Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A.

Hierarchical Ru- and RuO_2-foams as high performance cathodes for rechargeable lithium-oxygen batteries

Kyoung Hwan Kwak, Dong Wook Kim, Yongku Kang and Jungdon Suk*

Advanced Materials Division, Korea Research Institute of Chemical Technology, Yuseong, Daejeon 305-600, Republic of Korea

*Corresponding author. Tel.: +82-42-860-7335; fax: +82-42-860-7200.

E-mail address: jdsuk@krict.re.kr (J. Suk), ykang@krict.re.kr (Y. Kang)

Supporting Information

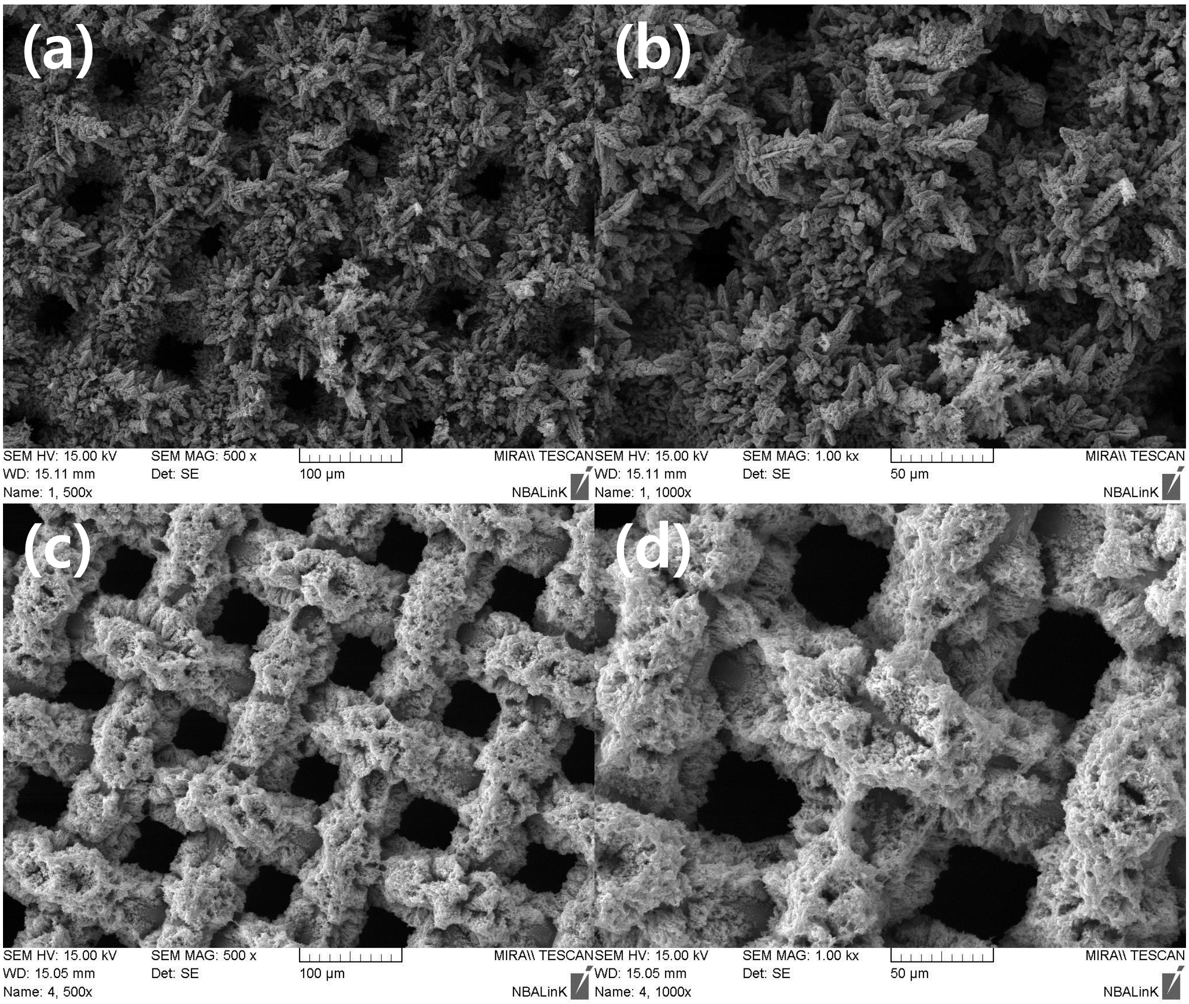

Fig. S1 SEM images of (a, b) porous Cu-Ru film and (c, d) porous Ru-foam with low magnification.

