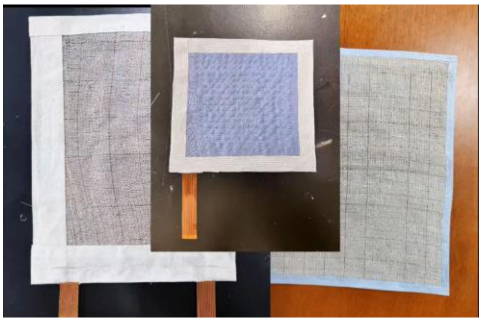
“纺织之光”纺织高等教育教学成果竞赛支撑材料

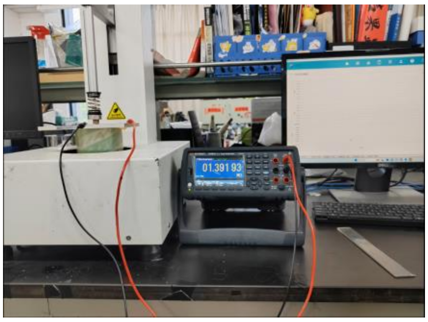
目录

1．实践教学代表案例

案例 1. 织物基压力湿度阵列式传感器

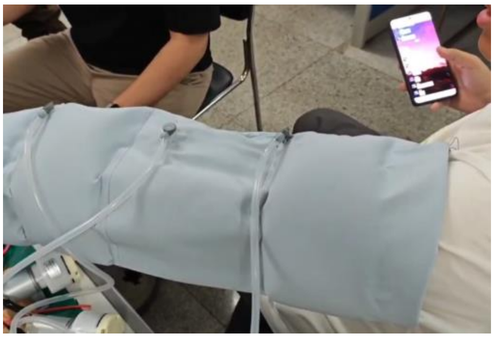
项目简介：开发了一种用于坐垫的智能感知织物，可同时检测压力和湿度。压力传感纱线采用镀银尼龙芯纱+石墨烯复合锦纶包缠结构，湿度传感纱线采用镀银尼龙芯纱+吸湿快干纤维包缠结构，均通过 HN32-04 花式捻线机制备。通过系统测试不同捻度纱线在压力下的电阻变化曲线和湿度下的电容变化曲线，筛选出最优性能的传感纱线。最终采用自动剑杆织机将优选纱线织造成阵列式传感织物，并集成到坐垫中，构建了完整的便携式测量系统。该智能织物兼具环境感知功能和穿着舒适性。

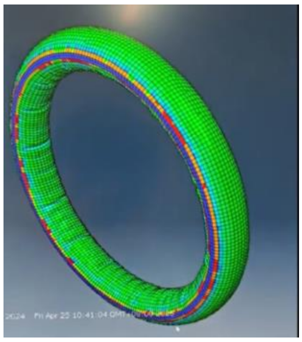




案例 2. 集加热加压电刺激于一身的多功能袖套的制备

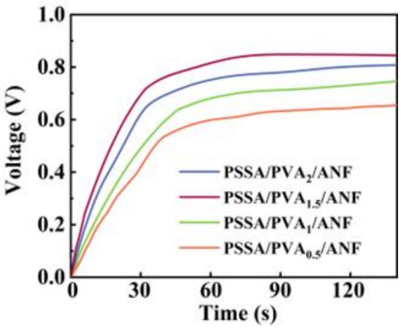
项目简介：当前手臂康复及运动护理产品功能单一，难以满足淋巴水肿治疗中热疗、加压疗法与电刺激协同作用的需求。基于临床知识，本研究开发一体化多功能袖套，通过融合热疗、气囊加压和电刺激三种模态，发挥协同效应以显著提升血液循环效率、促进肌肉激活并加速组织损伤修复，为运动恢复及术后康复提供创新解决方案。为了达成此目标，项目将此方案划分为气囊加压, 加热, 电刺激三个版块，并着重对气囊充气加压过程进行仿真。

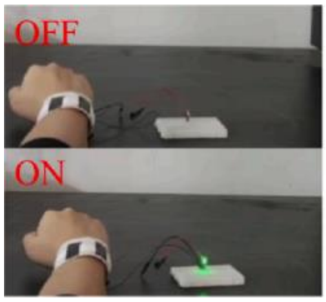




案例 3. 集加热加压电刺激于一身的多功能袖套的制备

项目简介：智能可穿戴的能源供应是制约其发展的核心瓶颈，目前存在的问题主要有传统电池的局限性、能源收集技术的效率与稳定性不足、材料与技术的集成等问题。湿气发电作为一种新型可再生能源捕集转换技术，在可穿戴电子设备供电、人工智能和物联网等领域具有巨大的应用潜力。基于此，我们小组通过构筑有利于离子高效运输的湿气发电功能材料，研究了一种基于芳纶纳米纤维的湿气发电机，致力于解决智能可穿戴纺织品的能源供应问题。





2. 教学成果奖与教师获奖

“纺织之光”2023年度中国纺织工业联合会纺织高等教育教学成果评审结果

序号	成果名称	完成人	完成单位	获奖等级
33	服装创新人才“四链四融通四特色三环”培养体系改革与实践	邓咏梅,吕钊,刘凯旋,任军,冯哲文,袁燕,薛媛,刘静伟	西安工程大学	特等奖
34	纺织类专业学位研究生“经纬纵横”贯通式培养模式的创新与实践	刘雍,王瑞,马崇启,肖志涛,钱晓明,陈利,陈汉军,巩继贤,王春红,康卫民,何鋆	天津工业大学	特等奖
35	国家级“平台+专业+课程”引领下轻化工程新工科教育生态体系的构建与实践	朱君江,王栋,李沐芳,何志艳,吕少仿,李明,于志财,张艳波	武汉纺织大学	特等奖
36	轻纺行业特色高校构建立体化本科教学质量保障体系的研究与实践	张健东,杨菲,吴海涛,陈晓艺,王军,张锋,赵建,游春,张伟钦	大连工业大学	特等奖
37	强内涵 筑生态 固平台，依托纺织优势构建工程创新能力导向的机械类卓越人才培养新范式	胡明,陈本永,严利平,杨金林,周健,郭亮,赵德明,王丙旭,马善红,杨景,高兴文,胡建新,王梅宝	浙江理工大学	特等奖
38	“中国纺织文化”混合式慕课的改革与实践	庞爱民,生鸿飞,柯群胜,杜利珍	武汉纺织大学	特等奖
39	《高端纺织品及应用》线上一流课程体系多维度创新教学改革与实践	冯建永,赵连英,吴莹,黄志超,武维莉,钱建华,翁鸣	浙江理工大学	特等奖
40	磨砺廿载 嬗变成蝶——东华大学自主培养纺织行业高层次拔尖创新人才的实践	丁明利,张翔,陈晓双,郭琪,孙增耀,杨超,查琳,单丹,匡思颖,俞昊	东华大学	特等奖
41	服装可持续设计与管理课程群建设的探索与实践	洪岩,戴晓群,杨勇,冯岑,孙玉钗	苏州大学	特等奖
42	《纺纱原理》“四重四融耦合育才”的教学模式创新	张美玲,张淑洁,周宝明,李凤艳,李翠玉,赵立环,胡艳丽,王建坤	天津工业大学	特等奖
43	以虚促实，融合创新——基于全流程虚拟仿真平台构建的纺纱学数字化教学改革与实践	王新厚,李志民,陈长洁,孙晓霞,郁崇文,陈玉洁,陈文娟,郭建生,李卫东	东华大学	特等奖
44	基于行业学院的锦荣服装设计人才培养模式创新与实践	张巧玲,孙有霞,郭锐,丁梦姝	河南工程学院	特等奖
45	基于“大思政”理念的“一体两翼四维四融”人才培养体系构筑及其在纤维特色材料类专业中的实践	张明,金达莱,傅雅琴,陈世昌,仰滢,张姗姗,董余兵,童再再	浙江理工大学	特等奖
46	基于“专业+”拔尖创新复合型人才自主自强培养的构建与实践	杨旭东,姬广凯,刘冰,马敬红,周卫平,陆嵘,周其洪,王永林,施美华,黄朝阳	东华大学	特等奖
47	基于校企院所合作基础的“纺织+”跨学科协同创新型人才培养研究与实践	马丕波,蒋高明,董智佳,丛洪莲,万爱兰,张琦,夏风林	江南大学	特等奖
48	智能辅助与虚拟仿真在服装类复合型人才培养中的探索与实践	刘凯旋,樊威,张俊杰,梁建芳,孙林,朱春,彭东梅,张蓓	西安工程大学,武汉纺织大学,大连工业大学	特等奖
49	厚基础•强实践•重创新，纺织智能制造复合型人才培养	孟婥,陈玉洁,张玉井,孙以泽,季诚昌,徐洋,李培波,盛晓伟	东华大学	特等奖

