

中国计量大学新增博士研究生指导教师申请表

申请一级学科：仪器科学与技术

除表中另有说明外，所填报各项与时间相关的内容均截至 2021 年 12 月 30 日，“近五年”的统计时间为 2017 年 1 月 1 日至 2021 年 12 月 30 日。

一、基本情况

姓名	王新庆	性别	男	出生年月	1977.08
高层次人才	浙江省中青年学科带头人		联系方式	18667107872	
最高学位及授予单位	博士学位，浙江大学				
最高学历，毕业时间，毕业单位	博士学位，200503，浙江大学				
职称，获得职称年月	教授，2010.12				
目前所在学院和一级学科	材料与化学学院，材料科学与工程学科				
主要研究方向	气体传感材料与传感器，先进炭材料，纳米磁性材料及应用				
主要学习和工作经历，从研究生开始					
自何年月	至何年月	单位		学习或工作	
2000.09	2005.03	浙江大学		硕博研究生	
2005.03	今	中国计量大学		教学科研	

二、指导研究生情况

序号	年级	研究生姓名 (层次)	本人担任的 主要工作	研究生培养单位	学院 审核人
1	2019 级	王璐（专硕）	指导教师	计量测试工程学院	陈飞
2	2019 级	许荣佳（专硕）	指导教师	材料与化学学院	蒋瑜仙
3	2018 级	毛佳楠（专硕） 刘金辉（学硕）	指导教师	材料与化学学院	蒋瑜仙
4	2017 级	陈慧东（学硕）	指导教师	材料与化学学院	蒋瑜仙

5	2016 级	魏俊麒（专硕）	指导教师	材料与化学学院	蒋瑜仙
6	2015 级	李晓青（学硕） 陈孝炯（专硕）	指导教师	材料与化学学院	蒋瑜仙

三、近五年立项主持的代表性科研项目

序号	项目名称及编号	项目来源 (项目类型)	起止时间	经费 (万元)	本人排名 /总人数	学院 审核人
1	高丰度稀土永磁体稀土元素分布追踪评价体系研究（编号：2019YFF0217202-1）	国家重点研发计划（课题）	2020.04— 2022.12	6	1/4	任丹丹
2	残留抗生素废水治理用磁性纳米光催化材料研发与示范（编号：2017C33078）	浙江省科技计划项目-公益项目	2017.03— 2019.12	15	1/6	任丹丹
3	竹炭在食品中应用开发（编号：H201872）	企业委托	2017.03— 2019.12	3	1/2	任丹丹
4	高性能自清洁 PE 复合材料研发与应用（编号：H191667）	企业委托	2017.03— 2019.12	10	1/6	任丹丹
5	石墨烯基导热复合材料研制及应用（编号：H191372）	企业委托	2017.03— 2019.12	50	1/8	任丹丹
6	一种永磁材料的制备方法（编号：H195179）	企业委托	2017.03— 2019.12	5	1/4	任丹丹
7	一种纳米钕铁氧体磁性材料的制备方法（编号：H195178）	企业委托	2017.03— 2019.12	5	1/4	任丹丹
8	污染物监测用关键材料及器件研发与应用（编号：H181199）	企业委托	2017.03— 2019.12	10	1/3	任丹丹
9	一种高矫顽力钕铁氧体磁性材料的制备方法（编号：H227004）	企业委托	2022.06— 2023.12	5	1/6	任丹丹
近五年到账总经费：				109	(万元)	

四、近五年发表的代表性学术论文

序号	论文名称	刊物名称	发表时间	SCI（中科院分区）、SSCI收录	本人排名 / 总人数	学院审核人
1	High-valence cations-doped mesoporous nickel oxides nanowires: Nanocasting synthesis, microstructures and improved gas-sensing performance	Sensors & Actuators: B. Chemical	2019. 10	SCI(一区)	通讯作者	任丹丹
2	The highly improved gas-sensing performance of α -Fe ₂ O ₃ -decorated NiO nanowires and the interfacial effect of p-n heterojunctions	Journal of Materials Chemistry C	2020. 06	SCI(一区)	通讯作者	任丹丹
3	Synergistic effects of α -Fe ₂ O ₃ nanoparticles and Fe-doping on gas-sensing performance of NiO nanowires and interface mechanism	Nanotechnology	2021. 09	SCI(二区)	通讯作者	任丹丹
4	Highly improved ethanol gas response of n-type α -Fe ₂ O ₃ bunched nanowires sensor with high-valence donor-doping	Journal of Alloys and Compounds	2020. 02	SCI(二区)	通讯作者	任丹丹
5	Highly improved ethanol gas-sensing performance of mesoporous nickel oxides nanowires with the stannum donor doping	Nanotechnology	2018. 11	SCI(二区)	通讯作者	任丹丹
6	Calcination-temperature-dependent gas-sensing properties of mesoporous nickel oxides nanowires as ethanol sensors	Powder Technology	2017. 09	SCI(二区)	通讯作者	任丹丹
7	Mesoporous-structure enhanced gas-sensing properties of nickel oxides nanowires	Materials Research Bulletin	2017. 11	SCI(二区)	通讯作者	任丹丹
8	Magnetic separation and adsorptive performance for methylene blue of mesoporous NiFe ₂ O ₄ /SBA-15 nanocomposites	Advanced Powder Technology	2017. 03	SCI(二区)	通讯作者	任丹丹
9	Zn ₂ SnO ₄ /activated carbon composites for high cycle performance supercapacitor electrode	Journal of Alloys and Compounds	2018. 12	SCI(二区)	通讯作者	任丹丹

10	Cobalt ferrites/activated carbon: Synthesis, magnetic separation and catalysis for potassium hydrogen persulfate	Materials Science & Engineering B	2019. 04	SCI (二区)	通讯作者	任丹丹
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五、近五年出版的学术专著

序号	专著名称	出版社名称, 时间	本人排名/总人数	学院审核人
1	XXX	XXXX 出版社, XXXX. XX	1/XX	

六、近五年获省部级及以上科研成果奖

序号	获奖名称	授予单位, 获奖等级, 时间	本人排名/总人数	学院审核人
1	高灵敏度气体传感器用介孔纳米材料结构调控与气敏性能增强机制	中国计量测试学会科学技术进步奖, 三等奖, 202105	1/6	任丹丹

七、近五年授权发明专利

序号	专利名称 (国别及专利号)	授权时间	专利有效期止	技术转让到账经费 (万元)	本人排名/总人数	学院审核人
1	一种有序介孔氧化镍气体敏感纳米材料的制备方法 ZL201610313779.1	2017. 06	2023. 12	未技术转让	1/8	任丹丹
2	一种 Ag/竹炭复合材料的制备方法 ZL201510344992.4	2018. 10	2023. 12	未技术转让	1/8	任丹丹
3	一种镍铁氧体磁性纳米复合材料的制备方法 ZL201510322499.2	2018. 02	2023. 12	未技术转让	1/7	任丹丹
专利技术转让到校总经费:			0 (万元)			

九、近五年获正省（部）级及以上领导肯定性批示

序号	成果名称	批示领导及职务	批示时间	本人排名/作者人数	学院审核人
1	XXXXXXXX	XXX	XXXX. XX	1/XX	

与学位授权点学科方向契合的成果(至少填一项)	第 <u>三</u> 项, 第 <u>1、8</u> 条 第 <u>四</u> 项, 第 <u>1-7</u> 条 第 <u>六</u> 项, 第 <u>1</u> 条	第 <u>七</u> 项, 第 <u>1</u> 条 第 <u> </u> 项, 第 <u> </u> 条 第 <u> </u> 项, 第 <u> </u> 条			
<p>本人以上填写内容真实性、准确性无误, 工作中未有学术不端行为, 自觉践行“四个统一”, 做学生成长成才的指导者和引路人。</p> <p style="text-align: right;">申请人签名: _____ 年 月 日</p>					
<p>申请人所在学院、党委审核推荐意见(明确填写是否符合博士生导师任职资格条件, 是否同意推荐):</p> <p>院长签名: _____ (学院盖章) _____ 年 月 日</p> <p>党委书记签名: _____ (党委盖章) _____ 年 月 日</p>					
学科委员会意见	应到委员人数	实到委员人数	同意票数	反对票数	弃权票数
	是否推荐: 是 <input type="checkbox"/> 否 <input type="checkbox"/> 委员会主任签名: _____ 年 月 日				
<p>研究生院复核意见:</p> <p style="text-align: right;">(研究生院盖章)</p> <p style="text-align: right;">分管领导签名: _____ 年 月 日</p>					
校外专家评审结果	评审专家数	强烈推荐	推荐	一般推荐	不推荐
校学科建设委员会意见	应到委员人数	实到委员人数	同意票数	反对票数	弃权票数
	是否通过: 是 <input type="checkbox"/> 否 <input type="checkbox"/> 委员会主任签名: _____ 年 月 日				
<p>学校意见:</p> <p style="text-align: right;">(签章)</p> <p style="text-align: right;">年 月 日</p>					