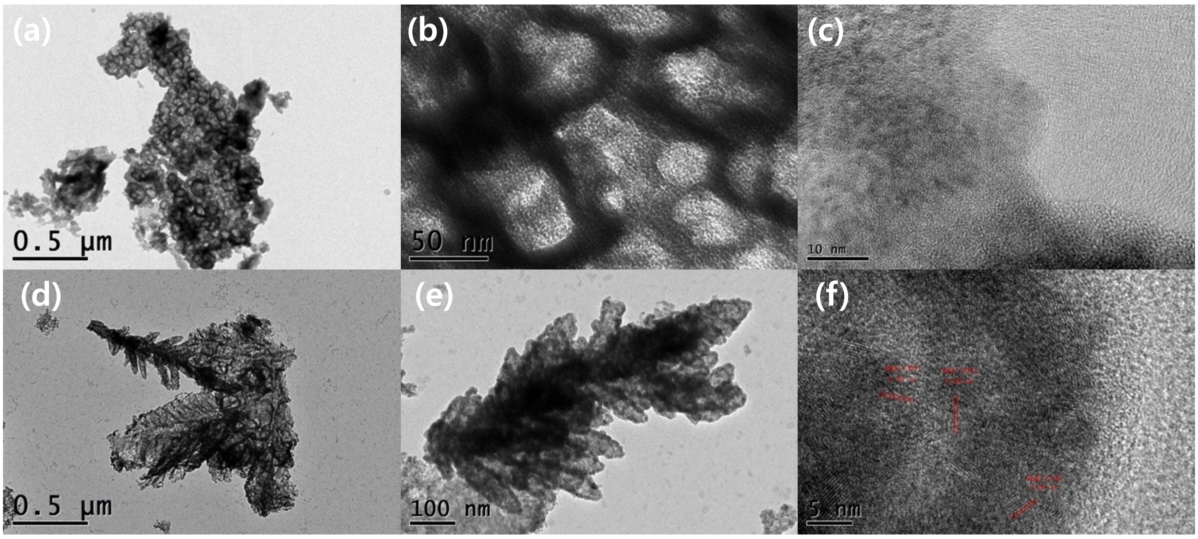

Fig S2. TEM images of (a-c) dendritic Ru-foam and (d-f) dendritic RuO_2-foam with various magnifications.