第 3 页，共 44 页

“纺织之光”2023年度中国纺织工业联合会纺织高等教育教学成果获奖名单

序号	成果名称	完成人	完成单位	获奖等级
618	“协同育人、五位一体”针织服装拔尖创新人才培养体系的构建与实施	王适,张健东,于佐君,王勇,王立慧,张宁,李文静	大连工业大学	二等奖
619	数字技术赋能背景下服装设计专业的核心课程建设与教学实践	王蕾,孔令奇,焦亚珂,彭娜,张冲	中原工学院	二等奖
620	“新工科”理念下以产出为导向的服装生产管理人才培养的创新与实践	师云龙,王晓云,钱晓明,何鋆,刘利,蒋蕾,许君	天津工业大学	二等奖
621	面向未来的“四个融合”拔尖创新人才培养模式改革与实践	吕媛媛,赵凯鹏,代琦,潘骏,许联,张燕,郭克楠,李英	浙江理工大学	二等奖
622	竞赛驱动，项目引导，平台支撑的纺织特色高分子专业人才培养与实践	马建华,王斌,张彩宁,孙元娜,赵强莉,王亮,刘毅,付翀,贺辛亥	西安工程大学	二等奖

“纺织之光”2023年度中国纺织工业联合会纺织高等教育教学成果获奖名单

345	构建“四化”教学体系，解决立体裁剪“两难”问题	宋金英,于丽华,李艾远,石荣玺,仇欣,汤爱青,李翔宇,吴楠	山东理工大学	二等奖
346	目标导向、案例驱动，服装工效学课程教学改革与实践	李艳梅,陈晓娜,孙光武,梁帅童,张云,沈云萍	上海工程技术大学	二等奖
347	知晓•明理•探索——新工科视角下递进式纺织技术类课程教学方法探索与实践	王迎,吕丽华,董媛媛,魏春艳,熊小庆	大连工业大学	二等奖
348	融入现代信息技术的创新创业类课程体系建设的研究与实践	李吉娜,赵景服,张建林,钱德亮,张洪涛,高冉,陈静,杨静,罗林	中原工学院	二等奖
349	融合产业学科优势，基于“三位一体”举措，推进男装设计课程创新人才培养	邓琼华,贺晓亚,丁雯,魏娴媛,高雅	江西服装学院	二等奖
350	“虚实结合，三位一体”—纺织材料课程群实验虚拟教学平台建设与实践	刘胜凯,胡艳丽,王春红,吴利伟,刘皓,杜娟娟,鹿超	天津工业大学	二等奖

23

中国纺织工业联合会纺织高等教育教学成果奖

获奖证书

为表彰在纺织服装行业推动教学研究、深化教学改革、提高教学水平和教学质量等方面做出突出贡献的项目，特发此证书，以资鼓励。

成果名称：基于“互联网+”的服装导论课程教学创新与实践

获奖等级：二等奖

完成单位：天津工业大学

主要完成人：何崟，王晓云，杨秀丽，单毓馥

证书号：2019-GJ-062

中国纺织工业联合会

2019年10月

中国纺织工业联合会纺织高等教育教学成果奖

获奖证书

为表彰在纺织服装行业推动教学研究、深化教学改革、提高教学水平和教学质量等方面做出突出贡献的项目，特发此证书，以资鼓励。

成果名称：面向一流学科建设的纺织学科学术学位硕士研究生培养方案的改革与实践

获奖等级：三等奖

完成单位：天津工业大学

主要完成人：刘雍，王瑞，范杰，马崇启，钱晓明，陈汉军，权全

证书号：2019-GJ-103

中国纺织工业联合会

2019年10月

聘书

兹聘请 杨 光 同志

作为特聘专家，参与中国科协全国学会服务国家战略专项“柔性智能可穿戴电子纺织品产业化关键技术领域创新资源图谱”项目工作。

特颁此证。

中国纺织工程学会

二〇二五年五月

证书

何鉴同志：

获评天津高校第十七届青年教师教学竞赛工科组二等奖，特发此证。

天津市总工会　中共天津市委教育工作委员会　天津市教育委员会

二〇二四年五月

NATIONAL TEACHING INNOVATION CONTEST FOR COLLEGE TEACHERS

全国高校教师教学创新大赛

荣誉证书

何 鉴 老师：

荣获第四届全国高校教师教学创新大赛天津赛区新工科副高组

三等奖

特发此证，以资鼓励。

课程名称：服装导论

团队成员：杨秀丽、师云龙、刘皓

工作单位：天津工业大学

证书编号：TIC2024TJ021

天津市教育委员会

2024年5月

荣誉证书

HONORARY CREDENTIAL

首届纺织类院校青年教师讲课竞赛

一等奖

获 奖 者：闫静

学　　校：天津工业大学

证书编号：JK2023-1-2

中国纺织服装教育学会

二零二三年九月十六日

荣誉证书

HONORARY CREDENTIAL

首届纺织类专业教师优秀教案评选

二等奖

获 奖 者：闫静

课　　程：纺织材料学

学　　校：天津工业大学

证书编号：JA2023-2-27

中国纺织服装教育学会

二零二三年九月四日

荣誉证书

闫静 同志：

荣获第九届全国纺织材料学教学研讨会暨青年教师教学创新大赛

三等奖

中国纺织服装教育学会

2023年6月10日

2023第二届全国电子材料与器件大会

National Conference on Electronic Materials and Devices

杨光 老师

经组委会审议，特邀您出席2023年10月13-15日于青岛举办的**“2023第二届全国电子材料与器件大会”**，担任大会—**有机电子材料与器件论坛专题**的“组织委员”一职。

并作 纳米纤维在柔性应变传感器中的应用 邀请报告。

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登录会议官网

2023第二届全国电子材料与器件大会
组委会

2022年天津市级教学团队公示名单

序号	学校	团队名称	负责人
1	南开大学	环境学科专业实验教学团队	孙红文
2	南开大学	自动控制教学团队	方勇纯
3	天津大学	程序设计课程教学团队	喻　梅
4	天津大学	钢结构系列课程教学团队	丁　阳
5	天津科技大学	环境工程专业教学团队	李桂菊
6	天津科技大学	微生态健康与药理学（双语）课程群教学团队	罗学刚
7	天津工业大学	纺织工程专业“新工科”建设核心课程群教学团队	刘　雍
8	天津工业大学	电子信息类工程教育课程群教学团队	牛萍娟

中共天津工业大学委员会
文　件

津工大党〔2023〕23 号

★

关于表彰天津工业大学 2022 年学生思想政治教育与管理工作先进单位、优秀辅导员、优秀班导师的决定

三、“优秀班导师”名单（按姓氏笔画为序）

纺织科学与工程学院	何天虹、李翠玉、李玉瑶、李　政、王　润、徐　磊、杨　光
材料科学与工程学院	耿宏章、王　薇、辛清萍、赵军强
化学工程与技术学院	安会琴、马爱静、王丽丽
环境科学与工程学院	刘虹吾
机械工程学院	邓凌虹、刘　欣、刘国华、王天琪
航空航天学院	郑　洋

人才工作办公室：2019年天津市高校“学科领军人才培养计划”、“中青年骨干创新人才培养计划”和“青年后备人才培养计划”拟推荐人选公示

创建人：郝希超　发稿时间：2019-11-27

各有关单位：

根据天津市教委《关于开展天津市高校“学科领军人才培养计划”、“中青年骨干创新人才培养计划”、“青年后备人才支持计划”推选工作的通知》（津教人函〔2019〕12号）文件精神，经各重点学科相关学院选拔推荐、校学术委员会评审、校长办公会审议、校党委常委会审定，现将我校拟推荐的人选予以公示。

