中国科学院院长奖申报表

申 报 类 别

姓　　　名　王毅林

单 位 名 称　中国科学院山西煤炭化学研究所

学 科 专 业　材料科学与工程

学科专业代码　080500

攻 读 学 位　博士研究生

导师姓名及职称　刘占军　研究员

中国科学院人才与人事局制

2026 年 04 月 14 日填

一、基本信息

姓名	王毅林	性别	男	民族	汉族	籍贯	山西省|运城市|盐湖区
出生年月	1994.12.18	政治面貌	群众	入学时间	2022.09.01		
办公电话		手机号码		电子邮件	wdcrwyl@sina.cn		

何时何单位何专业获何种学位	2017 年 6 月在天津理工大学获得材料科学与工程工学学士学位 2022 年 6 月在太原理工大学获得材料科学与工程工学硕士学位

个人简历	起止年月	学习和工作单位	获何种学位
	2013.9-2017.6	天津理工大学	学士学位
	2019.9-2022.6	太原理工大学	硕士学位
	2022.9 至今	中国科学院山西煤炭化学研究所	攻读博士学位

学位课成绩（请附成绩单）

学年学期	课程名称	学位课	学时	学分	成绩
2022—2023 学年秋季学期	中国马克思主义与当代	是	36	2.0	92
2022—2023 学年秋季学期	学术道德与学术写作规范	是	20	1.0	72
2023—2024 学年秋季学期	博士英语	是	64	2.0	91
2023—2024 学年春季学期	Seminar	是	42	3.0	94
2023—2024 学年春季学期	新能源过程与材料	是	42	3.0	92
总学分	11.0	学位课学分 11.0			

论文题目或成果名称	Releasing Free Radicals in Precursor Triggers the Formation of Closed Pores in Hard Carbon for Sodium-Ion Batteries Lowering Energy Barriers of Free Radicals Facilitates Defect Suppressed Carbon Layers of Hard Carbon

论文（或成果）性质	基础研究

二、申报人在学期间发表论文、出版专著、专利、获奖情况（请在附件中附有关证明材料）

发表论文统计	国内刊物	国际刊物	国内学术会议	国际学术会议	其中发表在核心期刊	其中被SCI(EI)收录篇数
	篇	7 篇	篇	篇	篇	7 篇
第一作者	2 篇	2 篇	篇	篇	篇	2 篇

论文名称	全部作者署名排序	发表时间	刊物名称
ReleasingFreeRadicalsinPrecursorTriggerstheFormationofClosedPoresinHardCarbonforSodium-IonBatteries	YilinWang,ZonglinYi,LijingXie,YixuanMao,WenjunJi,ZhanjunLiu,XianxianWei, FangyuanSu,*andCheng-MengChen*	2024.3	Advanced Materials
LoweringEnergyBarriersofFreeRadicalsFacilitatesDefect-SuppressedCarbonLayersofHardCarbon	YilinWang,ZonglinYi,ShengbinZhang,YixuanMao,LiLi,HaoLiu,ZhanjunLiu,LijingXie,*andFangyuanSu	2025.7	Small

专著统计	出版专著数量	出版专著数量（第一作者）
	部	部

专著名称	全部作者署名排序	出版时间	出版社名称

专利统计	已授权发明或实用新型专利数	已授权发明或实用新型专利数（第一发明人）
	件	件

专利号	专利名称	全部发明人排序	专利权人

获奖统计	国家级奖励	省部级奖励	校级奖励

	1 项	项	5 项

奖励名称	奖励级别	全部获奖人排序
2024 年度国家奖学金	国家级	王毅林
2024 年度炭室优秀研究生一等奖	校级	王毅林
2025 年度炭室优秀研究生优秀奖	校级	王毅林
2024 年度三好学生	校级	王毅林
2024 国科大研究生论坛优秀报告	校级	王毅林
宁德时代零碳科技解决方案创新大奖赛总决赛，优秀奖	企业级	易宗琳，贾惋茹，王毅林，侯玮琰

三、本人开展的科研工作及取得的成果情况介绍

本人自博士 2022 年入学以来以竹基硬碳为对象，系统揭示了热解过程中自由基行为与硬碳微观结构及储钠性能的构效关系。通过调控炭化参数、引入过渡金属催化剂、实施脱木质素处理及光化学侧链改性，分别实现了缺陷与闭孔的协同优化、长炭层与闭孔结构的构筑、氧中心自由基对闭孔形成的驱动，以及简单芳香自由基对三维连接结构的精准引导。基于上述策略，所制竹基硬碳的首次库伦效率、可逆容量、平台容量及倍率性能均显著提升，并在软包电池中表现出优异的循环与倍率性能；相关成果以第一作者发表于 Advanced Materials 和 Small。