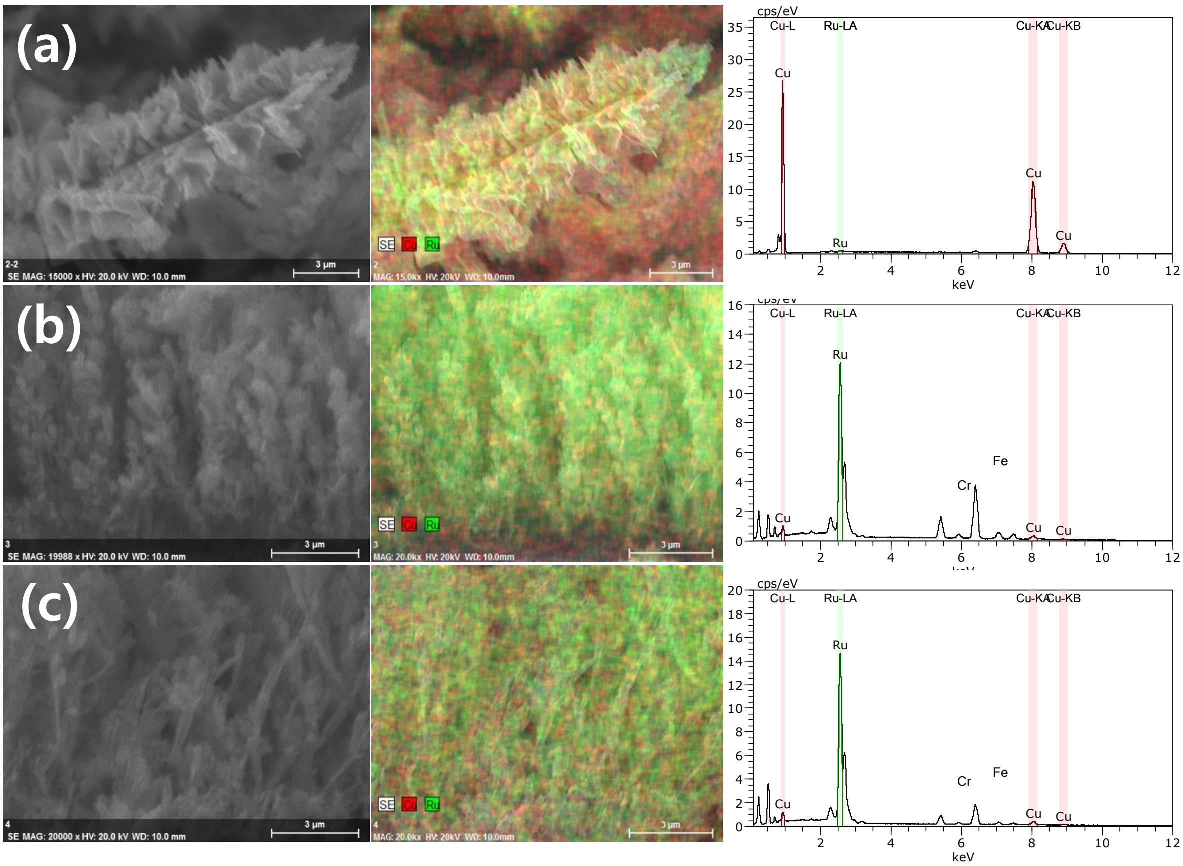

Fig. S3. EDS mapping images and spectra of (a) Cu-Ru foam, (b) dendritic Ru-foam and (c) dendritic RuO_2-foam.

	Ru (wt %)	Cu (wt %)	Cr (wt %)	Fe (wt %)	Ni (wt %)	Mo (wt %)
Stainless steel		0.26	17	69	10	2.1
Ru-Cu foam	2.58	11.7	13.1	53.7	7.71	1.62
Ru foam (Cu dealloyed)	2.32	0.42	15.7	64.2	9.49	1.95

Table S1. ICP results of stainless steel, Cu-Ru foam and dendritic Ru-foam.

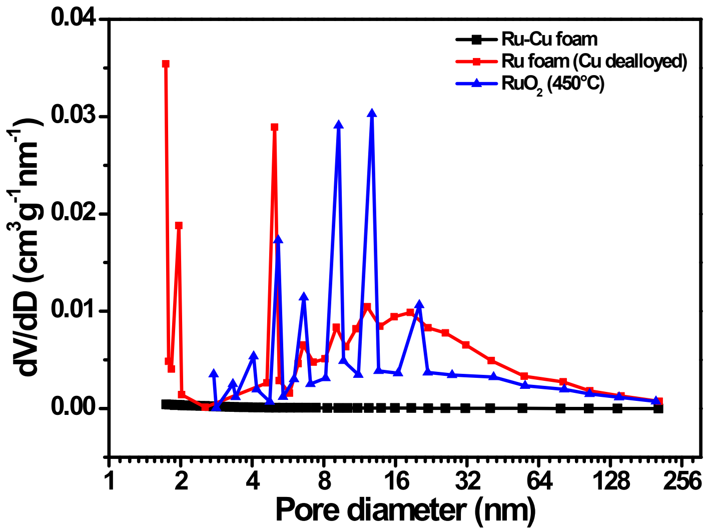

Fig. S4 The pore size distribution of Cu-Ru foam, dendritic Ru- and RuO_2-foam.