学科领军人才培养计划建议人选：

柴争义　陈 炜　陈晓霞　范 杰　胡云霞　金雪峰　康卫民　雷怀英　李 阳　刘胜强　桑宏强　苏卫星　武春瑞　徐志伟　姚明辉　岳建锋　张海明　张 献

中青年骨干创新人才培养计划建议人选：

常 娜　陈 熙　成 怡　段晓杰　耿 磊　巩继贤　顾 宏　韩 娜　黄宏亮　金日泽　孔庆军　李宝全　李 程　李杰　李金义　李新荣 李 政　刘 芳　刘 皓　刘 欣　吕云飞　孟建强　宁平凡　潘 杰　乔志华　申成霖　时志强　宋庆增　谭建国　田会娟　王国庆　王海涛　王慧敏　王慧泉　王 琦　王志强　吴 骏　吴 宁　肖朝霞　杨 帆　杨瑞梁　杨彦利　张宏杰　张 欣　张 旭　赵 静　赵莉芝　朱庆霞　祝丽花

青年后备人才培养计划建议人选：

曹淑娟　曹天庆　陈洪丽　杜 玲　韩 广　何 洋　纪 越　江婷婷　李龙女　李新旻　刘 畅　刘元军　马爱静　莫 帅　潘世光　石 嘉　孙士民　汪荣华　王晶晶　王胜蓓　王小超　王 瑶　魏 鹏　吴继旋　谢军波　辛清萍　许 君　闫 静　杨 光　张国政　张马亮　张

人才工作办公室：关于2019年度天津市“131”创新型人才培养工程第二、三层次拟推荐人选的公示

创建人：郝希超　发稿时间：2019-10-15

按照天津市人社局和市教委文件要求，现将我校拟推荐的2019年度“131”创新型人才培养工程第二、三层次人选予以公示。

天津市“131”创新型人才培养工程第二层次人选：

李宝全 刘欣 吕云飞 乔志华 王立群 王志强 张磊 赵传阵 赵莉芝

天津市“131”创新型人才培养工程第三层次人选：

董广宗　杜玺　郭丽艳　韩广　何洋　何崟　建蕾　江婷婷　刘倩　刘彦北
马爱静　齐业雄　石嘉　汪荣华　王红一　王晶晶　王亮　王少娜　吴继旋
肖轩　谢军波　颜晓琳　杨帆　杨光　姚福林　张马亮　张松楠　张政清
赵义侠　赵喆

公示期自2019年10月15日至10月21日

中共常州市委人才工作领导小组办公室
常州市人力资源和社会保障局
文件

常人才办〔2023〕34号

关于公布"龙城英才计划"第二十四批领军人才创业类项目名单（一）的通知

中共常州市委人才工作领导小组办公室　　常州市人力资源和社会保障局

2023年12月29日

序号	地 区	姓 名	项目名称	资助金额（万元）
11	武进区（区本级）	张嘉恒	超分子材料的研发及产业化	100
12	武进区（区本级）	王　猛	纳米微针药物递送注射器	100
13	武进区（区本级）	杨　光	高性能碱性制氢隔膜及其他关键材料	100
	武进区			

3．教改项目

中国纺织工业联合会文件

中国纺联函〔2021〕119 号

关于公布“纺织之光”中国纺织工业联合会高等教育教学改革研究立项项目的通知

“纺织之光”中国纺织工业联合会高等教育教学改革研究项目拟立项名单

序号	单位	教改项目名称	项目负责人	项目组成员	项目类别
1	西安工程大学	基于纺织类学生“三创”能力培养的实践育人体系探索	封彦	万明、郭西平、沈兰萍、王进美、付成程、乔晓荷	2
2	西安工程大学 中原工学院	新视域下“弘扬传统技艺，传承纺织非遗”理念融入轻化工程专业教学的探索研究	任燕	张鑫卿、罗璐、刘瑾姝、张帆、王雪燕、徐成书、郑艳	2
3	西安工程大学	数字化背景下混合式教学模式及教学效果评价的研究与实践	刘静	万明、赵凯威、任燕、周丹、张振方、李红艳、侯锦丽	3
4	西安工程大学	面向工程教育认证的课堂教学过程性评价	王伟	薛涛、王明明、薛文生、赵旭、刘沫萌	5
5	西安工程大学	三维教学目标下以观念系统构建艺术类专业课程思政教育模式研究	王坚	左志锋、姒晓霞、肖爱云、李易昕	3
603	天津工业大学	国际视域下纺织一流学科群相关本科专业布局与人才培养模式研究	陈莉	魏黎、陈洪霞、马涛、王春红、严峰、郭晶、刘荣娟、李尚乘、荆妙蕾	2
604	天津工业大学	面向纺织未来技术的纺织工程专业创新人才培养方案的构建与实践	刘雍	刘皓、李凤艳、王润、杨光、张松楠，夏兆鹏、赵晋、赵立环	2
605	天津工业大学	服务国家战略规划的新工科IT类专业人才培养机制改革与实践	王赜	宋国治、孙连坤、李志强、王瑞昆、刘丁、柴争义、于红	1
606	天津工业大学	新文科建设背景下行业特色高校经管人才培养研究	王巍	王巍、朱春红、李江、姜弘、闫瑞霞、郭晓辉	1
607	天津工业大学	思想政治理论课深度融入世界一流学科人才培养路径研究	聂丽琴	卢敬、张冠、张霞、武雅君、荆妙蕾、王丽伟、郑洪民	2、3
608	天津工业大学	基于校企合作共同发展培养模式，构建服装专项设计人才的教学改革与建设	孙戈	肖军、刘利、孙静、姚远、范文娲、陈昌	2
609	天津工业大学	纺织工程专业课程思政教学体系的构建与实践	荆妙蕾	胡艳丽、刘雍、张淑洁、钟智丽、石磊、李凤艳	3
610	天津工业大学	强基础、重实践，全链式机械类专业创新人才培养模式的探索与实践	刘国华	刘欣、杜宇、牛雪娟、岳建锋、王天琪	2
611	天津工业大学	服装专业“金课”在线开放课程与思政教育的融合模式创新与实践	何崟	杜娟娟、单毓馥、李晓志、杨秀丽、王晓云、龚雪燕、刘利	3
612	天津工业大学	面向智能纺织的电子科学与技术专业方向的课程体系建设	梅云辉	牛萍娟、张建新、付贤松、刘宏伟、韩丽丽、张博雯、宁平凡	2

天津工业大学文件

津工大〔2023〕110 号

关于公布 2023 年度天津工业大学学位与研究生教育改革立项项目的通知

各学院、部、处及直属部门：

根据《关于开展 2023 年度天津工业大学学位与研究生教育改革项目申报工作的通知》要求，学校组织了 2023 年度学位与研究生教育改革项目的申报与评审工作，现对通过专家评审的 44 项申报项目予以立项并公布。（请见附件）

附件：

2023 年度天津工业大学学位与研究生教育改革立项项目汇总表

序号	项目编号	项目名称	项目类别	项目负责人	所属单位
1	YJSJG202301	以应用为导向的研究生《矩阵论》公共课程教学改革的探索	学位与研究生教育教学改革与创新项目	王温琴	数学科学学院
2	YJSJG202302	工科研究生数学类公共课改革与实践创新研究	学位与研究生教育教学改革与创新项目	张国	数学科学学院
3	YJSJG202303	强基固本，思政铸魂——数学类专业学位研究生分析学课程体系的构建与实践	学位与研究生教育教学改革与创新项目	张霞	数学科学学院
4	YJSJG202304	基于新安全生产法背景下的研究生课程《防护纺织材料》教材改革研究与实践	学位与研究生教育教学改革与创新项目	刘元军	纺织科学与工程学院
5	YJSJG202305	面向一流研究生课程建设的《纺织物理》 课程建设与实践	学位与研究生教育教学改革与创新项目	范杰	纺织科学与工程学院
6	YJSJG202306	面向一流学科建设目标的研究生培养体系的构建与运行	学位与研究生教育教学改革与创新项目	毛丽贺	纺织科学与工程学院
7	YJSJG202307	基于纺织学科的《有限元基础及应用》融合研究与实践教学	专业学位研究生案例库建设项目	吴利伟	纺织科学与工程学院
8	YJSJG202308	《智能纺织品前沿》课程案例库建设	专业学位研究生案例库建设项目	杨光	纺织科学与工程学院
9	YJSJG202309	提高低年级专业硕士研究生实践能力的三位一体课程教学模式探索	学位与研究生教育教学改革与创新项目	梁小平	材料科学与工程学院
10	YJSJG202310	以创新能力培养为导向的《材料计算与模拟》教学研究与探索	学位与研究生教育教学改革与创新项目	何洋	材料科学与工程学院
11	YJSJG202311	“双系统四体系”材料类专业学位研究生培养模式创新和改革研究	学位与研究生教育教学改革与创新项目	付维贵	材料科学与工程学院

