lithium-Ion Battery Electrodes through a RuO2 Atomic Layer Deposition Process

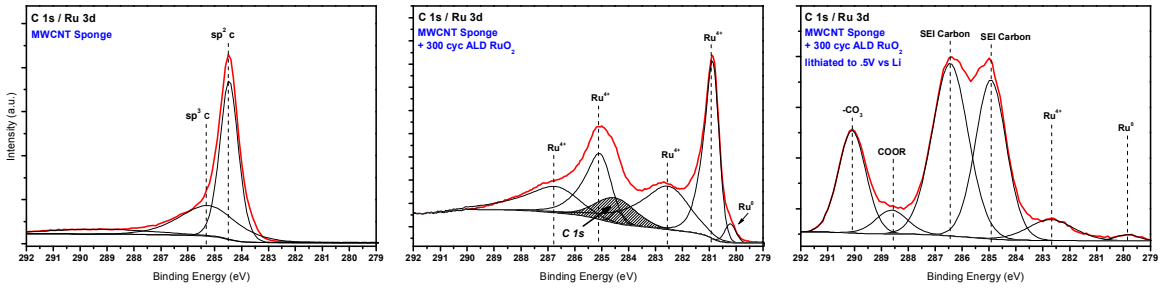
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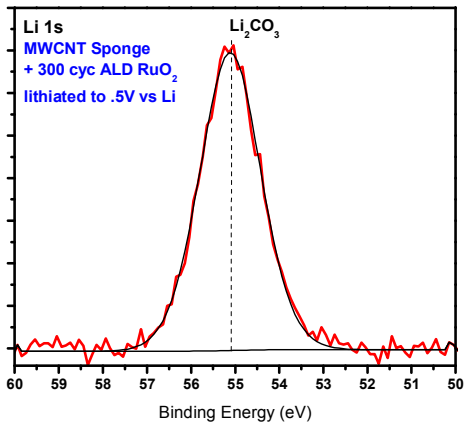
Supplemental Figure S1 shows the XPS analysis of a bare MWCNT sponge (Figure S1a), an ALD RuO_2 coated MWCNT sponge (Figure S1b), and a fully lithiated RuO_2 MWCNT core shell hetero nanoheterostructure (Figure S1c). There is significant overlap among the C 1s and Ru 3d photoelectron peaks, however clear differences between the bare MWCNT and the coated RuO_2/MWCNT can be seen in Figures S1a and S1b.



Supplemental Figure S1. X-ray photoelectron spectroscopy. The C 1s / Ru 3d spectra of the uncoated MWCNT is shown in a). After coating with 300 cycles of ALD RuO_2, peaks related to the Ru 3d region become apparent, as shown in b). Finally, after full lithiation the only significant peaks that are visible are related to the formation of the SEI layer.

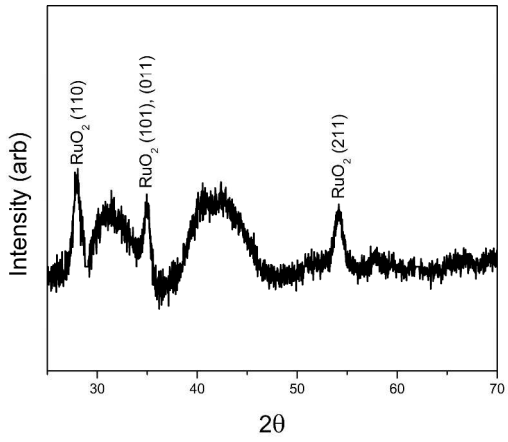
After lithiation in EC/DEC 1M LiPF6 to .5V vs Li, the C 1s spectrum becomes dominated by peaks related to the formation of the SEI layer, which has been shown to be largely composed of Li_2CO_3, as shown in Figure S1c.

Supplemental Figure S2 shows the Li 1s peak of the lithiated RuO_2 sponge. The Li peak is fit well by 1 curve, and it is in the correct position for Li_2CO_3, a major component of SEI. After lithiation the XPS signal is dominated by breakdown components of the electrolyte, or SEI (which can also be see in the TEM images shown in Figure 7). Quantification is especially challenging, due to the C 1s and Ru 3d photoelectron peak overlap; furthermore there may be differential charging of the nanoheterostructure making absolute peak identifications difficult.



Supplemental Figure S2. Li 1s spectrum of the fully lithiated RuO_2/MWCNT confirming the presence of Li_2CO_3.

Finally a XRD pattern of the RuO_2 coated MWCNT is shown in Supplemental Figure S3 further confirming the crystallinity of RuO_2.



Supplemental Figure S3. XRD pattern of RuO_2/MWCNT hetero nanostructure.