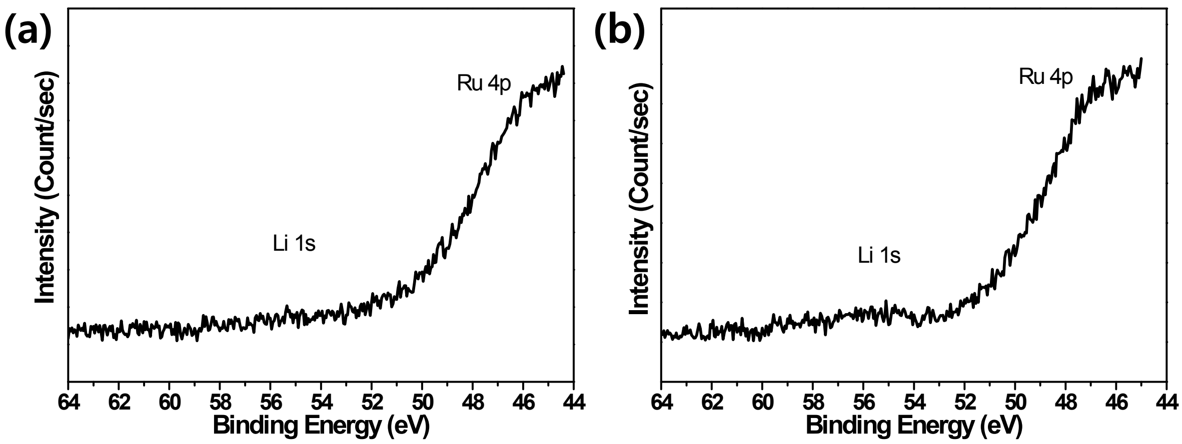

Fig. S5 High resolution XPS spectra of pristine dendritic (a) Ru- and (b) RuO_2-foam.

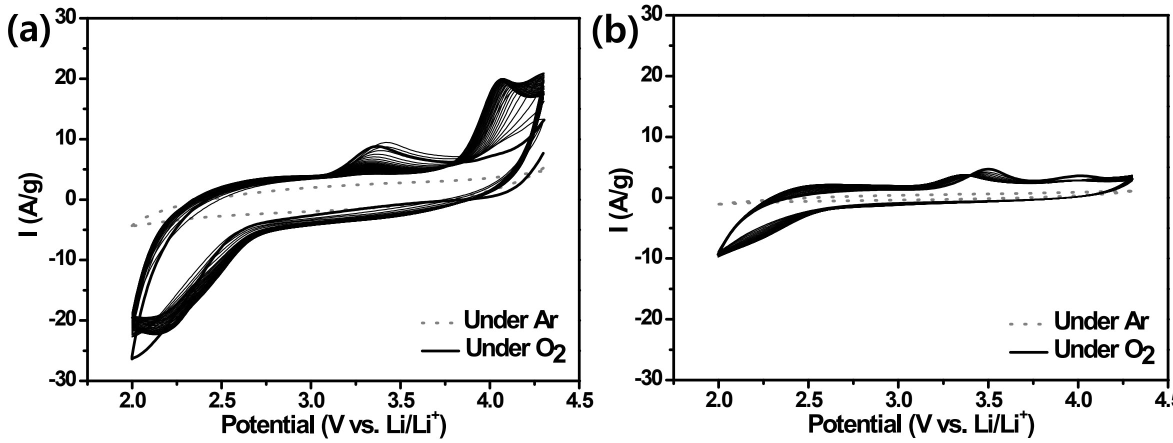

Fig. S6 CVs of Li-O_2 batteries with dendritic (a) Ru- and (b) RuO_2-foam at a scanning rate of 0.5 mV/s under Ar and O_2 atmosphere.

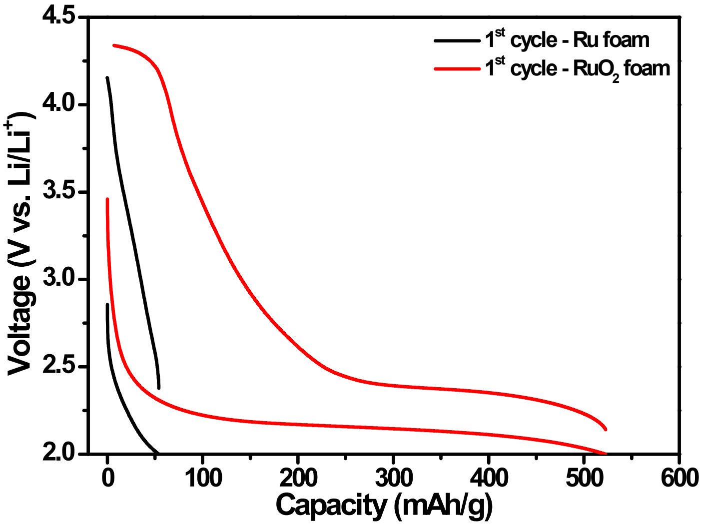

Fig. S7 Discharge-charge profile of Li-O_2 batteries with dendritic Ru- and RuO_2-foam under Ar atmosphere.