YJSJG20216

天津工业大学
学位与研究生教育改革研究项目
结项书

项目名称 《可穿戴智能电子纺织品》双语课程教材建设

项目类别 学位与研究生教改项目（重点）

项目负责人 闫静

负责人所属部门 纺织科学与工程学院（盖章）

联系方式 13001359739

立项时间 2021年6月

填表日期 2022年9月1日

天津工业大学研究生院制

天津工业大学文件

津工大〔2022〕17号

关于公布天津工业大学2022年校级本科规划教材建设项目立项名单的通知

7	纺织科学与工程学院	机织原理	马崇启
8	纺织科学与工程学院	Knitted Garments and Articles	刘丽妍
9	纺织科学与工程学院	纺纱设备	王建坤张美玲
10	纺织科学与工程学院	现代纺织颜色科学	刘建勇
11	纺织科学与工程学院	柔性电子技术与智能纺织品	刘 皓

4. 教材与教改论文

中 国 纺 织 出 版 社 有 限 公 司

图 书 出 版 合 同

编号：（2021）纺社第1-0-97号

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乙方（出版者）：中国纺织出版社有限公司

地址：北京市朝阳区百子湾东里甲406号楼1至3层102

邮政编码：100124

作品名称：柔性传感器

（选题编号：2021100116）
以下简称“上述作品”。

作者署名：刘皓 何崟 杨光 编著

请注明署名方式，如著、编著、编写、编、译、编译、主编

注意：该署名为甲方本名或笔名，确系甲方真实意愿

其他作者：

“可穿戴智能电子纺织品”双语课程建设探索

闫 静,望希言,朱 宁,杨 光

(天津工业大学 纺织科学与工程学院,天津 300387)

摘要:可穿戴智能电子纺织品是目前纺织领域的研究热点,“可穿戴智能电子纺织品”双语课程在行业发展和人才培养的需求下应运而生。该课程是天津工业大学纺织科学与工程学科硕士研究生的一门专业基础课,在传授相关基础知识的同时,使学生拓宽学术视野,了解科技前沿,提升创造能力,提高英语水平。对该课程建设的必要性进行分析,并从课程建设方法及内容、教学实践及存在问题等方面探讨该课程的建设。

关键词:可穿戴技术;智能电子纺织品;双语教学;课程建设

中图分类号:G642.0 **文献标志码**:A **文章编号**:2095-3860(2021)05-0451-04

DOI:10.13915/j.cnki.fzfzjy.2021.05.015

我国是一个纺织大国,向纺织强国的迈进需要先进纺织技术的支撑。目前,我国纺织行业正处于转型升级的重要时期,智能电子纺织是传统纺织提质升级的一个重要着力点。随着物联网及现代纺织技术的发展,可穿戴智能电子纺织品受到越来越多的关注,但相关内容还处于研究阶段,尚未形成系统的知识体系进入课堂。我校(天津工业大学)纺织科学与工程学科为“双一流”建设学科,为助力学科发展和学生培养,率先面向纺织工程专业硕士研究生开设了“可穿戴智能电子纺织品”双语课程,旨在使学生了解可穿戴智能电子纺织品的发展历程、研究方向、应用领域及最新研究进展。本文将从该课程建设的必要性、方法及内容、存在问题及改进措施等方面进行探讨。

一、“可穿戴智能电子纺织品”双语课程开设的必要性

1. 行业发展的需求

可穿戴技术(wearable technology,WT),最早是 20 世纪 60 年代由美国麻省理工学院媒体实验室提出的一项创新技术。利用该技术,可以把多媒体、传感器和无线通信等技术嵌入人们的衣物,可支持手势和眼动操作等多种交互方式,主要探索和创造能直接穿在身上或整合进穿戴者衣服、配件的设备[1]。起初该技术发展较慢,并未得到广泛的关注。从2010 年开始,可穿戴技术逐渐成为产业和学术热点,并进入大众视野。可穿戴产品可广泛应用于健康医疗、养老健身、生物工程、移动通信、时尚文化、教育和工业等领域,例如智能电子服装可以给军人用的电子设备供电,检测工作环境中的有害气体,观测军人的身体状况、受伤情况,传输位置信息等;在医疗方面,检测病人的心跳、呼吸、情绪等状况[2]。但市场上推出的如智能眼镜、智能手表、智能腕带、智能臂环等产品[3],基本上是可“戴”或者是将电子元件植入到纺织品中,还没有真正地实现穿着的功能。理想的可穿戴智能电子纺织品是以纤维、纱线或织物为载体,集柔性、轻便、可水洗、自供能、传感等特点为一体的智能纺织产品[4-5]。秉着对美好生活的向往,人们为开发真正的可穿戴智能纺织品不断奋斗着,很多研究工作者致力于开发性能优异的产品。我校设有可穿戴电子与智能

基金项目:天津市教育委员会科研计划项目(2017KJ067)
作者简介:闫 静(1987—),女,山西定襄人,讲师,博士,研究方向为智能纺织材料。E-mail:yanjing@tiangong.edu.cn

5. 国家级大学生创新创业大赛

天津市大学生创新训练计划项目

结题证书

项目名称：光触发自修复柔性应变传感器的制备及性能优化
项目编号：202110058021
项目类型：创新训练项目
项目级别：国家级
项目所属学校：天津工业大学
项目负责人：张莹/2110110053
项目成员：杨静雯/1910110051
张丁月/2110110050
李宸熙/2110110044
李笑阳/2210110041
指导教师：杨光

经结题验收，已完成项目研究任务，同意结题。
特发此证，以资鼓励。

天津市教育委员会
二〇二四年六月

项目编号: 201910058003

项目名称: 智能乳腺健康监测内衣关键技术的研发

项目类型: 创新训练项目

项目类别:

重点支持领域:

所属学校: 天津工业大学

项目实施时间: 2019-05-01 至 2020-05-31

所属学科门类: 工学

所属专业大类: 纺织类

立项时间: 2019-09-10

结题时间: 2020-08-07

项目成员:

姓名	年级	学号	所在院系	专业	联系电话	E-mail	是否主持人
赵辰	*	1610530110	*	*	*	*	第一主持人
左凯悦	*	1610530201	*	*	*	*	否
唐雨晴	*	1710530316	*	*	*	*	否
周颖	*	1710530225	*	*	*	*	否
闫纪硕	*	1610940101	*	*	*	*	否
林秋彤	*	1710940327	*	*	*	*	否

指导教师:

姓名	单位	专业技术职务	指导教师类型
何崟	天津工业大学	讲师	第一指导教师
王晓云	天津工业大学	教授	第二指导教师

6. 指导学生竞赛获奖

天津市大学生学科竞赛专用证书

Tianjin University Student Subject Competition

2024

天津市高等学校大学生学科竞赛

获奖证书

AWARD CERTIFICATE

孙颖、蒙磊、王雅泓、邢任权、王亚倩、苏一轩、刘颖、刘仁磊、王玲玲、马含冰　同学：

在中国国际大学生创新大赛（2024）天津赛区高教主赛道中，您的《氢途膜量——聚苯硫醚隔膜的技术革新助力高效低耗水电解》作品荣获研究生创意组铜奖。

指导教师：杨光、闫静

特发此证，以资鼓励。

天津市教育委员会

二〇二四年七月二十二日

证书编号：TJ–2024–CICSIC–GJZSD–0742

天津市教育委员会制

荣誉证书

HONORARY CREDENTIAL

“新澳杯”第十四届全国大学生纱线设计大赛

一等奖

作品名称：纤霞电绕——基于纳米纤维的发电包覆纱

设 计 者：张　莹、陈焱文

指导教师：闫　静、杨　光

学　　校：天津工业大学

中国纺织服装教育学会

二〇二三年十二月

"建行杯"第十六届
全国大学生节能减排社会实践与科技竞赛

The 16th National University Student Social Practice and Science Contest on Energy Saving & Emission Reduction