佐证材料

一、近五年立项主持的代表性科研项目，包括：合同首页、参加人员页、经费页、签名盖章页。【学校科技系统可查询信息】

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首页
密码维护
门户首页
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综合办公

个人资料

计划项目

项目一览

项目申报

合作项目

计划项目经费

合作项目经费

科研成果

知识产权

退出系统

项目查看

立项信息 | 项目成员 | 项目文档 | 项目预算 | 衍生成果 | 到账经费 | 支出经费 | 外拨经费 | 经费公开

审核记录 | 打印 | 返回

【基本信息】

项目名称:	高丰度稀土永磁体稀土元素分布追踪评价体系研究		
项目编号:	2019YFF0217202-1		
负责人类型:	本校老师		
负责人:	王新庆		
所属单位:	材料科学与工程学院		
教研室:	材料化学专业		
计划项目分类:	国家重点研发计划(课题)		
计划项目子类:		校内管理编号:	
协作单位:			

【详细信息】

批准号:		项目来源单位:	
承担单位排名:	第二单位	项目状态:	进行
立项日期:	2020-04-14	开始时间:	
计划完成日期:	2021-11-30	结项日期:	
成果形式:		合同类型:	独立合同
合同经费:	6 万元	配套经费:	0 万元
财务账号:	202018		

【统计信息】

学科门类:	科技类	学科分类:	材料科学
项目来源:	国家科技部	研究类别:	应用研究
国民经济行业(大类):	研究和试验发展	国民经济行业(中类):	自然科学研究和试验发展
合作形式:	与境内注册其他企业合作		
社会经济目标:	一般研究		
组织形式:	牵头单位		

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综合办公

个人资料

计划项目

项目一览

项目申报

合作项目

计划项目经费

合作项目经费

科研成果

知识产权

退出系统

项目查看

立项信息 | 项目成员 | 项目文档 | 项目预算 | 衍生成果 | 到账经费 | 支出经费 | 外拨经费 | 经费公开

审核记录 | 打印 | 返回

【基本信息】

项目名称:	残留抗生素废水治理用磁性纳米光催化材料研发与示范		
项目编号:	2017C33078		
负责人类型:	本校老师		
负责人:	王新庆		
所属单位:	材料科学与工程学院		
教研室:	材料化学专业		
计划项目分类:	浙江省科技计划项目		
计划项目子类:	公益技术应用研究项目	校内管理编号:	
协作单位:			

【详细信息】

批准号:		项目来源单位:	
承担单位排名:	第一单位	项目状态:	进行
立项日期:	2017-03-29	开始时间:	
计划完成日期:	2020-03-29	结项日期:	
成果形式:		合同类型:	独立合同
合同经费:	15 万元	配套经费:	0 万元
财务账号:	176034		

【统计信息】

学科门类:	科技类	学科分类:	材料科学
项目来源:	省、市、自治区科技项目	研究类别:	应用研究
国民经济行业(大类):	研究和试验发展	国民经济行业(中类):	工程和技术研究和试验发展
合作形式:	独立完成		
社会经济目标:	一般研究		
组织形式:	牵头单位		

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首页

密码维护

门户首页

退出系统

登录人员: 王新庆

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停留时间: 00:05:28

综合办公

个人资料

计划项目

合作项目

合作项目一览

计划项目经费

合作项目经费

科研成果

知识产权

退出系统

合作项目查看

合作项目信息

合作项目成员

项目文档

项目预算

衍生成果

到账经费

支出经费

外拨经费

经费公开

审核记录

打印

返回

【基本信息】

合作项目名称:	竹炭在食品中的应用开发		
合作项目类别:	开发	合作项目编号:	H201872
负责人类型:	本校老师		
负责人:	王新庆		
承接单位:	材料科学与工程学院	部门:	材料化学专业
负责人电话:		合作项目状态:	进行
合作项目金额:	3 万元	支付方式:	一次性支付或分期支付
签订日期:	2019-04-01	登记时间:	2020-12-22
开始日期:	2020-12-22	终止日期:	2020-12-22
财务账号:		校内管理编号:	
协作单位:			

【甲方信息】

委托方名称:	浙江节节高炭业有限公司	委托方类别:	有限责任公司
委托方地址:		委托方地市:	浙江省
委托方区县:	丽水	委托方邮编:	
委托方电话:		委托方代表人:	

【统计信息】

学科门类:	科技类	学科分类:	工程与技术科学基础学科
项目来源:	企事业单位委托科技项目	研究类别:	基础研究
合作形式:	独立完成	国民经济行业(大类):	研究和试验发展
国民经济行业(中类):	工程和技术研究和试验发展		
社会经济目标:	一般研究		
组织形式:	牵头单位		

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首页

密码维护

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计划项目

合作项目

合作项目一览

计划项目经费

合作项目经费

科研成果

知识产权

退出系统

合作项目查看

合作项目信息 | 合作项目成员 | 项目文档 | 项目预算 | 衍生成果 | 到账经费 | 支出经费 | 外拨经费 | 经费公开

审核记录 | 打印 | 返回

【基本信息】

合作项目名称:	高性能自清洁PE复合材料研发与应用		
合作项目类别:	开发	合作项目编号:	H191667
负责人类型:	本校老师		
负责人:	王新庆		
承接单位:	材料科学与工程学院	部门:	材料化学专业
负责人电话:		合作项目状态:	进行
合作项目金额:	30 万元	支付方式:	一次性支付或分期支付
签订日期:	2019-12-10	登记时间:	2019-12-24
开始日期:	2019-12-10	终止日期:	2019-12-31
财务账号:		校内管理编号:	
协作单位:			

【甲方信息】

委托方名称:	杭州国塑高分子材料科技有限公司	委托方类别:	有限责任公司
委托方地址:	杭州建德	委托方地市:	浙江省
委托方区县:	杭州建德	委托方邮编:	
委托方电话:		委托方代表人:	

【统计信息】

学科门类:	科技类	学科分类:	材料科学
项目来源:	其他课题	研究类别:	研究与发展成果应用
合作形式:	独立完成	国民经济行业（大类）:	研究和试验发展
国民经济行业（中类）:	自然科学研究和试验发展		
社会经济目标:	自然科学领域的非定向研究		
组织形式:	牵头单位		

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首页

密码维护

门户首页

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当前日期: 2022-10-04

停留时间: 00:07:40

综合办公

个人资料

计划项目

合作项目

合作项目一览

计划项目经费

合作项目经费

科研成果

知识产权

退出系统

合作项目查看

合作项目信息

合作项目成员

项目文档

项目预算

衍生成果

到账经费

支出经费

外拨经费

经费公开

审核记录

打印

返回

【基本信息】

合作项目名称:	石墨烯导热复合材料研制及应用		
合作项目类别:	开发	合作项目编号:	H191372
负责人类型:	本校老师		
负责人:	王新庆		
承接单位:	材料科学与工程学院	部门:	材料化学专业
负责人电话:		合作项目状态:	完成
合作项目金额:	100 万元	支付方式:	一次性支付或分期支付
签订日期:	2019-10-25	登记时间:	2019-11-11
开始日期:	2019-10-25	终止日期:	2020-06-25
财务账号:	191372	校内管理编号:	
协作单位:			

【甲方信息】

委托方名称:	杭州白熊科技有限公司	委托方类别:	有限责任公司
委托方地址:	浙江杭州下沙	委托方地市:	浙江省
委托方区县:	钱塘新区	委托方邮编:	
委托方电话:		委托方代表人:	

【统计信息】

学科门类:	科技类	学科分类:	材料科学
项目来源:	其他课题	研究类别:	研究与发展成果应用
合作形式:	独立完成	国民经济行业（大类）:	研究和试验发展
国民经济行业（中类）:	工程和技术研究和试验发展		
社会经济目标:	工程与技术科学领域的非定向研究		
组织形式:	牵头单位		