四、在政治思想、道德品质、学风等方面自我评价

首先在思想觉悟上我始终向党组织靠拢，通过不间断的政治思想理论学习，我已能用习近平新时代中国特色社会主义思想来认识世界认识社会，能清醒的意识到自己所担负的社会责任，对个人的人生理想和发展目标，有了相对成熟的认识和定位。

其次在专业课程的学习上，作为学生我从不放松学习，根据自身研究方向的要求及导师的建议，有针对性的认真研读了有关核心课程，为自己的科研工作打下了扎实基础;同时涉猎了部分其他课程，积极参加各种学术活动，开阔视野，对本研究方向的应用背景以及整个学科的结构有了宏观的认识。在外语学习方面，更从未放松过学习，大一时层一次性通过英语四六级，后续也一次性通过了雅思考试，具备了较强的英语听说能力，在撰写论文期间，查阅了大量的英文资料，加强了自己的英语读写能力。

在科研工作上，根据导师的指导，研读了大量论著及国内外相关的文献资料，逐步明确了研究方向，通过自身不断的努力，以及与师长同学间的探讨交流，取得了一些比较满意的成果。在这期间，查阅资料，综合分析等基本素质不断提高，书面表达的能力也得到了锤炼，尤其是独立思考判断和研究的能力，有了很大进步。博士期间，以独立一作在 Advanced Materials，Small 上发表研究型论文一篇。

平时生活中，为人处世和善热情，和同学关系融洽，并积极参与各项集体活动，热情为同学们服务，同时根据自身爱好和能力，业余参与了一些社会活动，为个人综合素质的全面发展打下基础。

博士阶段我所获颇丰，从学业、科研工作，到个人素质，都得到了充分的培养和锻炼，是充实且有意义的时光。相信这些经历和积累都将成为我人生道路上的宝贵财富。在以后的工作和学习中，我将继续保持并发扬严谨治学的作风，兢兢业业，争取取得更大的成绩。

五、导师对申请人的评价及推荐意见

同意推荐

签名：刘心军

2026 年 4 月 15 日

五、研究所/院系推荐意见   负责人签名：（公　章） 年　月　日
六、学校推荐意见 负责人签名：（公　章） 年　月　日

院长奖学金申请者申请信息情况统计表

<table>
<tr><td>姓名</td><td>王毅林</td><td colspan="2">以第一作者发表论文情况（含学术会议）</td><td rowspan="2">SCI/EI 收录文章累计影响因子</td><td rowspan="2">参与专利</td><td colspan="2" rowspan="2">重要获奖荣誉</td></tr>
<tr><td>类别</td><td>博士</td><td>论文篇数</td><td>主要论文刊物名称（当年 IF）</td></tr>
<tr><td>专业</td><td>材料科学与工程</td><td rowspan="3">1</td><td rowspan="3">A、Advanced Materials (29.4)
B、Small (12.2)</td><td rowspan="3">41.6</td><td rowspan="3">1</td><td>科研学习</td><td>学生工作</td></tr>
<tr><td>联系电话</td><td>18722227320</td><td rowspan="3">1. 2024 年度国家奖学金
2. 2024 年度炭室优秀研究生一等奖
3. 2025 年度炭室优秀研究生优秀奖
4. 2024 年度三好学生
5. 2024 国科大研究生论坛优秀报告
6. 宁德时代零碳科技解决方案创新大奖赛总决赛，优秀奖</td><td rowspan="3">1. 2023 年科学日志愿者
2. 2024 年科学日志愿者
3. 第十七届新炭会议志愿者</td></tr>
<tr><td>指导教师审核签名</td><td>刘占军</td></tr>
<tr><td colspan="6">发表论文题目列表：
1、 Releasing Free Radicals in Precursor Triggers the Formation of Closed Pores in Hard Carbon for Sodium-Ion Batteries (A)
2、 Lowering Energy Barriers of Free Radicals Facilitates Defect-Suppressed Carbon Layers of Hard Carbon (B)
申请专利：
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</table>

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Releasing Free Radicals in Precursor Triggers the Formation of Closed Pores in Hard Carbon for Sodium-Ion Batteries