获奖证书

在2023年"建行杯"第十六届全国大学生节能减排社会实践与科技竞赛中，经评审，获得

三等奖

参赛院校：天津工业大学

作品名称：自知"智"明——一种环境智能响应的可穿戴自供能传感器

作品类型：科技作品

参赛学生：邢任权、丁云鹏、刘夏颖、刘晶晶、王浩轩、王凯博、苏一轩

指导教师：杨光、闫静

全国大学生节能减排
社会实践与科技竞赛委员会
二〇二三年八月

证书编号：20231660011

荣誉证书

闫静、程博闻 老师：

你们指导的学生刘敏、王蒙、杨琪、王雪纯、赵慧娟、王利媛的作品《稳定锂金属电池用柔性多孔碳纤维水刺无纺布夹层》获得第七届“金三发·兰精·安德里茨”杯全国大学生非织造材料开发与应用大赛 特等奖 ，你们被评为优秀指导教师，特发此证，以资鼓励。

教育部高等学校纺织类专业教学指导委员会（主任单位代章）

中国纺织服装教育学会

中国产业用纺织品行业协会

二〇一九年七月

获奖证书

天津工业大学

罗丹、闫晗、孙海博、彭鹏飞、李君、邱悦、李至洁

你们的作品《“纤”知“纤”觉柔性纤维汗液传感器》在第九届中国国际“互联网+”大学生创新创业大赛天津赛区比赛高教主赛道中荣获铜奖。

指导教师：刘皓、牛鑫

特发此证，以资鼓励。

天津市教育委员会

二〇二三年十月十七日

天津市大学生学科竞赛专用证书

Tianjin University Student Subject Competition

2024

天津市高等学校大学生学科竞赛

获奖证书

AWARD CERTIFICATE

王探宇、朱小宇、王海燕、朱少瑞、余海涛、俞淏玥、丁培根　同学：

在中国国际大学生创新大赛（2024）天津赛区“青年红色筑梦之旅”赛道中，您的《知冷“智”热—智能控温加热服装一体化赋能健康乡村的先锋者》作品荣获公益组铜奖。

指导教师：张江路、刘皓、牛鑫、李凯、王俊宇

特发此证，以资鼓励。

天津市教育委员会

二〇二四年七月二十二日

证书编号：TJ–2024–CICSIC–HLSD–0196

天津市教育委员会制

荣誉证书

HONORARY CREDENTIAL

天津工业大学《运动不止，能量不息——可穿戴摩擦纳米发电机服装》　项目：

在第六届天津市大学生创客马拉松大赛中荣获　优秀　奖

项目成员：钟智研、朱宁、吕梦蝶、吴娟、孙苗苗、罗雪雪、常悦、薛子东、裴艾斐

指导教师：闫静、杨光

特发此证，以资鼓励。

天津市教育委员会　天津海河传媒中心

二〇二二年六月

荣誉证书

《柔性应变传感器的定点自修复技术》荣获中国国际大学生创新大赛（2024）高教主赛道本科生创意组二等奖。

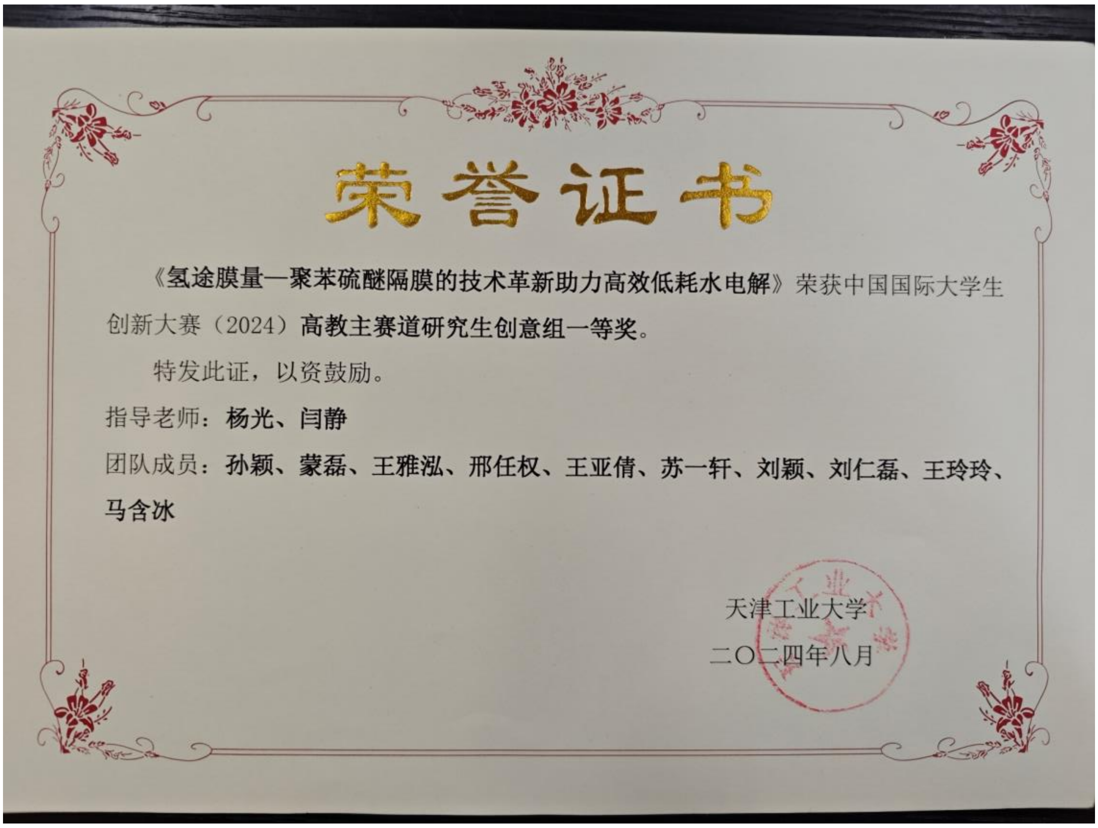
特发此证，以资鼓励。

指导老师：杨光

团队成员：金可煜、任静茹、周峻逸、张遨

天津工业大学

二〇二四年八月



荣誉证书

《氢途膜量—聚苯硫醚隔膜的技术革新助力高效低耗水电解》荣获中国国际大学生创新大赛（2024）高教主赛道研究生创意组一等奖。

特发此证，以资鼓励。

指导老师：杨光、闫静

团队成员：孙颖、蒙磊、王雅泓、邢任权、王亚倩、苏一轩、刘颖、刘仁磊、王玲玲、马含冰

天津工业大学

二〇二四年八月

荣誉证书

HONORARY CREDENTIAL

罗浩峻、郭婉茹 同学：

在“纺织科普博览”——天津市第五届凝胶产品开发和设计大赛中表现优异，参赛作品荣获 一等奖

作品名称：芳纶纳米纤维增强水凝胶用作应变传感器

指导老师：李政、杨光

申报单位：天津工业大学

特发此证，以资鼓励。

天津市胶粘剂研究会

二〇二四年十月二十七日

中国纺织报

CHINA TEXTILE NEWS

国务院部署对中小企业加强精准帮扶

迈好2021第一步

聚力新发展　展现新作为

■ 山东魏桥创业集团有限公司党委书记、总经理 张红霞

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江西万年纺织新材料年营收突破百亿元

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6. 智能纺织品相关优秀毕业论文

天津市教育委员会
Tianjin Municipal Education Commission

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关于2022年天津市优秀硕士、博士学位论文评选结果的公示

来源： 天津市教育委员会 发布时间： 2023-03-23 18:00

根据《关于开展2022年天津市优秀硕士、博士学位论文评选工作的通知》，现将2022年天津市优秀硕士、博士学位论文评选评选结果予以公示。公示期三天。任何单位和个人对公示的天津市优秀硕士、博士学位论文评选评选结果持有异议，均可向我委署名提出。匿名异议恕不受理。

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天津市教育委员会

津教高函〔2025〕15号

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Nano Energy 140 (2025) 111037

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Nano Energy

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ELSEVIER

Full paper

An efficient charge extraction strategy for high-performance piezoelectric nanogenerators via a 3D nanostructured conductive network