Journal	Title	Capacity	electrolyte and test condition	cycle retention with limited capacity	full cycle capacity retention	OER/ORR efficiency
Nano lett. 2015, 15, 8084	Reversibility of noble metal-catalyzed aprotic Li-O2 batteries	No test	TEGDME	100 cycling with 1000 mAh/g	No cycling test	20.90%
Sicence, 2013, 337, 563	A reversible and higher rate Li-O2 battery	300 mAh/g	DMSO, 500 mA/g	No cycling test	95% after 100 cycle	98%
Chem. Comm. 2013, 49, 5984	Carbon-free cobalt oxide cathodes with tunable nanoarchitectures for rechargeable Li-O2 batteries	2280 mAh/g	TEGDME, 20 mA/g	No cycling test	No cycling test	No test
		500 mA/g	TEGDME, 100 mA/g	50 cycle with 500 mA/g	No cycling test	
J. Power Sources, 2014, 248, 1270	carbon and binder free rechargeable Li-O2 battery cathode with Pt/Co3O4 flake arrays as catalyst	500 mAh/g	TEGDME, 200 mA/g	No cycling test	10% after 40 cycle	No test
		930 mAh/g	TEGDME, 100 mA/g	No cycling test	No cycling test	
Adv. Energy. Mater. 2014, 1401030	Optimization of carbon- and binder-free Au nanoparticle coated Ni nanowrie electrodes for Li-O2 batteries	1563 mAh/g	TEGDME, 100 mA/g	No cycling test	No cycling test	No test
		371 mAh/g	DMA, 500 mA/g	No cycling test	99% after 50 cycle	
J. Mater. Chem. A 2015, 3, 5714	Mushroom-like Au/NiCo2O4 nanohybrids as high performance binder-free catalytic cathodes for Li-O2 batteries	1275 mAh/g	DME, 42.5 mA/g	10% after 40 cycle with 510 mAh/g	No cycling test	No test
ACS Appl. Mater. Interfaces 2015, 7, 5488	Exploring Metal Nanoclusters for Lithium−Oxygen Batteries	5759 mAh/g	TEGDME, 100 mA/g	60 cycle with 1000 mAh/g	No cycling test	No test
J. Mater. Chem. A, 2016, 4, 7727	Mesoporous Cr2O3 nanotubes as an efficientcatalyst for Li–O2 batteries with low charge potential and enhanced cyclic performance	8100 mA/g	TEGDME, 50 mA/g	55 cycles with 1000 mA/g	29% after 5 cycle	No test
This work	Hierarchical Ru-and RuO2 foams as high performance cathodes for rechargeable Li-O2 batteries	4900 mA/g-RuO2 1570 mA/g-Ru	DMA, 50 mA/g	100% after 100 cycle with 500 mA/g	75% after 25 cycle-Ru, 50% after 25 cycle-RuO2	97% after 10 cycle-Ru 66% after 10 cycle-RuO2
		3340 mA/g-RuO2 2000 mA/g-RuO2	TEGDME, 50 mA/g	100% after 100 cycle with 200 mA/g	58% after 110 cycle-Ru, 38% after 110 cycle-RuO2	

Table S2. Summary of the state-of-art cathode materials for Li-O_2 batteries.