Yilin Wang, Zonglin Yi, Lijing Xie, Yixuan Mao, Wenjun Ji, Zhanjun Liu, Xianxian Wei, Fangyuan Su, and Cheng-Meng Chen**

Increasing closed pore volume in hard carbon is considered to be the most effective way to enhance the electrochemical performance in sodium-ion batteries. However, there is a lack of systematic insights into the formation mechanisms of closed pores at molecular level. In this study, a regulation strategy of closed pores via adjustment of the content of free radicals is reported. Sufficient free radicals are exposed by part delignification of bamboo, which is related to the formation of well-developed carbon layers and rich closed pores. In addition, excessive free radicals from nearly total delignification lead to more reactive sites during pyrolysis, which competes for limited precursor debris to form smaller microcrystals and therefore compact the material. The optimal sample delivers a large closed pore volume of 0.203 cm^3 g^{-1}, which leads to a high reversible capacity of 350 mAh g^{-1} at 20 mA g^{-1} and enhanced Na^+ transfer kinetics. This work provides insights into the formation mechanisms of closed pores at molecular level, enabling rational design of hard carbon pore structures.

1. Introduction

Sodium-ion batteries (SIB) have been regarded as the supplement for lithium-ion batteries due to the abundance of Na element worldwide.[1–3] Unfortunately, there are still shortcomings such as power density and energy density that limit the large-scale application of SIB. SIB with exceptional electrochemical performance primarily rely on the construction of superior anode.[4,5] Therein, hard carbon (HC) is the most cost-effective anode candidate and is gaining recent attention for scalable production.[6–8] HC consists of turbostratic graphene structures and internal pores enclosed by them.[9] Although the sodium storage mechanism of HC is disputed, the plateau capacity below 0.1 V, which is the main source of sodium storage capacity, is highly correlated with pore structure.[10,11]

Modification of HC precursors is found to be an effective approach to regulating the structure of closed pores. Among various precursors that can prepare HC, lignocellulosic biomass possesses innate cross-linked structure that originates from the bonding of the structural bio-macromolecules such as cellulose, hemicellulose, and lignin.[5] It makes lignocellulosic biomass precursors precisely modified at molecular level to regulate closed pore structures in HC. Xia and co-workers report the introduction of carbonyl groups into pine wood to regulate the closed pore structure.[12] Huang and co-workers use chemical-enzymatic fractionation method to improve the amount of closed pores in grain-derived HC.[13] Chou and co-workers construct rich closed pore structures in tissue-derived HC by regulating the molecular structure of cellulose by Mn^{2+} catalysis.[14] Although closed pores are successfully constructed by applying these methods, these works lack insights into the formation mechanisms of closed pores. Based on this, Wang and co-workers utilize waste wood as model materials to comprehensively construct the formation mechanism of closed pores.[15,16] By adjusting the ratio of crystalline (cellulose) to amorphous (hemicellulose/lignin) components in the precursor, they find that cellulose with high crystallinity tends to transform into long graphitic layers, and the amorphous part plays a role in preventing the over-graphitization of carbon layer. However, they only focus on the evolution of the structure from the precursor to the final HC and fail to reveal the mechanisms of closed pore formation at molecular level.

Herein, we propose a strategy of molecular structural design that can enhance free radical reactions in bamboo precursor and precisely regulate the abundance of closed pores in HC. Deliberate removal of lignin from bamboo exposes free radicals in cellulose and hemicellulose, resulting in higher utility of small molecules and acuter free radical reactions during pyrolysis. Ideal abundance and structure of closed pores are hence formed.

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Lowering Energy Barriers of Free Radicals Facilitates Defect-Suppressed Carbon Layers of Hard Carbon

Yilin Wang, Zonglin Yi, Shengbin Zhang, Yixuan Mao, Li Li, Hao Liu, Zhanjun Liu, Lijing Xie, and Fangyuan Su**

Construction of closed pores by optimizing the length of the carbon layer is considered the most effective way to improve the electrochemical performance of hard carbon in sodium-ion batteries. However, the lack of understanding of the carbon layer growth mechanism limits the development of hard carbon. Here, Mn^{2+} is introduced during the pyrolysis process to control the length of the carbon layer of hard carbon. It is demonstrated that the introduction of the transition metal facilitates electron transfer to C—O bonds and thereby promotes homolytic cleavage of chemical bonds to generate free radicals. The simple aromatic radicals generated from oxygen-centered radicals, coupled with those directly derived from biomass, synergistically accelerate the formation of well-developed carbon layers, which improve the initial coulombic efficiency and plateau capacity. The optimal sample has a reversible capacity of 325 mAh g^{-1} and a competitive ICE of 92.7%. Pouch cell batteries exhibit a capacity retention of 280 mAh g^{-1} after 200 cycles and a capacity retention rate of 93.3% at 100 mA g^{-1}. This work enables rational design of carbon structure at molecular level.