Jing Yan, Lingling Wang, Yuebin Qin, Weimin Kang *, Guang Yang *

State Key Laboratory of Advanced Separation Membrane Materials, School of Textile Science and Engineering, Tiangong University, Tianjin 300387, PR China

ARTICLE INFO

Keywords:
Piezoelectric nanogenerator
3D conductive network
Charge extraction
High performance
Energy harvesting

ABSTRACT

Flexible piezoelectric nanogenerators (PENGs) have emerged as a promising technology for energy harvesting and wearable sensing applications. However, their output power is often low due to high inherent impedance and inefficient charge transfer. Herein, an efficient charge extraction strategy is proposed for developing high-performance PENGs by integrating a three-dimensional (3D) nanostructured conductive network within piezoelectric nanofibers. This 3D conductive network, composed of aligned antimony tin oxide (ATO) nanofibers and in situ grown carbon nanotube (CNT) bridges, facilitates internal instantaneous charge transfer and significantly improves the output performance of PENGs. Consequently, the fabricated barium titanate ($BaTiO_3$) nanofiber-based PENG with the 3D conductive network exhibits a voltage of 64.4 V and a current of 29.4 μA, corresponding to 8.8-fold and 12.7-fold improvements, respectively, compared to a PENG with neat $BaTiO_3$ nanofibers. Additionally, this versatile charge extraction strategy can be applicable to other piezoelectric materials, such as $PbZr_{0.52}Ti_{0.48}O_3$ and $(Ba_{0.85}Ca_{0.15})(Ti_{0.9}Zr_{0.1})O_3$ nanofibers, achieving remarkable energy output. The application of the developed PENG has been demonstrated in a wearable emergency communication system, highlighting its ability to achieve high-resolution in signal transmission. This work offers an effective and broadly applicable charge extraction strategy for boosting the output of PENGs, greatly expanding their applications across various domains.

1. Introduction

The rapid development of flexible electronic devices in the fields of health monitoring, human-computer interaction, and artificial intelligence has underscored a critical challenge of ensuring a reliable and efficient energy supply [1,2]. Piezoelectric nanogenerator (PENG), which possess the capability to capture ambient, irregular mechanical energy and convert it into electrical energy, present a promising solution to this enduring power supply dilemma [3,4]. Despite their significant potential, the output performance of PENGs remains constrained, primarily due to low energy conversion efficiencies [5]. Therefore, enhancing the output performance of PENGs is an essential area of research to fully harness their potential in powering flexible electronics.

Perovskite ceramics with high piezoelectric coefficient dominate the landscape of piezoelectric materials [6]. The structural features of these materials, including their physical morphology and arrangement, are intimately linked to the piezoelectric performance of corresponding PENGs. Aligned piezoelectric materials have demonstrated considerable promise in improving the performance of PENGs by enabling more efficient stress transfer and enhancing energy harvesting capacity [7,8]. Several studies have shown that the polymer composites incorporating aligned piezoelectric materials, such as lead zirconate titanate (PZT) nanofibers [9], barium titanate ($BaTiO_3$) nanofibers [10] and barium calcium zirconate titanate (BCTZ) nanofibers [11,12], exhibit superior piezoelectric properties compared to their randomly oriented counterparts. However, a critical issue persists that under mechanical compression, only charges near the interfaces between the composite and the electrodes are efficiently utilized, whereas those in the deep piezoelectric regions remain inactive or dissipate due to the insulating nature of the polymer matrix. Consequently, a significant portion of the piezoelectric charges are not effectively captured, limiting the overall energy output [13–15].

One of the most effective strategies to address this charge utilization issue is the incorporation of conductive materials within piezoelectric composites. Conductive fillers, such as carbon nanotubes (CNTs) [16,17], copper (Cu) nanorods [18], silver nanowire [19], etc., establish conductive pathways between the piezoelectric elements, reducing internal resistance and facilitating charge transfer, ultimately enhancing

ADVANCED FUNCTIONAL MATERIALS
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Engineering Aramid Aerogel Fibers with Core-Shell Structure for High-Performance Thermal Protective Textiles

Yinghe Hu, Zhifeng Yan, Guang Yang, Ming Jiang, Chang Liu, Heyi Li, Chuxin Yue, Gongyu Zhang, Chuqing Tang, Vitali Lipik, Youwei Ma,* and Xupin Zhuang**

Overcoming the trade-off between thermal protection and mechanical strength in aerogel fibers represents a significant challenge. To address this, it has structurally engineered aramid aerogel fibers (SEAAFs) with a hierarchical core-shell structure through a two-step coagulation treatment in wet-spinning. The treatment involves the rapid gelation of aramid nanofiber (ANF) spinning sol precursor in acid, forming a rigid and highly ordered shell, followed by a slower gelation process in water, which results in an amorphous and porous core. This structural design enhances the mechanical robustness and preserves high porosity of SEAAFs, properties that can be further optimized by adjusting key spinning parameters, including the type and concentration of acid used, as well as the ANF precursor concentration. Upon optimization, SEAAFs achieve a high stress at break of up to 64.3 MPa and an ultralow thermal conductivity of 28.3 mW m^{-1} K^{-1}. The excellent mechanical property then enables the successful fabrication of a SEAAF fabric demo with a dimension of 1 × 0.2 m ($l \times w$) on an automatic rapier loom. Moreover, the 0.8 mm-thick aerogel fabric demonstrates excellent thermal insulation performance, comparable to significantly thicker conventional insulating materials under both high temperature (200 °C) and low temperature (−15 °C) conditions.

1. Introduction

Temperature-related risks are prevalent for individuals who work or live in high- and/or low-temperature environments.[1] According to the statistics from International Labour Organization in 2020, overheated work environments cause around 22.87 million occupational injuries each year, including 18 970 fatalities and 2.09 million "disability adjusted life years", underscoring the imperative and significance of personal thermal protection.[2] Of many thermal protection approaches is the development of thermal protective textiles, which can ensure both comfort during regular use and human safety in extreme environments, particularly in the scenarios involving intense heat radiation and fire hazards.[3,4]

Various high-performance fibers with ultrafine, hollow, coarse, and/or heterogeneous structures have been employed to prepare thermal protective textiles and provided effective protection against heat-related injuries.[5–7] However, these materials sometimes show vulnerability when dealing with harsh conditions (such as fire scenes and metalworking industries) due to their limited insulation capability and/or bulkiness.[8] Aerogels, characterized by a 3D porous structure, ultralight weight and exceptionally low thermal conductivity, have garnered considerable attention for thermal insulation applications.[9–12] The thermal insulation performance can be further enhanced when the aerogels are used in fiber form, since it offers them extra processing capability to fabricate porous wearable aerogel textiles.[4,5]

To date, a plethora of materials have been explored for the fabrication of aerogel fibers, with the examples of silica,[13,14] graphene,[15] cellulose,[16,17] polyimide,[5,18] to name a few. Among them, aramid nanofibers (ANFs), also known as Kevlar fibers, are of our particular interest, given their excellent thermal insulation, high-temperature and flame resistances.

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Journal of Colloid and Interface Science 671 (2024) 205–215

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Journal of Colloid And Interface Science

journal homepage: www.elsevier.com/locate/jcis

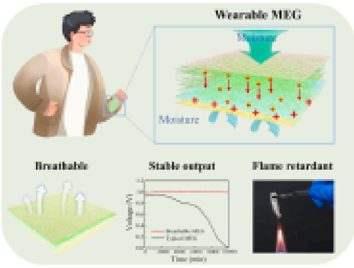
Regular Article

High-performance, breathable and flame-retardant moist-electric generator based on asymmetrical nanofiber membrane assembly

Renquan Xing, Ying Liu, Jing Yan, Run Wang, Xupin Zhuang *, Guang Yang *

State Key Laboratory of Separation Membranes and Membrane Processes/National Center for International Joint Research on Separation Membranes, School of Textile Science and Engineering, Tiangong University, Tianjin 300387, China

GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Moist-electric
Nanofiber
Breathability
Flame retardancy
Wearable electronics

ABSTRACT

Moist-electric generators (MEGs), which are capable of spontaneously generating energy from ubiquitous moisture, are considered as a potential power supply candidate for wearable electronics. However, the application of the MEGs in the wearable field is still challenging due to the low electric output and the lack of wearable attributes such as breathability and flame retardancy. Herein, we demonstrated a wearable MEG with high power-output, breathability and flame retardancy, which was fabricated by designing an asymmetrical nanofiber assembly using hydrophilic polyvinyl alcohol/phytic acid (PVA/PA) and hydrophobic polyvinylidene difluoride (PVDF) nanofiber membranes. Owing to the synergistic effects of strong water absorption, enhanced ion release and numerous micro-nano transport channels, a single MEG of 1 cm^2 could constantly generate high direct-current (DC) power, i.e., a voltage of 1.0 V, a current of 15.5 μA, and a power density of 3.0 $\mu W\ cm^{-2}$, outperforming other reported nanofiber-based MEGs. More importantly, the asymmetric nanofiber structure ensured the moisture circulation inside MEG and thus produced a sustained voltage output for 7 days without any deterioration. The MEG also showed good flexibility, air/moisture permeability and flame retardancy, which give it necessary wearable attributes. Furthermore, large-scale integration of MEG units could be readily realized to fabricate a power source device for driving different portable electronics, while the moisture sensitivity made the MEG well used for sensing applications (e.g., respiration monitoring, fire warning).

