【点赞】我校材料院李星博士在国际顶级期刊《Advanced Energy Materials》发表论文

新闻来源：科研处 审核：杨兆中 编辑：杨玉凤 发布日期：2018年07月04日 点击率:2267

近日，我校材料科学与工程学院新能源材料与器件教研室（储能及动力电池科研团队）李星博士与美国西北太平洋国家实验室联合以第一作者在《Advanced Energy Materials》发表学术论文，系统阐述了利用酰亚胺-硼酸盐（Imide-Orthoborate）双盐电解质体系抑制锂枝晶生长、提升锂金属库仑效率的工作原理。

《Advanced Energy Materials》是能源材料类国际顶级期刊，2018年影响因子为21.875，位于中国科学院JCR分区一区。

据李星博士介绍，先进便携式电子产品、电动汽车等的快速发展，对电池的能量密度提出了更高的要求。金属锂具有高的理论比容量（3860 mAh/g）及-3.04 V的超负电极电势（相对标准氢电极），是理想的高比能量二次电池负极材料。因此，开发基于金属锂负极的高比能量二次电池，如锂金属电池、锂空气电池及锂硫电池等重新受到关注，并成为近年来国内外化学电源领域的研究热点。然而，金属锂作为负极使用时，在反复充放电过程中容易出现粉化、枝晶生长等问题，导致对应二次电池的循环性能极差、容量衰减迅速、库仑效率低、极化严重，更为严重的是，锂枝晶生长还会刺穿隔膜导致电池短路并可能引发严重的安全问题。

国内外研究现状表明，锂金属负极性能的改善途径主要包括：锂金属合金化、固体电解质、锂金属表面结构设计、有机电解液促进锂金属/电解质界面SEI膜稳定性。其中，通过优化有机电解液成分及改性添加剂促进锂金属/电解质界面SEI膜稳定性，被认为是抑制锂枝晶生长、提升库仑效率的最简便、有效的途径之一。

在此背景下，该论文通过研究Imide-Orthoborate双盐电解质体系发现，LiTFSI-LiBOB是化学及电化学相对最稳定的双盐电解质体系、能够在锂金属表面形成无锂枝晶、致密、稳定的SEI膜；通过利用$LiPF_6$作为添加剂改性LiTFSI-LiBOB双盐体系，可以使生成的SEI膜展现出更薄、更致密、更稳定等特性；而使用$LiPF_6$+ VC + FEC组合添加剂改性的LiTFSI-LiBOB双盐体系，还可以使对应的锂金属负极的库仑效率提升至98.1%左右。上述研究结果对于解决下一代高能量密度锂金属电池的安全性问题、推动其产业化进程具有重要意义。（科研处供稿）

相关研究论文信息：

Title：Dendrite-Free and Performance-Enhanced Lithium Metal Batteries through Optimizing Solvent Compositions and Adding Combinational Additives

Authors：Xing Li, Jianming Zheng, Xiaodi Ren, Mark H. Engelhard, Wengao Zhao, Qiuyan Li, Ji-Guang Zhang,* and Wu Xu*

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FULL PAPER

Lithium Metal Batteries

Dendrite-Free and Performance-Enhanced Lithium Metal Batteries through Optimizing Solvent Compositions and Adding Combinational Additives

Xing Li, Jianming Zheng, Xiaodi Ren, Mark H. Engelhard, Wengao Zhao, Qiuyan Li, Ji-Guang Zhang, and Wu Xu**

The instability of lithium (Li) metal anodes due to dendritic growth and low Coulombic efficiency (CE) hinders the practical application of high-energy-density Li metal batteries. Here, the systematic studies of improving the stability of Li metal anodes and the electrochemical performance of Li metal batteries through the addition of combinational additives and the optimization of solvent compositions in dual-salt/carbonate electrolytes are reported. A dendrite-free and high CE of 98.1% for Li metal anode is achieved. The well-protected Li metal anode and the excellent cyclability and rate capability of the 4-V Li metal batteries are obtained. This is attributed to the formation of a robust, denser, more polymeric, and higher ionic conductive surface film on the Li metal anode via the electrochemical reductive decompositions of the electrolyte components and the ring-opening polymerization of additives and cyclic carbonate solvents. The key findings of this work indicate that the optimization of solvent compositions and the manipulation of additives are facile and effective ways to enhance the performances of Li metal batteries.

1. Introduction

The lithium (Li) metal battery (LMB) is a promising high-energy-density energy storage system. However, the uncontrollable dendrite formation and low Coulombic efficiency (CE) associated with the Li metal anode have largely hindered the practical applications of LMBs.[1] In recent years, extensive efforts have been made to address the main problems of Li metal anode and to improve the electrochemical performances of the related LMBs, and plenty of promising results have been achieved, which include the applications of additives to the liquid electrolytes,[2] solid-state electrolytes,[3] concentrated electrolytes,[4] ionic liquids,[5] protective layers on the Li metal anode,[6] nanoscale design,[7,8] selective deposition,[9] etc.

Among the reported approaches, the reformulation of electrolytes with different Li salts and additives has been regarded as an easy and cost-effective method.[10] The conventional lithium hexafluorophosphate ($LiPF_6$)/carbonate electrolytes have been found to be detrimental to Li metal anode, especially at high charge current densities, which is mainly due to the serious corrosion of Li metal anode, the consumption of electrolyte, the continuous formation of solid electrolyte interphase (SEI) layer, and the increase of cell impedance.[8] The highly concentrated electrolytes of lithium bis(trifluoromethanesulfonyl)imide (LiTFSI) or lithium bis(fluorosulfonyl)imide (LiFSI) in ether solvents have been reported to be effective in suppressing the Li dendrite growth and improving the Li CE.[4] However, the ether-based electrolytes normally are not electrochemically stable at the voltages around and above 4 V versus Li/Li^+.[8] Recently, a dual-salt electrolyte of LiTFSI and lithium bis(oxalato) borate (LiBOB) in a carbonate solvent mixture has been proved to be favorable for suppressing the Li dendrite and improving the CE value of the Li metal anode.[2,8] Especially, our recent work discovered that a robust and conductive surface layer on the Li metal anode could be formed by adding 0.05 M (an optimal additive amount) $LiPF_6$ to the 1 M LiTFSI-LiBOB/carbonate

Dr. X. Li, Dr. J. Zheng, Dr. X. Ren, W. Zhao, Q. Li, Dr. J.-G. Zhang, Dr. W. Xu
Energy and Environment Directorate
Pacific Northwest National Laboratory
Richland, WA 99354, USA
E-mail: jiguang.zhang@pnnl.gov; wu.xu@pnnl.gov
Dr. X. Li
School of Materials Science and Engineering
Southwest Petroleum University
Chengdu, Sichuan 610500, China
M. H. Engelhard
Environmental Molecular Sciences Laboratory
Pacific Northwest National Laboratory
Richland, WA 99354, USA
W. Zhao
School of Energy Research
Xiamen University
Xiamen, Fujian 361102, China
The ORCID identification number(s) for the author(s) of this article can be found under https://doi.org/10.1002/aenm.201703022.

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