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 首页

 密码维护

 门户首页

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综合办公

个人资料

计划项目

合作项目

合作项目一览

计划项目经费

合作项目经费

科研成果

知识产权

退出系统

合作项目查看

合作项目信息

合作项目成员

项目文档

项目预算

衍生成果

到账经费

支出经费

外拨经费

经费公开

审核记录

打印

返回

【基本信息】

合作项目名称:	一种永磁材料的制备方法(专利权转让)		
合作项目类别:	转让	合作项目编号:	H195179
负责人类型:	本校老师		
负责人:	王新庆		
承接单位:	材料科学与工程学院	部门:	材料化学专业
负责人电话:		合作项目状态:	进行
合作项目金额:	5 万元	支付方式:	一次性支付或分期支付
签订日期:	2019-08-06	登记时间:	2019-08-16
开始日期:	2019-08-06	终止日期:	2019-12-31
财务账号:		校内管理编号:	
协作单位:			

【甲方信息】

委托方名称:	东阳市通强磁钢有限公司	委托方类别:	有限责任公司
委托方地址:	浙江金华东阳	委托方地市:	浙江省
委托方区县:	浙江金华东阳	委托方邮编:	
委托方电话:		委托方代表人:	

【统计信息】

学科门类:	科技类	学科分类:	材料科学
项目来源:	其他课题	研究类别:	研究与发展成果应用
合作形式:	独立完成	国民经济行业(大类):	研究和试验发展
国民经济行业(中类):	工程和技术研究和试验发展		
社会经济目标:	工程与技术科学领域的非定向研究		
组织形式:	牵头单位		

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首页密码维护门户首页退出系统

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当前日期: 2022-10-04

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个人资料

计划项目

合作项目

合作项目一览

计划项目经费

合作项目经费

科研成果

知识产权

退出系统

合作项目查看

合作项目信息合作项目成员项目文档项目预算衍生成果到账经费支出经费外拨经费经费公开

审核记录打印返回

【基本信息】

合作项目名称:	一种纳米钕铁氧体磁性材料的制备方法(专利权转让)		
合作项目类别:	转让	合作项目编号:	H195178
负责人类型:	本校老师		
负责人:	王新庆		
承接单位:	材料科学与工程学院	部门:	材料化学专业
负责人电话:		合作项目状态:	进行
合作项目金额:	5 万元	支付方式:	一次性支付或分期支付
签订日期:	2019-08-06	登记时间:	2019-08-16
开始日期:	2019-08-06	终止日期:	2019-12-31
财务账号:		校内管理编号:	
协作单位:			

【甲方信息】

委托方名称:	东阳市江南电磁有限公司	委托方类别:	有限责任公司
委托方地址:	浙江金华东阳	委托方地市:	浙江省
委托方区县:	浙江金华东阳	委托方邮编:	
委托方电话:		委托方代表人:	

【统计信息】

学科门类:	科技类	学科分类:	材料科学
项目来源:	其他课题	研究类别:	研究与发展成果应用
合作形式:	独立完成	国民经济行业(大类):	科技推广和应用服务业
国民经济行业(中类):	其他科技推广和应用服务业		
社会经济目标:	工程与技术科学领域的非定向研究		
组织形式:	牵头单位		



- 综合办公
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- 计划项目
- 合作项目
- 合作项目一览
- 计划项目经费
- 合作项目经费
- 科研成果
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- 退出系统

[合作项目查看](#)

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[合作项目成员](#)
[项目文档](#)
[项目预算](#)
[衍生成果](#)
[到账经费](#)
[支出经费](#)
[外拨经费](#)
[经费公开](#)

审核记录

打印

[返回](#)

【基本信息】

合作项目名称:	污染物监测用关键材料及器件研发与应用		
合作项目类别:	开发	合作项目编号:	H181199
负责人类型:	本校老师		
负责人:	王新庆		
承接单位:	材料科学与工程学院	部门:	材料化学专业
负责人电话:		合作项目状态:	完成
合作项目金额:	30 万元	支付方式:	一次性支付或分期支付
签订日期:	2018-07-01	登记时间:	2018-07-12
开始日期:	2018-07-12	终止日期:	2021-12-31
财务账号:	181199	校内管理编号:	
协作单位:			

【甲方信息】

委托方名称:	杭州川岳环保科技有限公司	委托方类别:	有限责任公司
委托方地址:		委托方地市:	浙江省
委托方区县:		委托方邮编:	
委托方电话:		委托方代表人:	

【统计信息】

学科门类：	科技类	学科分类：	材料科学
项目来源：	企事业单位委托科技项目	研究类别：	应用研究
合作形式：	独立完成	国民经济行业（大类）：	研究和试验发展
国民经济行业（中类）：	工程和技术研究和试验发展		
社会经济目标：	一般研究		
组织形式：	牵头单位		

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科研管理系统

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项目查看

合同信息

合同成员

外拨单位

合同预算

合同经费

衍生成果

审核记录

修改记录

合同文档

执行过程

经费到账

基本信息

合同编号	H227004		
合同名称	一种高矫顽力钕铁氧体磁性材料的制备方法	负责人类型	教师
负责人	王新庆	负责人电话	18667107872
负责人邮箱	wxqnano@cjlu.edu.cn	所属单位	材料与化学学院
合同经费	5 万元	外拨经费	0 万元
合同类别	知识产权转化		
转让类型	知识产权所有权转让		
转让专利	一种高矫顽力钕铁氧体磁性材料的制备方法		
签订日期	2022-06-08	开始日期	2022-06-08
终止日期	2023-06-08	进行状态	进行
支付方式	一次性支付或分期支付		
是否办理免税	是		
免税号	2022330001001913		
设备归属方	乙方	经费卡号	227004
经费卡负责人	王新庆	自备车	否

甲方信息

甲方名称	东阳市强联磁性有限公司	甲方类型	有限责任公司
甲方联系人	金宇鸿	甲方联系电话	13706798669
甲方所属省份	浙江省	甲方所属地市	金华市
甲方所属区县	东阳市	甲方地址	浙江省东阳市湖溪工业区
甲方邮编		备注	收8%管理费

教育部统计信息

统计归属	科技类	一级学科	材料科学
社会经济服务目标	工商业发展-化学工业	项目来源	其他课题
研究类别	应用研究	合作形式	独立完成
国民经济行业	制造业-化学原料和化学制品制造业-合成材料制造		

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 首页
  密码维护
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 计划项目
 合作项目
 计划项目经费
 项目经费
 项目到账
 项目支出
 项目外拨
 合作项目经费
 科研成果
 知识产权
 退出系统

经费到账信息列表

到账经费合计: 242.5 万元 查询

全选	凭证号	项目名称	负责人	财务账号	到账金额(万元)	拨款单位	到账时间	操作
<input type="checkbox"/>	20200841	高丰度稀土永磁体稀土元素分布追踪评价体系研究	王新庆	202018	3.9	浙江凯文磁钢有限公司	2020-09-21	打印
<input type="checkbox"/>	20200066	高丰度稀土永磁体稀土元素分布追踪评价体系研究	王新庆	202018	2.1	浙江凯文磁钢有限公司	2020-04-14	打印
<input type="checkbox"/>	20170124	残留抗生素废水治理用磁性纳米光催化材料研发与示范	王新庆	176034	15	省科技厅	2017-03-29	打印



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 首页
  密码维护
  门户首页
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 个人资料
 计划项目
 合作项目
 计划项目经费
 合作项目经费
 合作项目经费
 合作项目到账
 合作项目支出
 合作项目外拨
 科研成果
 知识产权
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全选	凭证号	合作项目名称	负责人	财务账号	到账金额(万元)	拨款单位	到账时间	操作
<input type="checkbox"/>	20200276	竹炭在食品中的应用开发	王新庆		3	浙江节节高炭业有限公司	2020-12-22	打印
<input type="checkbox"/>	20200441	石墨烯基导热复合材料研制及应用	王新庆	191372	5	杭州白熊科技有限公司	2020-06-11	打印
<input type="checkbox"/>	20200219	石墨烯基导热复合材料研制及应用	王新庆	191372	25	杭州白熊科技有限公司	2020-04-29	打印
<input type="checkbox"/>	20191146	高性能自清洁PE复合材料研发与应用	王新庆		10	杭州国塑高分子材料科技有限公司	2019-12-24	打印

共53条 每页 10 条


 首页 < 1 2 3 > 末页 1

[首页](#)
[«](#)
[1](#)
[»](#)
[尾页](#)

二、近五年发表的代表性学术论文，包括：检索证明、封面、目录、正文首页、刊号。【学校科技系统可查询信息】


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文献检索报告
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附件一：经检索《Science Citation Index Expanded》，下述论文被 SCI-E 收录。（检索时间2022年10月4日）

第1条，共10条：

标题: High-valence cations-doped mesoporous nickel oxides nanowires: Nanocasting synthesis, microstructures and improved gas-sensing performance

作者: Chen, HD (Chen, H. D.); Jin, KL (Jin, K. L.); Xu, JC (Xu, J. C.); Han, YB (Han, Y. B.); Jin, HX (Jin, H. X.); Jin, DF (Jin, D. F.); Peng, XL (Peng, X. L.); Hong, B (Hong, B.); Li, J (Li, J.); Yang, YT (Yang, Y. T.); Gong, J (Gong, J.); Ge, HL (Ge, H. L.); Wang, XQ (Wang, X. Q.)