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High-performance textile-based triboelectric nanogenerators with damage insensitivity and shape tailorability

Jing Yan [1], Jingjing Liu [1], Yafang Li, Kaibo Wang, Weimin Kang *, Guang Yang *

State Key Laboratory of Separation Membranes and Membrane Processes, National Center for International Joint Research on Separation Membranes, School of Textile Science and Engineering, Tiangong University, Tianjin 300387, PR China

ARTICLE INFO

Keywords:
Triboelectric nanogenerator
Dual-faced triboelectric fabric
Knitting technology
Energy harvesting
Wearable technology

ABSTRACT

Textile-based triboelectric nanogenerators (TENGs) represent a groundbreaking advancement in the field of wearable technology for supplying sustainable energy. In this study, a knitted dual-faced textile-based TENGs was proposed to address the existing challenges of low energy output and poor wearability. The fabric, composed of polytetrafluoroethylene (PTFE) yarn and silver-plated yarn, features a unique intermeshed structure that enhances the corresponding TENG's output performance by increasing the contact area between the tribo-material and electrode. Such textile-based TENG have demonstrated an ability to attain open-circuit voltage, short-circuit current, and power density up to 133.8 V, 21.9 μA, and 0.53 W/m^2, respectively. More importantly, the dual-faced triboelectric fabric exhibited exceptional damage insensitivity and shape tailorability, making it sustainable for long-term use in wearable devices. The textile-based TENG can power various microelectronic devices, including LED arrays and calculators, showcasing their potential as reliable energy sources for wearable electronics. Furthermore, a real-time wireless direction indication system integrated into a smart garment was developed, demonstrating the TENG's versatility in applications beyond energy harvesting, potentially in navigation assistance. The advent of the dual-faced triboelectric fabric signifies an important step forward in wearable technology, promising enhanced performance and expanded applications in both energy collection and sensing technology.

1. Introduction

In the realm of modern wearable technology, one of the most pressing challenges is the provision of a sustainable and efficient energy supply [1]. The increasing popularity of wearable devices has heightened the demand for compact, lightweight, and flexible energy sources [2]. Traditional batteries, often bulky and with limited lifespan, poses significant limitations in this context [3,4]. Triboelectric nanogenerator (TENG), an innovative energy-harvesting device that converts mechanical energy into electrical energy based on the triboelectric effect and electrostatic induction, offers a promising solution to this challenge [5]. Specifically, the daily activities of the human body can be collected and converted into electrical energy, providing an effective solution for the energy supply of wearable devices [6]. By exploiting the natural motion of the human body, it is necessary to develop wearable TENGs.

Textile-based TENGs have garnered increasing attention due to their flexibility, lightweight, and potential integration with clothing [7,8]. These innovations open up exciting possibilities for powering wearable devices in a more efficient and user-friendly manner, heralding a new era in wearable technology. However, the output performance of textile-based TENGs currently remains relatively low, necessitating further improvements for practical applications [9–12]. Textile-based TENGs come in multiple forms, including weaving [13–17], knitting [18,19], and non-woven [20–22], having been explored to create effective energy-generating fabrics. Knitting, as a standout method among textile-based TENG fabrication techniques, has attracted considerable interest recently, primarily for its streamlined process, adaptable structural design, and suitability for mass production [10, 23–26]. The power generation efficiency of these devices is primarily determined by materials used, surface properties, and structural design [27]. The performance improvement of the TENGs were mainly focused on the tribo-dielectrics, such as increasing the friction area, creating the surface microstructure, and designing various structures to fit human motion. Comparatively, the electrodes, another crucial component of

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Thermally robust hierarchical nanofiber triboelectric yarns for efficient energy harvesting in firefighting E-textiles

Jing Yan *, Haoxuan Wang, Kaibo Wang, Weimin Kang, Guang Yang *

State Key Laboratory of Separation Membranes and Membrane Processes/National Center for International Joint Research On Separation Membranes, School of Textile Science and Engineering, Tiangong University, Tianjin 300387, PR China

ARTICLE INFO

Keywords:
Triboelectric nanogenerator
Hierarchical nanofiber yarn
MXene
Charge-trapping interlayer
Thermal robustness

ABSTRACT

Textile-based triboelectric nanogenerators (TENGs) face challenges in achieving high performance and fulfilling functional requirement for special applications. This paper presents the development of a high-performance, thermally robust hierarchical polyimide (PI) nanofiber triboelectric yarns with a charge-trapping interlayer for application in firefighting E-textiles. The hierarchical nanofiber yarns, comprising a stainless-steel core electrode, a PI/MXene interlayer and PI outer tribo-layer, exhibit enhanced triboelectric performance due to the charge-trapping capabilities of MXene, which preventing the recombination of triboelectric and induced charges. When the MXene content in the charge-trapping interlayer reached 1 wt%, the corresponding TENG achieved its optimal output performance, with an output voltage of 153 V and a current of 13.13 μA and a peak power density of 0.84 W/m^2 under optimal conditions. It also demonstrates exceptional thermal stability, maintaining stable output at temperatures up to 400 °C. The integration of the TENG into E-textiles enables real-time monitoring of firefighters' physical activities and location tracking, significantly enhancing their safety and operational efficiency in fire scenarios. Additionally, the TENG powers electroluminescent yarns, improving visibility in dense smoke and dust environments. This research opens new avenues for the application of smart wearable systems in high-temperature environments, providing effective strategies for ensuring the safety of firefighters in fire rescue operations.

1. Introduction

Fire has been a fundamental element in human civilization, symbolizing progress and serving as a crucial source of energy. It provides light and warmth, facilitating the societal advancement and significantly contributing to the development of human communities [1,2]. However, the dangers posed by uncontrolled fires highlight the need for effective firefighter monitoring [3,4]. Firefighters often face environments filled with toxic fumes, obscured visibility, and extreme heat. Therefore, enhancing real-time activity monitoring is essential for their safety and operational efficiency. The invention of the triboelectric nanogenerators (TENGs), capable of converting human-induced micro-energy movements into electricity through triboelectrification and electrostatic induction, presents a novel approach to improve firefighter safety in challenging conditions [5–9]. In this context, wearable smart sensing systems based on TENGs are expected to monitor the activity of firefighters and provide rescue information timely [10–12].