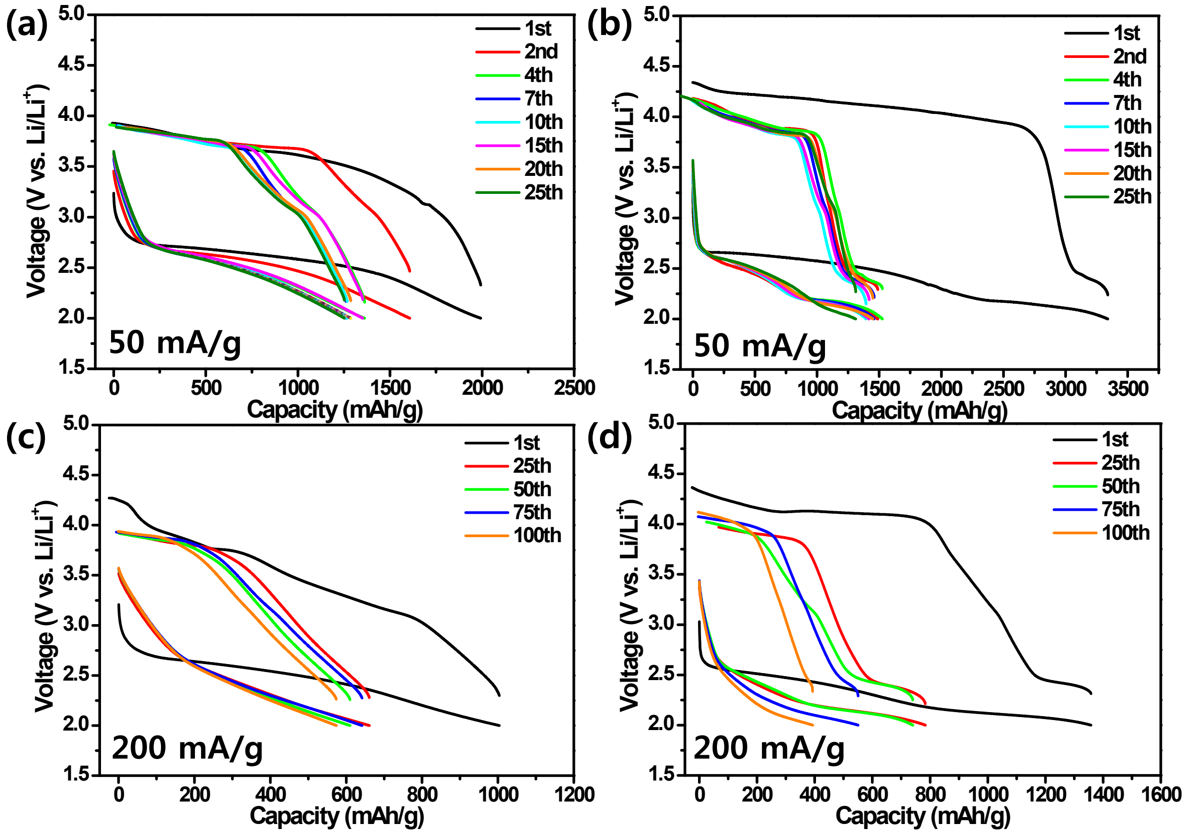

Figure S8. Discharge-charge profiles of (a,c) dendritic Ru foam and (b,d) dendritic RuO_2 foam of Li-O_2 batteries at a current density of 50 mA/g and 200 mA/g in LiTFSi/TEGDME electrolyte.