来源出版物: SENSORS AND ACTUATORS B-CHEMICAL 卷: 296 文献号: 126622 DOI: 10.1016/j.snb.2019.126622 出版年: OCT 1 2019

Web of Science 核心合集中的“被引频次”: 20

入藏号: WOS:000475314800048

语言: English

文献类型: Article 出版物类型: J

作者地址: [Chen, H. D.; Jin, K. L.; Xu, J. C.; Han, Y. B.; Jin, H. X.; Jin, D. F.; Peng, X. L.; Hong, B.; Li, J.; Yang, Y. T.; Gong, J.; Ge, H. L.; Wang, X. Q.] China Jiliang Univ, Coll Mat Sci & Engrn, Hangzhou 310018, Peoples R China

通讯作者地址: Wang, XQ (通讯作者); China Jiliang Univ, Coll Mat Sci & Engrn, Hangzhou 310018, Peoples R China

电子邮件地址: wxqnano@cjlu.edu.cn

IDS 号: I16PC

eISSN: 0925-4005

第2条，共10条：

标题: Zn2SnO4/activated carbon composites for high cycle performance supercapacitor electrode

作者: Jin, KL (Jin, Kaile); Wang, QY (Wang, Qiyue); Chen, LY (Chen, Luyue); Lv, ZX (Lv, Zixuan); Xu, JC (Xu, Jingcai); Hong, B (Hong, Bo); Wang, XQ (Wang, Xinqing)

来源出版物: JOURNAL OF ALLOYS AND COMPOUNDS 卷: 767 页: 419-423 DOI: 10.1016/j.jallcom.2018.07.140 出版年: OCT 30 2018

Web of Science 核心合集中的“被引频次”: 14

入藏号: WOS:000446316500052

语言: English

文献类型: Article 出版物类型: J

作者地址: [Jin, Kaile; Wang, Qiyue; Chen, Luyue; Lv, Zixuan; Xu, Jingcai; Hong, Bo; Wang, Xinqing] China Jiliang Univ, Coll Mat Sci & Engrn, Hangzhou 310018, Peoples R China; [Xu, Jingcai] Zhejiang Univ Technol, Coll Chem Engrn, Hangzhou 310014, Zhejiang, Peoples R China

通讯作者地址: Xu, JC; Wang, XQ (通讯作者); China Jiliang Univ, Coll Mat Sci & Engrn, Hangzhou 310018, Peoples R China

电子邮件地址: xujingcai@cjlu.edu.cn; wxqnano@cjlu.edu.cn

IDS 号: GV70D

ISSN: 0925-8388 eISSN: 1873-4669

第3条，共10条：

标题: Synergistic effects of alpha-Fe2O3 nanoparticles and Fe-doping on gas-sensing performance of NiO nanowires and interface mechanism

作者: Niu, JY (Niu, J. Y.); Wang, L (Wang, L.); Hong, B (Hong, B.); Xu, JC (Xu, J. C.); Han, YB (Han, Y. B.); Jin, HX (Jin, H. X.); Zeng, YX (Zeng, Y. X.); Peng, XL (Peng, X. L.); Ge, HL (Ge, H. L.); Wang, XQ (Wang, X. Q.)

来源出版物: NANOTECHNOLOGY 卷: 32 期: 48 文献号: 485502 DOI: 10.1088/1361-6528/ac1afb 出版年: NOV 26 2021

Web of Science 核心合集中的“被引频次”: 0

入藏号: WOS:000693408600001

文献类型: Article 出版物类型: J

作者地址: [Niu, J. Y.; Wang, L.; Hong, B.; Xu, J. C.; Han, Y. B.; Jin, H. X.; Zeng, Y. X.; Peng, X. L.; Ge, H. L.; Wang, X. Q.] China Jiliang Univ, Coll Mat Sci & Chem, Hangzhou 310018, Peoples R China

通讯作者地址: Wang, XQ (通讯作者); China Jiliang Univ, Coll Mat Sci & Chem, Hangzhou 310018, Peoples R China

电子邮件地址: wxqnano@cjlu.edu.cn

第4条，共10条：

标题: Highly improved ethanol gas response of n-type alpha-Fe2O3 bunched nanowires sensor with high-valence donor-doping

作者: Mao, JN (Mao, J. N.); Hong, B (Hong, B.); Chen, HD (Chen, H. D.); Gao, MH (Gao, M. H.); Xu, JC (Xu, J. C.); Han, YB (Han, Y. B.); Yang, YT (Yang, Y. T.); Jin, HX (Jin, H. X.); Jin, DF (Jin, D. F.); Peng, XL (Peng, X. L.); Li, J (Li, J.); Ge, HL (Ge, H. L.); Wang, XQ (Wang, X. Q.)

来源出版物: JOURNAL OF ALLOYS AND COMPOUNDS 卷: 827 文献号: 154248 DOI: 10.1016/j.jallcom.2020.154248 出版年: JUN 25 2020

Web of Science 核心合集中的“被引频次”: 34

入藏号: WOS:000520405900050

文献类型: Article 出版物类型: J

作者地址: [Mao, J. N.; Hong, B.; Chen, H. D.; Gao, M. H.; Xu, J. C.; Han, Y. B.; Yang, Y. T.; Jin, H. X.; Jin, D. F.; Peng, X. L.; Li, J.; Ge, H. L.; Wang, X. Q.] China Jiliang Univ, Coll Mat Sci & Chem, Hangzhou 310018, Peoples R China

通讯作者地址: Hong, B; Wang, XQ (通讯作者); China Jiliang Univ, Coll Mat Sci & Chem, Hangzhou 310018, Peoples R China

电子邮件地址: bohong@cjlu.edu.cn; wxqnano@cjlu.edu.cn

第5条，共10条：

标题: The highly improved gas-sensing performance of alpha-Fe2O3-decorated NiO nanowires and the interfacial effect of p-n heterojunctions

作者: Wang, L (Wang, L.); Hong, B (Hong, B.); Chen, HD (Chen, H. D.); Xu, JC (Xu, J. C.); Han, YB (Han, Y. B.); Jin, HX (Jin, H. X.); Jin, DF (Jin, D. F.); Peng, XL (Peng, X. L.); Ge, HL (Ge, H. L.); Wang, XQ (Wang, X. Q.)

来源出版物: JOURNAL OF MATERIALS CHEMISTRY C 卷: 8 期: 11 页: 3855-3864 DOI: 10.1039/c9tc06614d 出版年: MAR 21 2020

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High-valence cations-doped mesoporous nickel oxides nanowires: Nanocasting synthesis, microstructures and improved gas-sensing performance

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ABSTRACT

Mesoporous p-type nickel oxides nanowires (NiO NWs) and Li-, Zn-, Fe- and Sn-doped NiO NWs were synthesized with the nanocasting method, and then the influence of different valence cations doping on components, microstructure and gas-sensing performance was discussed in detail. All as-prepared NiO NWs with the same diameter exist in bundles and present mesoporous-structure, while the doping concentrations decrease with the increasing hydrated ions radius of Zn, Fe and Sn. The gas-sensing results indicate that the different valence cations doping greatly affects the gas-sensing properties of NiO NWs sensors. Li-doped NiO NWs sensor exhibits the decreased response to ethanol gas for the acceptor doping and Zn-doping weakly improve the response of NiO NWs sensor for the defects from the substitution of Ni. The responses are greatly enhanced by the high-valence Fe and Sn doping and Sn-doped NiO NWs sensor presents the highest sensitivity at the high concentration. The extra electrons from the high-valence Fe and Sn donor-doping recombine with the holes in valence band, which leads to the thicker hole-accumulation layer in air and the higher resistance of NiO NWs. In this way, the gas response of mesoporous NiO NWs sensor could be further improved with the high-valence donor-doping through adjusting the carrier concentration.