1. Introduction

Hard carbon (HC) is a crucial electrode material for sodium-ion batteries and other energy storage devices, offering a high theoretical specific capacity and excellent cycling stability.[1–3] With the growing demand for high-performance energy storage materials, enhancing the electrochemical properties of hard carbon has become a key research focus. The Length of microcrystalline (L_a) of HC is an essential parameter that describes the size of the crystalline domains within the carbon structure.[4,5] A longer microcrystalline length helps reduce the diffusion resistance of sodium ions from the electrolyte into the electrode material and enhances its electrical conductivity.[6] Moreover, an extended L_a promotes the formation of closed pores, thereby significantly improving energy storage capacity and initial coulombic efficiency (ICE).[7] Studies have shown that the microcrystalline length of HC not only influences the performance of its energy storage capacity but is also closely related to its rate capability, cycling lifespan, and other electrochemical properties.[8,9] Therefore, it is imperative to optimize the microcrystalline length of HC to enhance its sodium storage performance.

Numerous studies have demonstrated a significant correlation between the L_a of lignocellulose-based HC and its sodium storage capacity.[5,10–12] By adjusting carbonization parameters such as temperature and heating rate, the L_a can be effectively optimized to enhance the sodium storage capacity of HC. However, solely optimizing the carbonization process is insufficient to fully overcome the challenge of low capacity in HC.[13,14] To address this bottleneck, researchers have explored the introduction of external factors to further regulate the microstructure of HC. Tang et al. investigated the preparation of HC using lignocellulosic precursors with different crystallinities and found that the high content of microcrystalline cellulose in natural wood could be converted into elongated graphite-like layers, which enclose and contract around active sites, forming a closed-pore structure. The resulting HC exhibited a high reversible discharge capacity of 430 mAh g^{-1} at 20 mA g^{-1}.[6] Mao et al. develop HC with long L_a by controlling the degree of oxidation. The optimal HC possesses a specific capacity of 335 and 230 mAh g^{-1} of plateau capacity.[5] Chou et al. employ a two-step rapid thermal annealing strategy to prepare highly cross-linked topologically graphitized carbon from corncob. The extended carbon layers form cavities and tunnels that provide multidimensional pathways for sodium ion migration, resulting in HC materials with a ≈100% contribution of the plateau capacity.[15] These studies have highlighted the effect of L_a of HC, thereby enhancing its sodium storage capacity. However, they only focus on the effect of the modification on the microcrystalline structure of final HC and fail to reveal the mechanisms of the formation for long carbon layers in detail. Therefore, it is imperative to investigate the fundamental mechanism governing the formation of L_a to guide the rational structural design of HC.

