Materials Panel Abstract & Speaker Biography

Li Metal Anode Protection to Inhibit Dendrite Growth in Safe Lithium-Sulfur Batteries

*Qiang Zhang**

Beijing Key Laboratory of Green Chemical Reaction Engineering and Technology, Department of Chemical Engineering, Tsinghua University, Beijing, 100084

Li metal is considered as the "Holy Grail" of energy storage systems due to its extremely high theoretical specific capacity (3860 mAh g^{-1}), low gravimetric density (0.59 g cm^{-3}), and lowest negative redox potential (−3.040 V vs. standard hydrogen electrode). The bright prospects give rise to worldwide interests in the metallic Li for the next generation energy storage systems, including highly considered rechargeable metallic Li batteries such as Li-O_2 and Li-sulfur (Li–S) batteries. However, the formation of Li dendrites induced by inhomogeneous distribution of current density on the Li metal anode and the concentration gradient of Li ions at the electrolyte/electrode interface is a crucial issue that hinders the practical demonstration of high-energy-density metallic Li batteries.

A unique nanostructured anode with Li metal distributed in fibrous Li_7B_6 matrix is proposed as a promising anode to prevent the dendrite growth. The nanostructured anode is with a large specific area, thus rendering a low current density on the Li metal anode. The dendrite growth is effectively inhibited via decreasing the growth velocity of Li deposits and then limiting the final size of deposited Li on the nanostructured matrix, thus leading to the dendrite-free morphology at macroscale. The concentration gradient of Li ions near the anode surface are sharply reduced, because the 3D Li_7B_6 fibrous structure provides quantities of free space to accommodate electrolyte.

To improve the Coulombic efficiency of Li depositing/dissolution, a dual-phase Li metal anode containing polysulfide-induced SEI and nanostructured graphene framework was investigated for Li-S batteries. Free-standing graphene foam provides several promising features as underneath layer for Li anode, including (1) relative larger surface area than 2D substrates to lower the real specific surface current density and the possibility of dendrite growth, (2) interconnected framework to support and recycle dead Li, and (3) good flexibility to sustain the volume fluctuation during repeated incorporation/extraction of Li. The synergy between the LiNO3 and polysulfides provides the feasibility to the formation of robust SEI in an ether-based electrolyte. The efficient in-situ formed SEI-coated graphene structure allows stable Li metal anode with the cycling Coulombic efficiency of ~97 % with high safety and efficiency performance, which is with a low resistance of 19.65 Ω (29.10 Ω for Cu foil based Li metal anode) and high ion conductivity of 5.42×10^{-2} mS cm-1 (2.33×10^{-2} mS cm^{-1} for Cu foil based Li metal anode).

These results indicated that interfacial engineering of nanostructured electrode were a promising strategy to handle the intrinsic problems of Li metal anodes, thus shed a new light toward LMBs, such as Li-S and Li-O_2 batteries with high energy density.

References

1. X. B. Cheng, H. J. Peng, et al, Small 2014, 10, 4257.
2. X. B. Cheng, H. J. Peng, et al, ACS Nano 2015, 9, 6373.
3. R. Zhang, X.B. Cheng, et al. Adv Mater 2016, 28, 2155.
4. X.B. Cheng, T.Z. Hou, et al. Adv Mater 2016, 28, 2888.

Speaker Biography:

Qiang Zhang graduated as a PhD from the Chemical Engineering Department, Tsinghua University (China). He had been as a Research Associate in Case Western Reserve University (USA), a postdoc in Fritz Haber Institute of the Max Planck Society (Germany), and a visiting professor in Queen Mary University of London (UK). He was appointed an associate professor of chemical engineering of Tsinghua University in 2011.

His research interests are energy materials, especially lithium metal, lithium-sulfur batteries, graphene, and oxygen electrochemistry. He has authored and coauthored over 100 refereed publications, 29 ESI highly cited paper, >8500 citation and an *h*-index of 51. He is associate editor of RSC Advances. He received awards of Newton Advanced Fellowship from Royal Society, UK, NSFC Excellent Young Scientist in China, and 2012-2014 Excellence in Review Awards for CARBON, USA.