1. Introduction

Detection and monitoring of the explosive, flammable, toxic and exhaust gases are very important for energy saving and environmental protection [1,2]. Various gas sensors have been developed and used to monitor and detect all kinds of dangerous gases. Owing to their low cost, low power consumption, reliable and simple usability, semiconductor metal oxide (SMO) sensors have widely been used in the field of safety and health [3,4]. These sensors should meet requirements of high sensitivity, selectivity, long-term stability and fast response/recovery time to effectively detect the hazardous volatile organic compounds (VOCs), explosive vapors, and exhaled breath for diagnosis of diseases. With the increasing demand for better SMO sensors with the excellent selectivity and high sensitivity, rigorous efforts are in progress to find more suitable SMO to control the surface and inner electrical properties.

SMO sensors are resistive type devices based on the change of resistance in air and target gas. According to the major charge carrier type, SMO are divided into two categories: n-type (SnO₂ [5,6], ZnO

[6], In₂O₃ [6,7], WO₃ [6,8] and α -Fe₂O₃ [9,10]) and p-type (CuO [11,12], Co₃O₄ [13,14] and NiO [15,16]) semiconductors. The most representative sensing materials focus on n-type SMO, such as SnO₂, In₂O₃, ZnO and WO₃, while the studies on p-type SMO of CuO, NiO, Co₃O₄ and Cr₂O₃ mediums are gradually sparked due to the high selectivity to VOCs for the catalysis [17]. The gas response (or sensitivity) of p-type SMO to the target gas is much smaller than that of n-type SMO with the similar microstructure and morphology [18]. Moreover, p-type SMO sensors present the advantages of higher baseline, humidity stability and safer positive response to reducing gases compared to n-type SMO sensors [4]. In order to improve the gas-sensing performance of p-type SMO, much more efforts have been devoted to the research on the microstructures and components (doping and loading) for the practical applications.

The working mechanism of p-type SMO sensor is mainly based on the resistance change, resulting from adsorption and desorption of oxygen/target gas on the surface of SMO. The adsorptive oxygen ions (O₂⁻, O⁻ and O²⁻) extract electrons from SMO and lead to the hole-accumulation layer in air, which present a low resistance state at the

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The highly improved gas-sensing performance of α -Fe₂O₃-decorated NiO nanowires and the interfacial effect of p–n heterojunctions

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Mesoporous n-type α -Fe₂O₃-decorated p-type NiO nanowires (NiO NWs) were synthesized via a two-step nanocasting method, and then the influence of the heterogeneous α -Fe₂O₃ decoration on the components, microstructure and gas-sensing performance of the NiO NWs was discussed in detail. All prepared samples with a uniform diameter present similar mesoporous microstructures. No α -Fe₂O₃ nanoparticles are observed on the surfaces of the NiO NWs and α -Fe₂O₃ nanoparticles are found to exist in the mesopores between nanowires. Decoration with α -Fe₂O₃ nanoparticles greatly affects the ethanol gas response. The response of the (Fe₂O₃)_{0.027}/NiO NW sensor is about 13 times that of a pristine NiO NW sensor toward 100 ppm ethanol gas at 280 °C. The (Fe₂O₃)_{0.027}/NiO NW sensor presents an excellent gas response, and good reproducibility and selectivity due to the α -Fe₂O₃ nanoparticles. The formation of α -Fe₂O₃/NiO p–n heterojunctions at the interfaces of the α -Fe₂O₃ nanoparticles and NiO NWs significantly affects electron transitions in air and ethanol gas. The small α -Fe₂O₃ nanoparticles (2–3.85 nm) are entirely within the electron depletion region in different gases due to the interfacial effects of p–n heterojunctions, leading to decreased resistance in air and increased resistance in ethanol gas.

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1. Introduction

In past decades, a great number of gas sensors, such as catalytic combustion sensors,^{1,2} infrared sensors^{3,4} and semiconductor sensors,^{5–7} have been developed to detect and monitor dangerous, harmful, pathogenic and toxic gases. Among these, metal oxide semiconductor (MOS) gas sensors have been widely employed for practical applications due to their low cost, easy synthesis, good physicochemical stability, and long service-life.^{8–10} Common representative MOS gas sensors are n-type oxides, such as SnO₂, ZnO and α -Fe₂O₃, with better gas responses.^{11–13} The responses of p-type MOS sensors (NiO, CuO, Cr₂O₃, Cr₃O₄, etc.) are much smaller (square root relationship) than those of n-type MOS sensors with similar microstructures.^{14–18} However, for highly improved selective oxidation in response to most volatile organic compounds, p-type MOS sensors have also been widely investigated.^{16–18} More and more research has focused on improving the gas-sensing performance through microstructure control, ion-doping, and heterogeneous loading (including noble metals, graphene and p–n heterojunctions) to obtain higher surface areas or to change the resistance of p-type MOS sensors.^{19–21}

The p-type nickel oxide (NiO) semiconductor with a wide bandgap (about 3.4 eV) exhibits excellent performance and potential applications in the fields of photocatalysis, gas sensing, magnetism and supercapacitance due to its high thermal and chemical stability, environmental friendliness, and lower cost.^{21–24} In order to increase the amount of absorbed oxygen at the surface, several methods have recently been reported for preparing NiO nanostructures with higher surface areas, such as the use of nanotubes, nanosheets, nanowires, nanobelts, and nanospheres.^{25–27} Furthermore, enormous amounts of research into NiO nanostructures have been carried out to optimize the gas-sensing performance through ion-doping, noble-metal loading, and the formation of heterojunctions.^{28–30} Among these approaches, p–n heterojunctions can greatly affect the surface carrier concentration at the interface (depletion layer) and effectively improve the gas-sensing performance of NiO-based gas sensors.^{31–33} The Fermi levels across the interface of a p–n heterojunction equilibrate to the same energy level, leading to the formation of a charge depletion layer for carrier recombination at the interface. In this way, a large change in the p–n heterojunction resistance results in obvious improvement of the gas-sensing performance. Wang *et al.* reported that hierarchical α -Fe₂O₃/NiO heterojunction sensors exhibited excellent gas-sensing performance toward toluene, about 13.18 times higher than a pristine NiO sensor.²⁸ A NiO semi-shielded SnO₂

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Synergistic effects of α -Fe₂O₃ nanoparticles and Fe-doping on gas-sensing performance of NiO nanowires and interface mechanism

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Abstract

High surface area nickel oxide nanowires (NiO NWs), Fe-doped NiO NWs and α -Fe₂O₃/Fe-doped NiO NWs were synthesized with nanocasting pathway, and then the morphology, microstructure and components of all samples were characterized with XRD, TEM, EDS, UV-vis spectra and nitrogen adsorption-desorption isotherms. Owing to the uniform mesoporous template, all samples with the same diameter exhibit the similar mesoporous-structures. The loaded α -Fe₂O₃ nanoparticles should exist in mesoporous channels between Fe-doped NiO NWs to form heterogeneous contact at the interface of n-type α -Fe₂O₃ nanoparticles and p-type NiO NWs. The gas-sensing results indicate that Fe-dopant and α -Fe₂O₃-loading both improve the gas-sensing performance of NiO NWs sensors. α -Fe₂O₃/Fe-doped NiO NWs sensors presented the highest response to 100 ppm ethanol gas (55.264) compared with Fe-doped NiO NWs (24.617) and NiO NWs sensors (3.189). The donor Fe-dopant increases the ground state resistance and the absorbed oxygen content in air. α -Fe₂O₃ nanoparticles in electron depletion region result in the increasing resistance in ethanol gas and decreasing resistance in air. In this way, α -Fe₂O₃/Fe-doped NiO NWs sensor presents the excellent gas-sensing performance due to the formation of heterogeneous contact at the interface.

Keywords: nanowires, nanocasting, gas-sensing performance, heterogeneous contact

(Some figures may appear in colour only in the online journal)

1. Introduction

With the rapid development of human economic activities and industrial production, a large number of waste gas, smoke and dust are discharged into the atmosphere. As the result, air pollution has become one of the most important factors to harm human health. Therefore, it has become an urgent social requirement to develop gas sensors with the excellent gas sensitivity and realize the effective monitoring and detection of toxic and harmful gases. Among them, semiconductor metal oxide (SMO) gas sensors have been widely used in practical applications due to the advantages of low cost, low

power consumption, high selectivity and long-term stability [1–4]. The gas-sensing performance of SMO sensors depends on the change of resistance caused by the adsorption/desorption of target gas on the surface of SMO [5]. It is a great significance to control the microstructure of gas-sensing materials, improve the gas-sensing properties and clarify the physical mechanism for the development of SMO gas sensors with the excellent performance.