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DOI: 10.1002/smll.202506923

国家奖学金荣誉证书

编号: BSY202411211

王毅林同学荣获 2024 年博士研究生国家奖学金，特颁此证。

中华人民共和国教育部

2024 年 12 月

荣誉证书

王毅林同学：

荣获炭材料重点实验室2023-2024年度优秀研究生

一等奖

特发此证，以资鼓励。

中国科学院炭材料重点实验室

炭材料山西省重点实验室

2024年12月

中国科学院大学
University of Chinese Academy of Sciences

授予：王毅林

三好学生

荣　誉　称　号

（2023－2024 学年）

校长：（签名）

2024年[illegible]月20日

No.　42402688

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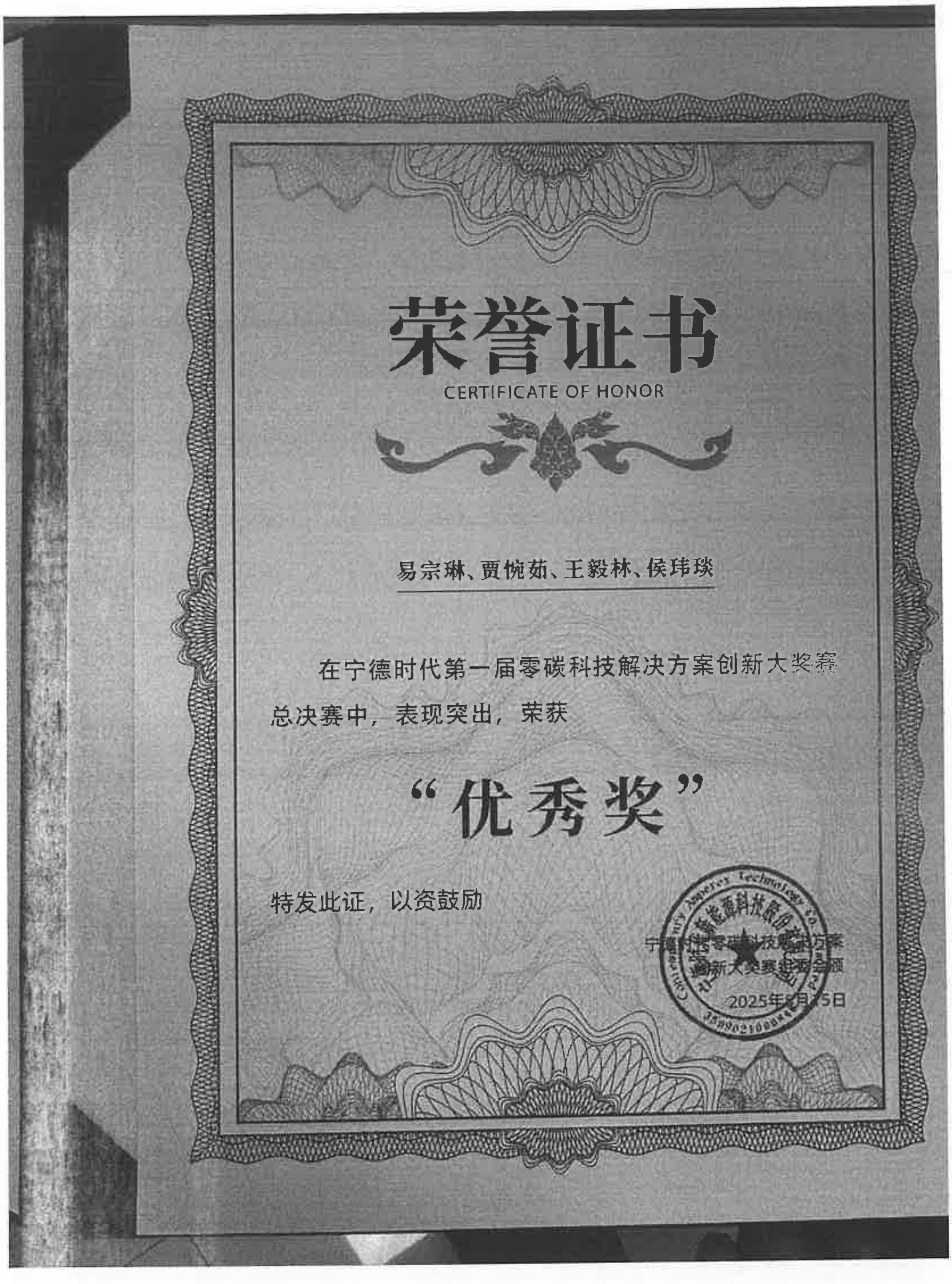

荣誉证书

CERTIFICATE OF HONOR

易宗琳、贾惋茹、王毅林、侯玮琰

在宁德时代第一届零碳科技解决方案创新大奖赛总决赛中，表现突出，荣获

“优秀奖”

特发此证，以资鼓励

宁德时代第一届零碳科技解决方案
创新大奖赛组委会颁

2025年[illegible]月[illegible]5日

荣誉证书

王毅林 同学：

荣获炭材料山西省重点实验室2024-2025年度优秀研究生

优秀奖

特发此证，以资鼓励。

炭材料山西省重点实验室

2025年12月

荣誉证书

王毅林 同学：

在2024中国科学院大学研究生学术论坛–材料科学与工程学科分论坛中，获得

优秀报告奖

特发此证，以资鼓励！

中国科学院上海硅酸盐研究所

二〇二四年十月[illegible]日

附件 3

奖学金申请诚信承诺书

申请人：王毅林，博士/硕士研究生，学号202218004322010，身份证号：142701199412181230。本人已认真阅读《中国科学院山西煤炭化学研究所申报材料科研诚信提醒清单》（附件 4），对照提醒内容逐项自查确认。现郑重承诺：

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承诺人：王毅林

日期： 2026 年 4 月 27 日