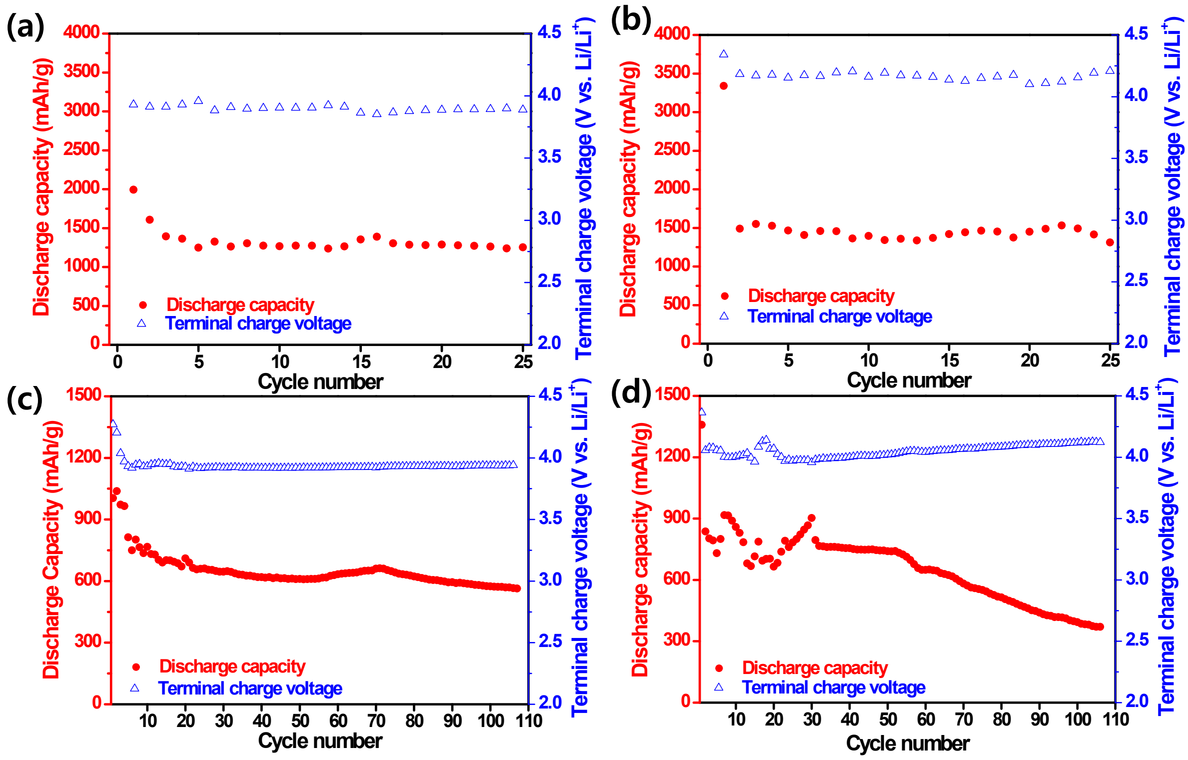

Figure S9. Cycle performance and terminal voltages after charging of Li-O_2 batteries with (a, c) dendritic Ru- and (b, d) RuO_2- foams at a current density of 50 mA/g and 200 mA/g.

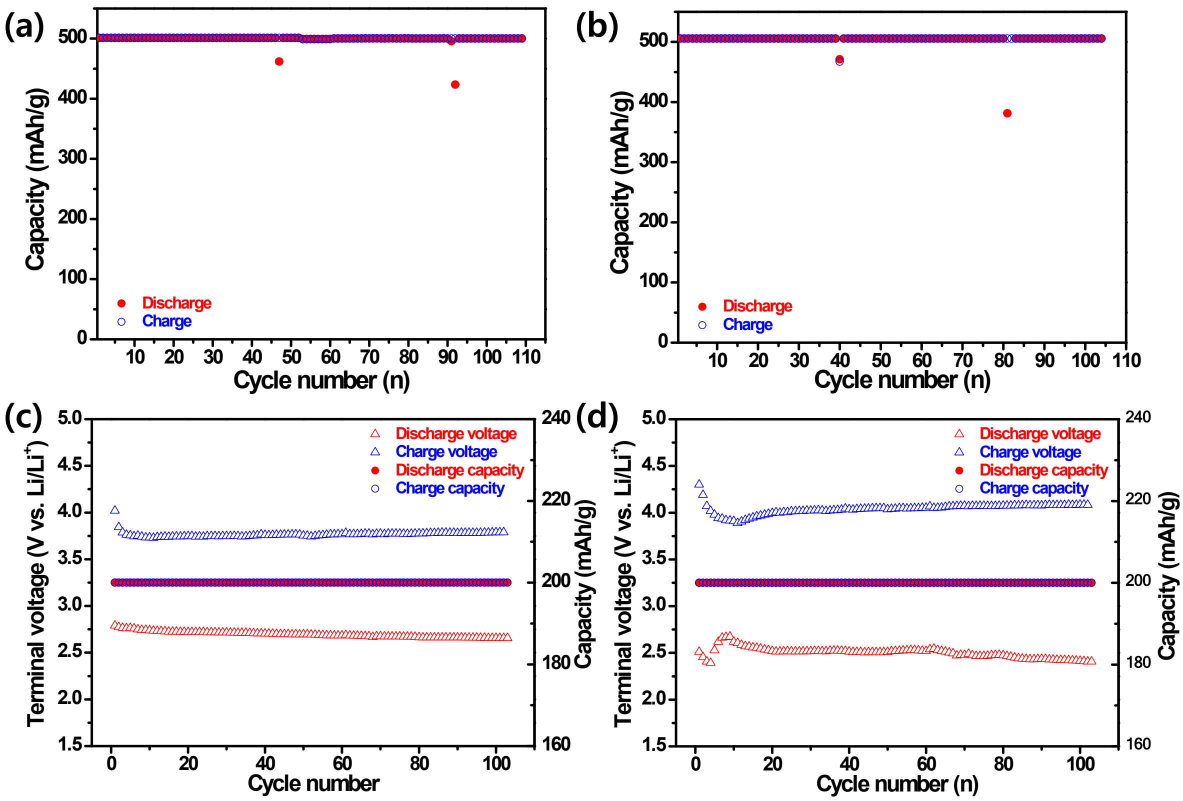

Figure S10. Cycle performance and terminal voltages after charging of Li-O_2 batteries with (a, c) dendritic Ru and (b, d) RuO_2 at a limited capacity of 500 and 200 mAh/g