Owing to the excellent physicochemical stability, low toxicity, chemical stability and impressive electrical conductivity, p-type NiO nanostructures with bandgap of 3.6–4.0 eV have been used in various fields, such as supercapacitors, magnetic mediums, electrochromic elements, catalysts, gas sensors and so on [6, 7]. The sensitivity of p-type

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Highly improved ethanol gas response of n-type α -Fe₂O₃ bunched nanowires sensor with high-valence donor-doping

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ABSTRACT

Mesoporous n-type hematite bunched nanowires (α -Fe₂O₃ BNWs) and Zn-, In- and Sn-doped α -Fe₂O₃ BNWs were synthesized by nanocasting method, and then the influence of the different-valence metals-doping on the microstructures, components and gas-sensing properties is discussed in detail. All samples present mesoporous-structure and are composed of the uniform α -Fe₂O₃ nanowires. The Zn, Fe, Sn and In-doped concentration decreased with the increasing radius of their hydrated ions. The ethanol gas-sensing results indicate that the different-valence metals-doping greatly affects the response of α -Fe₂O₃ BNWs sensors to ethanol gas. The sensitivity to 100 ppm ethanol gas increased from 10.046 for Fe_{1.896}Zn_{0.104}O_{2.948} BNWs sensor up to 45.556 for Fe_{1.938}Sn_{0.062}O_{3.031} BNWs sensor with the increasing metal valence. The high-valence Sn-doping not only decreases the ground state resistance, but also reduces barrier and work function of α -Fe₂O₃ BNWs, which results in the improved the sensitivity of α -Fe₂O₃ BNWs.

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1. Introduction

Owing to the excellent electric, optical and redox properties, metal oxide semiconductor (MOS) nanostructures have been widely used as the electron devices [1], photocatalysts [2,3] and gas sensors [4–8]. MOS nanostructures have attracted a great deal of attention as gas sensors for their low-cost, considerable chemical stability [9,10]. MOS gas sensors have been always used to detect the trace amounts of volatile organic compounds, inflammable and explosive gases [10,11]. However, the low sensitivity, selectivity and response/recovery time of MOS gas sensors greatly limits their applications, and more and more works have been focused on the improvement of gas-sensing performance of MOS sensors with the microstructures controlling, doping and loading [11–13].

As reported, the response of p-type MOS sensor to target gas was the square root of that of n-type MOS sensor with the same morphology and microstructures [14]. The researches on the gas-

sensing properties are mainly focus on n-type MOS nanostructures, including SnO₂, In₂O₃, α -Fe₂O₃, ZnO and so on [15]. Hematite (α -Fe₂O₃) nanostructures with the bandgap of about 2.1 eV is one of the most important MOS as the gas-sensing mediums due to the low-cost, high stability and environment friendly [16]. In order to optimize the gas-sensing performance of α -Fe₂O₃ nanostructures, more studies have been devoted to the research on the microstructures, morphologies and components to adjust the surface and body resistance of α -Fe₂O₃ nanostructures [17].

The work mechanism of α -Fe₂O₃ nanostructures gas sensors should be attributed to the resistance change in air and target gas from the adsorption and desorption of target gas molecules [11,12]. The adsorptive oxygen extract body electrons to form anionic oxygen (O_2^- , O^- , O^{2-}) on surface in air, which leads to the formation of electron depletion layer. As the result, the total resistance of α -Fe₂O₃ nanostructures greatly increases in air. When the reducing gases are introduced, the adsorptive anionic oxygen on the surface prefers to react with the reducing gases and re-injected electrons back to α -Fe₂O₃ nanostructures. In this way, the electron depletion layer weakens and the resistance of α -Fe₂O₃ decreases in the reducing gas. Therefore, there are two ways to improve the sensitivity of α -Fe₂O₃ nanostructures, one is to increase the resistance in air and another is to decrease the resistance in reducing gas [16,17].

The equivalent circuits of n-type MOS sensors can be explained

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Highly improved ethanol gas-sensing performance of mesoporous nickel oxides nanowires with the stannum donor doping

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Abstract

Mesoporous nickel oxides (NiO) and stannum(Sn)-doped NiO nanowires (NWs) were synthesized by using SBA-15 templates with the nanocasting method. X-ray diffraction, transmission electron microscope, energy dispersive spectrometry, nitrogen adsorption/desorption isotherm and UV-vis spectrum were used to characterize the phase structure, components and microstructure of the as-prepared samples. The gas-sensing analysis indicated that the Sn-doping could greatly improve the ethanol sensitivity for mesoporous NiO NWs. With the increasing Sn content, the ethanol sensitivity increased from 2.16 for NiO NWs up to the maximum of 15.60 for $\text{Ni}_{0.962}\text{Sn}_{0.038}\text{O}_{1.038}$, and then decreased to 12.24 for $\text{Ni}_{0.946}\text{Sn}_{0.054}\text{O}_{1.054}$ to 100 ppm ethanol gas at 340 °C. The high surface area from the Sn-doping improved the adsorption of oxygen on the surface of NiO NWs, resulting in the smaller surface resistance in air. Furthermore, owing to the recombination of the holes in hole-accumulation layer with the electrons from the donor impurity level and the increasing the body defects for Sn-doping, the total resistance in ethanol gas enhanced greatly. It was concluded that the sensitivity of Sn-doped NiO NWs based sensor could be greatly improved by the higher surface area and high-valence donor substitution from Sn-doping.

Keywords: nickel oxide, donor doping, mesoporous-structure, gas-sensing properties

(Some figures may appear in colour only in the online journal)

1. Introduction

Oxide semiconductors were one of the candidate materials for the detection of explosive and toxic gases for their low cost, high sensitivity, rapid response/recovery rate and selective detection. Oxide semiconductors for gas sensors could be classified into two different groups according to the major charge carrier type: n-type (SnO_2 [1, 2], ZnO [3, 4], TiO_2 [5, 6], $\alpha\text{-Fe}_2\text{O}_3$ [7, 8], WO_3 [9, 10]) and p-type (CuO [11, 12], NiO [13, 14], Co_3O_4 [15, 16]). It was reported the response of a p-type oxide semiconductor gas sensor to a target gas was equal to the square root of that of an n-type oxide semiconductor gas sensor to the same gas when the

morphological configurations of both sensor materials were identical [17]. Although p-type oxide semiconductors showed the lower response to target gas compared to the n-type oxide semiconductor, it was very sensitive to the low concentration hazardous gas and presented the practical value in gas sensor application. Among the p-type oxide semiconductor, nickel oxide (NiO) with bandgap energy of 3.6–4.0 eV was believed to be a promising gas-sensing material due to its excellent physicochemical properties including chemically and thermally stability, low toxicity and impressive electrical conductivity [18]. Therefore, efforts still wanted to be devoted to the improvement of the gas-sensing characteristics.



Calcination-temperature-dependent gas-sensing properties of mesoporous nickel oxides nanowires as ethanol sensors

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ABSTRACT

In this paper, the mesoporous NiO nanowires (NWs) were synthesized by using SBA-15 silica as the hard templates with the nanocasting method, and then calcined from 550 to 750 °C. X-ray diffraction, transmission electron microscopy (TEM), nitrogen adsorption/desorption isotherm and UV-vis spectrum were used to characterize the morphology, phase structure and microstructure of the as-prepared samples. All results indicated that the calcination temperature greatly affected crystallization degree and specific surface area of the as-prepared NiO NWs. And the crystallization degree increased and specific surface area decreased with the calcination temperature. The higher specific surface area created more active sites for the surface redox reaction, while the higher crystallization degree led to the wider bandgap and made the charge carriers transport easily. It was concluded that the calcination temperature of NiO NWs greatly affected the gas-sensing performance. The optimized results from the gas-sensing behavior indicated that NiO NWs-650 based sensor exhibited the highest sensitivity to ethanol for the suitable calcination temperature. Furthermore, NiO NWs-650 sensor exhibited a better selectivity to ethanol than n-hexane, methanol, acetone and formaldehyde.

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1. Introduction

Owing to their highly electroactive nature, high stabilities, low cost, low toxicity and impressive electrical conductivity switch between the air and analyte and so on, metal oxide semiconductors (such as ZnO [1–3], SnO₂ [4–5], TiO₂ [6], In₂O₃ [7], WO₃ [8], CuO [9], Fe₂O₃ [10–12], MoO₃ [13]) have been considered the most promising gas sensitive materials, and had been successfully applied in many fields of photocatalysis, magnetic materials, lithium battery materials and gas sensors. As one of the p-type semiconductor with bandgap energy of 3.6–4.0 eV with the high chemical stability and thermostability, nickel oxide (NiO) presented a significantly higher oxygen sorption than other metal oxides [14–15], indicating the promising potential in dangerous gas detection and alarm. Recently, NiO nanostructures (nanoparticles [16], nanosheets [17], nanotubes [18], nanowires (NWs), nanoribbons and complicated hierarchical microspheres) had been synthesized and the gas-sensing properties were investigated in detail to improve the gas sensitivity.

The working mechanism of metal oxide semiconductor gas sensor was mainly based on the electrical conductivity change, resulting from adsorption and desorption of gas molecules on the surface of the gas-sensing materials. For p-type NiO nanostructures, the adsorbed oxygen

ions extracted electrons from the gas-sensing materials and led to the hole-accumulation layer at the surface, which presented the low resistance state. When the reducing gases were introduced, the adsorbed oxygen ions at the surface preferred to react with the reducing gas, and released electrons to NiO nanostructures. As the result, the hole-accumulation layer disappeared and the resistance increased [25–27]. As reported before, the gas-sensing performance was primarily affected by the morphology, dimension, specific surface area and the energy band structure of nanostructures. Miao et al. had synthesized NiO NWs with the high aspect ratio by the hydrothermal method, and indicating the excellent gas sensing performance [19]. Tian et al. had prepared hierarchically porous NiO microspheres with the chemical bath deposition and observed the enhanced gas-sensing properties [20]. Compared with the traditional nanostructures, mesoporous structures had exhibited the excellent performances as gas sensors due to their high specific surface area, low charge carrier recombination rate and so on. Therefore, some efforts had been engaged in the preparation of mesoporous metal oxide structure by various methods, including sputtering [21], sol-gel [22], hydrothermal [23] and template methods [24]. X. Lai et al. had prepared the mesoporous NiO with thin pore walls via the nanocasting route, indicating a much higher response to HCHO than the bulk NiO at low concentration levels [24]. The higher specific surface area of mesoporous structure possessed the more surface defects and oxygen vacancies at the surface for the surface redox reaction.

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Mesoporous-structure enhanced gas-sensing properties of nickel oxides nanowires



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ABSTRACT

Nickel oxides (NiO) nanowires were synthesized using the ordered mesoporous silica SBA-15 as hard templates with the nanocasting method, and then mesoporous NiO nanowires (NiO MNWs) were separated from the dispersed NiO nanowires (NiO DNWs) by the centrifugation technique. XRD, TEM, nitrogen adsorption/desorption isotherm and UV-vis spectrum were used to characterize the phase structure and microstructure. Both samples existed in bundles with the different grain size and NiO MNWs with the larger grain size presented the higher mesopores percent. The specific surface area ($92.61 \text{ m}^2/\text{g}$) and bandgap (3.31 eV) of NiO MNWs were higher than those of NiO DNWs for the higher mesoporous-structure. Therefore, the NiO MNWs based sensor exhibited the good sensitivity and fast response-recovery to ethanol at 340°C . The gas-sensing properties of NiO MNWs were better than those of the NiO DNWs, which should be attributed to the higher surface area and wider bandgap.

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1. Introduction

Various oxide semiconductor based gas sensors have been used to detect harmful and toxic gases [1–7]. The most representative sensor materials, such as SnO_2 , ZnO , TiO_2 , In_2O_3 and Fe_2O_3 [1–4], exhibit *n*-type oxide semiconductivity. Gas sensors fabricated using *p*-type oxide semiconductors such as NiO, CuO, Co_3O_4 and Cr_2O_3 to date have received relatively little attention [5,6], and the related research is still in the early stages of development. The markedly different gas-sensing characteristics of *n*- and *p*-type oxide semiconductors should be understood in the context of the receptor functions, conduction paths, and gas-sensing mechanisms of these two types of materials with different majority charge carriers [5]. Compared to *n*-type oxide semiconductor gas sensors, *p*-type oxide semiconductor gas sensors exhibit not only shortcomings of lower sensitivity but also promising potentials for practical applications in trace concentrations of various analyte gases. Hübner et al. [6] suggested that the response of a *p*-type oxide semi-conductor gas sensor to a given gas was equal to the square root of that of an *n*-type oxide semiconductor gas sensor to the same gas when the morphological configurations of both sensor materials were identical. Owing to the wide bandgap (3.6–

4.0 eV), chemical and thermal stability, NiO may be considered as an ideal gas-sensitive material [7–10]. The *p*-type semiconductivity of undoped NiO can be explained by the deficiency of metal ions in the material. However, some limitations, such as the high operating temperature, low sensitivity and poor selectivity [11–13] were still wanted to further improve for the practical applications in hazard and toxic-gas detection.

The working mechanism of oxide semiconductor based gas sensors were mainly based on the obvious change of the electrical conductivity resulting from adsorption and desorption of gas molecules on the surface of gas-sensing materials [14–16]. When *p*-type metal oxides was exposed to air, oxygen molecules, absorbed on its surface, would generate chemisorbed oxygen species (O_2^- , O^- and O^{2-}) by capturing electrons from its surface and lead to the formation of hole-accumulation layers (HALs) on the surface of materials [17–19]. And the hole conduction occurred mainly along the near surface HAL, which resulted in the increase of the conductivity. When the reducing gases were introduced, the reducing gases molecules preferred to react with the chemisorbed oxygen species and the hole concentration and HAL decreased. Recently, the research for improving the performance of gas sensors had carried out in two directions: one was doping with metal elements or heavy metal modified and the other was fabricating sensors with nanostructures. Therefore, the synthesis of the gas-sensing materials with nanostructures was one of ideal choices for the enhanced gas-sensing performance.

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Original Research Paper

Magnetic separation and adsorptive performance for methylene blue of mesoporous NiFe₂O₄/SBA-15 nanocomposites

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ABSTRACT

Magnetic NiFe₂O₄/SBA-15 nanocomposites were synthesized by a facile impregnation method, and NiFe₂O₄ nanoparticles presented spinel phase structure and existed in the mesopores of SBA-15. Partial mesopores were blocked by NiFe₂O₄ nanoparticles and micropores formed, which the capillarity of micropores played a decisive role for methylene blue (MB) adsorption. The saturation magnetization increased from 2.34 emu g⁻¹ to 10.03 emu g⁻¹ with the NiFe₂O₄ content, while the specific surface area decreased from 552.18 m² g⁻¹ to 260.40 m² g⁻¹ and pore volume decreased from 1.13 cm³ g⁻¹ to 0.49 cm³ g⁻¹. MB adsorption could be improved by optimizing the NiFe₂O₄ content of the nanocomposites. MB could be adsorbed completely in 60 min with the optimum nanocomposites and could be separated easily from water by magnetic separation technique.

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1. Introduction

Artificial dyes have been used in many industrial fields such as textiles, leather, cosmetics, paper and printing [1]. As the results, hazardous dyes became one of the main sources for the water pollution [2]. Most of them were toxic, mutagenic, teratogenic and carcinogenic which destroyed the aquatic systems and associated flora and fauna [3]. Furthermore, it was difficult to remove dyes from effluent with the conventional wastewater treatment [4]. A great deal of work had been engaged to develop the method and technique to remove the dyes in the water, such as photocatalysis, chemical oxidation, coagulation, oxidation or ozonation and membrane separation. However, the efficiency and cost of the above techniques had been the largest stumbling block for the wastewater treatment [5–8]. Furthermore, artificial dyes were much more difficult to biodegrade completely because of their complex structure and xenobiotic properties [9]. Up to now, adsorption method has been the most popular technique for the last one process in wastewater treatment, which the adsorbents included diatomite, activated alumina, activated carbon, molecular sieves etc. [10,11]. Usually, the adsorbents should present the high specific surface area, for which nanostructured and porous materials were often considered [12].

Ordered mesoporous SBA-15 silica, one of the typical molecular sieves, offered the unique microstructural characteristics such as large specific surface area, uniform pore size distribution, adjustable pore size, thick walls and high hydrothermal stability, which was widely employed as catalyst supports, drug delivery materials and adsorption materials [13–20]. Many works proved that SBA-15 nanocomposites presented the good potential in the application of adsorption for dye in water. Lee et al. synthesized amino-functionalized SBA-15 materials with the different morphologies, which indicated the good adsorption of acid orange 12 and acid red 73 in aqueous solutions [21]. Qian et al. prepared calcium phosphate coated TiO₂/SBA-15 by a facile sol-gel process to enhance adsorption-photocatalysis performances [22]. El-Nahhal et al. synthesized ammonium functionalized SBA-15 silica, and the adsorption and release of anionic bromothymol blue and cationic malachite green was controlled by adjusting the pH of solution [23]. Chai et al. proved that the adsorption capability of Ag₃PO₄/SBA-15 increased by 3 times of the Ag₃PO₄ particles [24]. Qiao et al. fabricated bifunctionalized SBA-15 with oxygen-containing/amino groups, indicating the improved adsorption performance toward methylene blue (MB) [25].

Up to now, SBA-15-based adsorbents have not been easily separated after the adsorption of dyes. Filtration, the traditional method for separating the SBA-15, could cause the blockage of filter and the loss of SBA-15-based adsorbents. Hence, magnetic separation technique could overcome these disadvantages, in which

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Zn₂SnO₄/activated carbon composites for high cycle performance supercapacitor electrode

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ABSTRACT

Owing to the advantages of the conductive activated carbon (AC) and capacitive Zn₂SnO₄, a series of Zn₂SnO₄/AC composites are successfully prepared by a co-precipitation method. The textural structure of Zn₂SnO₄/AC composites illustrate that the Zn₂SnO₄ nanoparticles are anchored into the micropores of AC. The systematical electrochemical investigation demonstrates that the specific capacitance of the Z-150 sample (including 25% Zn₂SnO₄) is 322.6 F g⁻¹ at a current density of 1 A g⁻¹. The specific capacitance values are retained 96.5%, 91.1% and 81.6% at the current density of 1 A g⁻¹, 8 A g⁻¹ and 16 A g⁻¹ after 3000 cycles, respectively. This confirms the excellent electrochemical performance and good long-term cycling stability of Zn₂SnO₄/AC composites as supercapacitor electrodes at high current densities.

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1. Introduction

With the deterioration of environment and depletion of traditional non-renewable energy (such as coal, oil and nature gas), the flexible, lightweight and environmentally friendly renewable energy storage devices are promoted [1–3]. Supercapacitor, a promising candidates for next-generation power devices, has attracted widespread attention because of its high power density, fast charging capability, excellent cycle stability and long cycle life [4,5]. Carbon based materials [6], metal oxides [7], metal sulfides [8] and conducting polymers [9] are used as supercapacitor electrode materials. The ternary metal oxides, such as MCo₂O₄ (M = Zn [10], Ni [11]), MFe₂O₄ (M = Zn [12], Co [13], Ni [14]) and M₂SnO₄ (M = Mg [15], Zn [16], Co [17]), play an important role in supercapacitor electrode because of the high theoretical specific capacitance. Among them, the cobalt oxides are viewed as the most excellent electrochemical materials. However, due to the rarity, costly and toxicity of Co element, many researchers try to use the cheaper and lower toxic elements instead of Co element [18]. Zn and Sn with low

price and toxicity are one of the ideal elements. Therefore, Zn₂SnO₄ is considered to be an important ternary electrode material due to its high electron mobility (10–15 cm² V⁻¹ S⁻¹), excellent adsorption and chemical stability [16]. However, Zn₂SnO₄ as electrode materials will cause huge volume expansion (>200%) in the process of electrochemical reaction, resulting in the rapid attenuation of the specific capacity, which prevent the commercialization process of Zn₂SnO₄ electrode materials [19]. Recently, the researchers discover that the nanocrystallization, doping and compound of Zn₂SnO₄ could avoid volume expansion and improve the electrochemical performances. C.T. Cherian et al. [20] demonstrated that the Zn₂SnO₄ nanowires showed much more stable capacity than the Zn₂SnO₄ nanoplates. K. Wang et al. [21] exploited polypyrrole doped hollow Zn₂SnO₄ to overcome the expansion problem and improve cycling performance. L. Bao et al. [16] fabricated flexible Zn₂SnO₄/MnO₂ Core/Shell nanocable-carbon microfiber hybrid composites to improve the electrochemical performance supercapacitor electrodes. In addition, the comparative worse conductivity of bare Zn₂SnO₄ also causes the unsatisfactory electrochemical performances. Tremendous efforts have been devoted to combine carbon based materials and Zn₂SnO₄ as composites to improve the electrochemical performances. The combined materials could take the advantages of both components: high conductivity and buffer huge volume changes of carbon based materials and high specific capacity of Zn₂SnO₄. The nanocarbon

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Cobalt ferrites/activated carbon: Synthesis, magnetic separation and catalysis for potassium hydrogen persulfate

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ABSTRACT

Magnetic cobalt ferrites (CoFe₂O₄)/activated carbon (AC) nanocomposites were prepared by the hydrothermal method, and then the catalysis for potassium hydrogen persulfate (PMS) to degrade methylene blue (MB) was investigated. The results indicated that 9 wt% CoFe₂O₄ nanoparticles supplied the sufficient magnetic response for magnetic separation and activated PMS to generate SO₄^{•-} radicals. The pore-structures of AC could adsorb the residual MB in high concentration near CoFe₂O₄ catalysts, and promoted MB degradation with SO₄^{•-} radicals. CoFe₂O₄/AC nanocomposites presented the good stability and reusability. It was proved that the synergistic effect of PMS and CoFe₂O₄/AC nanocomposites could greatly improve the MB removal to 100% at the optimized conditions for 60 min.

1. Introduction

Nowadays, water protection had become one of the most widely concerned problems in human society, and the high-concentration organic in wastewater presented the largest threat to our water resources with the rapid development of economy. However, it was difficult to deal with the refractory organics with the relative molecular mass from several thousand to tens of thousands by the biological treatment methods [1]. Compared with the traditional method, advanced oxidation process (AOPs) had been developed to solve the above challenges for the universality and presented the huge potential prospect in application [2–4]. With the strong oxidative radicals, AOPs could degrade the refractory organics to the low-toxic and non-toxic small molecules in the reaction conditions of the high temperature, high pressure, electricity, sound, light irradiation and catalysts [5,6]. According to the difference of radical-generation and reaction conditions, it was divided into photochemical oxidation, catalytic wet oxidation, sonochemical oxidation, ozone oxidation, electrochemical oxidation and Fenton oxidation [7–9].

Owing to the high oxidizing ability, the sulfate radicals (SO₄^{•-}) and hydroxyl radicals (•OH) have been widely used in AOPs to degrade organic pollutants. The application of •OH was limited by many

conditions such as pH, formation of sludge residues, ineffective utilization of quickly generated •OH and limited removal of organic carbon [10,11]. Due to the higher redox potential (2.5–3.1 V) at natural pH, more selective for destruction of pollutants and longer-lived, SO₄^{•-} had attracted the great interest for the degradation of the refractory organics, which could be generated by peroxymonosulfate (PMS) or persulfate (PS) during their activation [12,13]. Potassium hydrogen persulfate (PMS, 2KHSO₅·KHSO₄·K₂SO₄), the mixture of persulfate (PS, S₂O₈²⁻) and peroxymonosulfate (PM, HSO₅⁻), was very stable in water solution both in acidic and alkaling conditions [14,15]. Up to now, there was a variety of methods for the generation of SO₄^{•-} by the catalyzing to PMS, such as transition metal catalysis (e.g., Co²⁺, Fe²⁺, Mn²⁺, Ru³⁺), UV, electrochemistry method [16–20]. Each way had already been reported by researchers in sewage treatment. Because of the low production cost and high catalytic efficiency, transition metal catalysis was widely used in catalyzing PMS [21–23]. For example, Gong et al. [24] prepared Fe₃O₄/graphene nanocomposites as the heterogeneous catalysts to activate PMS for degradation of methylene blue (MB). Lin et al. [25] used cobalt hexacyanoferrate to prepare the magnetic carbon/cobalt/iron nanocomposites to activate PMS, which exhibited the higher catalytic activity than Co₃O₄. Deng et al. [16] successfully synthesized spinel CoFe₂O₄ and MnFe₂O₄ ferrites to

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首页 < 1 2 > 末页 1

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发明专利证书

发明名称：一种有序介孔氧化镍气体敏感纳米材料的制备方法

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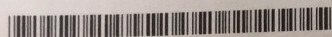
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专利权人：中国计量大学

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证书号第2784688号



发明专利证书

发明名称：一种镍铁氧化物磁性纳米复合材料的制备方法

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六、近五年主持制定并颁布实施的规程/规范/标准：相关材料全文。

七、近五年获省（部）级正职以上领导肯定性批示：相关材料全文。

八、学校引育的高层次人才：相关证明材料。