For wearable applications, textile-based TENGs are preferred due to their inherent advantages such as flexibility [13], breathability [14], and seamless integration with clothing [15]. Traditional textile-based TENGs feature a multilayer configuration, incorporating both fabric and electrode components, which require precise alignment and adhesion between the triboelectric layer and electrodes throughout the fabrication and operation. However, maintaining such precision is challenging over time, leading to reduced efficiency and reliability [16–18]. Additionally, the electrical performance of textile-based TENGs is often limited by restricted active contact areas at textile interfaces [19]. In contrast, TENGs constructed with core-spun nanofiber yarn offer a superior resolution to these challenges. The core, serving as the internal electrode, typically employs flexible conductive materials, surrounded by a tribo-layer consisting of commercially available yarn bundles and micro- or nanofibers. These fibers or yarns, tightly twisted or wrapped around the electrode, ensure thorough and effective material engagement [20]. This core-spun structure not only ensures a consistent and ample contact between the tribo-layer and the electrode, providing robust structural stability, but also enhances charge collection

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Thermal-Triggered "On–Off" Switchable Triboelectric Nanogenerator Based on Two-Way Shape Memory Polymer

Guang Yang, Haiqiong Li, Renquan Xing, Mengdie Lv, Chongqi Ma, Jing Yan,* and Xupin Zhuang**

Developing multifunctional triboelectric nanogenerators (TENGs) with special intelligence is of great significance for next-generation self-powered electronic devices. However, the relevant work on the intelligent TENGs, especially those spontaneously responsive to external stimuli, is rarely reported. Herein, an intelligent TENG with thermal-triggered switchable functionality and high triboelectric outputs is developed by designing a movable triboelectric layer, which is driven by a two-way shape memory polyurethane. The resultant TENG device can be spontaneously switched on/off in response to the environmental temperature change, i.e., switching on at 0 °C and off at 60 °C. At the "on" state, the developed TENG exhibits excellent triboelectric performance with a maximum output power density of 5.15 W m^{-2} at a pressure of 30 kPa due to the unique advantages of micro-/nanofiber triboelectric surfaces. Furthermore, the great potential of the switchable TENG in intelligent wearable electronic applications is demonstrated, which can serve as not only the sensing element for monitoring human movement and physical condition in a cold environment but also the thermal-driven switch for turning on/off the heating function on demand. The intelligent "on–off" switchable TENG combined with excellent triboelectric performance may provide new opportunities for future self-powered wearable electronics.

1. Introduction

Recently, triboelectric nanogenerators (TENGs) have attracted much attention and are widely used as sustainable energy harvesters and self-powered sensors since they are capable of effectively converting various surrounding mechanical energies into electrical energy and signals based on the combined actions of the contact electrification and the electrostatic induction.[1–5] Compared to conventional power sources such as capacitors or batteries, TENGs show great superiority in the weight, volume, personal safety, material diversity, and environmental friendliness, which lead to great potential in a variety of fields such as electronic skins, sensing systems, soft robots, and human-machine interfaces.[6–8] So far, most researches focus on the triboelectric output enhancement of TENGs, and many efforts aiming to this end have been made, e.g., the micro-/nanostructure construction, the surface modification, the combination of functional materials, etc.[9–12] Consequently, the development of high-performance TENGs has made tremendous progress, broadening their application fields. However, with the ever-growing demands for applying the TENG devices into more advanced and complicated occasions, it is highly desirable to develop novel TENGs with intelligence and multifunction, which will be of great significance for next-generation self-powered electronic systems.[13–16]

The polymers, as the key components of TENGs, play an important part in determining the performance and the function of the device.[17–19] It is regarded that the polymer materials that have unique characteristics will bring additional functions and features to the TENG devices. Therefore, a promising and feasible strategy of developing the intelligent and multifunctional TENGs is to employ smart polymers as the core materials.[20–22] Following this principle, several intelligent and multifunctional TENGs have been reported based on shape memory polymers (SMPs), which are a class of stimulus-responsive materials capable of preserving a temporary shape and recovering their original shape.[23–26] By taking advantage of unique properties of SMPs, the resultant TENGs exhibited the microstructure retention capability for the lifetime improvement and the shape-adaptability for the good object surface fitting.[27–30] For example,

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Triboelectric Nanogenerators Based on Membranes Comprised of Polyurethane Fibers Loaded with Ethyl Cellulose and Barium Titanate Nanoparticles

Jing Yan, Mengdie Lv, Yuebin Qin, Baojing Wang, Weimin Kang, Yafang Li,* and Guang Yang*

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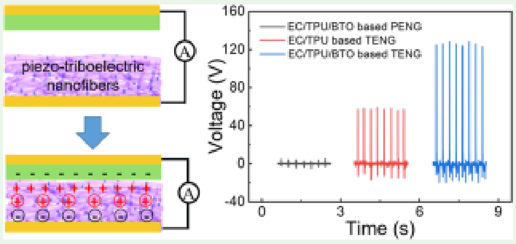
ABSTRACT: High performance is always the research objective in developing triboelectric nanogenerators (TENGs) for future versatile applications. In this study, a flexible ethyl cellulose/thermoplastic polyurethane (EC/TPU) nanofiber triboelectric layer with barium titanate (BTO) nanoparticles is proposed for high-performance TENGs, in which electrospun EC/TPU nanofiber membranes supply the high-roughness friction surfaces and piezoelectric BTO nanoparticles are further incorporated to boost the electric outputs by the synergistic effect of piezoelectricity and triboelectricity. Consequently, when the content of the BTO nanoparticle is 8 wt % in the EC/TPU (1:4 in weight ratio) nanofibers, the composite membrane displayed a stress of 9.25 MPa and a strain of 275.2%. The corresponding TENG achieves electric outputs of 125.8 V, 34.1 μA, and 1.68 W/m^2, much higher than those of an individual piezoelectric nanogenerator or TENG. The TENGs are potentially used to supply energy for commercial LEDs and microelectronics and as self-powered sensors to monitor human physical training conditions. This research provides a guideline for developing TENGs with high performance, which is crucial for their long-term use.



KEYWORDS: *triboelectric nanogenerator, electrospun nanofiber, barium titanate, ethyl cellulose, thermoplastic polyurethane*

1. INTRODUCTION

Wearable electronics have significantly improved the quality of human life in health monitoring, physical training, and entertainment.[1,2] At the same time, their energy supply problems also raise great concerns. Traditional batteries have the shortcomings of nonflexibility, limited service life, and severe environmental pollution, restricting their further application in the field of wearable electronics.[3] The emergency of nanotechnology and nanoenergy proposes a new pathway for supplying sustainable and renewable energy. The triboelectric nanogenerator (TENG) is one of the novel nanoenergy harvesters capable of converting universal mechanical energy into electric power based on the combination of triboelectricity and electrostatic induction.[4] Due to their diverse applicable materials, broad applicability, easy operation, and so on, TENGs have received enormous attention and experienced rapid development in the past 10 years.[5] In addition, TENGs can be

promising approach to developing high-performance TENGs. Nanofiber membranes prepared by electrospinning have the remarkable characteristics of micro/nanostructures, large specific surface area, and high porosity, which reveal their unique advantages in boosting triboelectric performance such as high roughness, large active areas, and good charge storage ability.[7] However, according to our fundamental research, the most widely used polymeric materials in nanofibrous structures like poly(vinylidene fluoride) (PVDF), polyimide, etc., are not durable to withstand intense and cyclic friction actions resulting in rapid performance deterioration. Thermoplastic polyurethane (TPU) possesses the characteristics of high flexibility, good abrasion resistance, and excellent mechanical robustness.[8] However, its triboelectricity is not strong enough for high-performance TENGs and needs to be strengthened sufficiently.[9] Mixing a tribo-positive material on the top rank of the triboelectric series such as ethyl cellulose (EC) with a strong

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Hierarchically Structured Carbon Nanofiber-Enabled Skin-Like Strain Sensors with Full-Range Human Motion Monitoring and Autonomous Self-Healing Capability

Guang Yang,* Haojun Luo, Yunpeng Ding, Jingwen Yang, Yafang Li, Chongqi Ma, Jing Yan,* and Xupin Zhuang*

Cite This: ACS Appl. Mater. Interfaces 2023, 15, 7380−7391 Read Online

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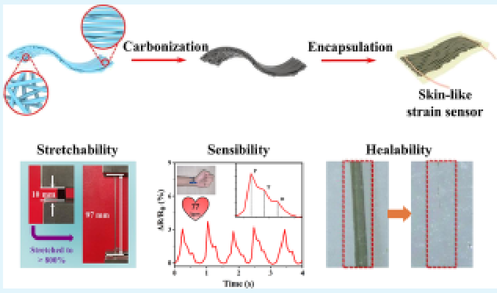
ABSTRACT: Flexible strain sensors that mimic the properties of human skin have recently attracted tremendous attention. However, integrating multiple functions of skin into one strain sensor, e.g., stretchability, full-range motion response, and self-healing capability, is still an enormous challenge. Herein, a skin-like strain sensor was presented by the construction of hierarchically structured carbon nanofibers (CNFs), followed by encapsulation of elastic self-healing polyurethane (PU). The hierarchical sensing structure was composed of diversified CNFs with orientations from highly aligned to randomly oriented, and their different fracture mechanisms enabled the resultant strain sensor to successfully integrate key sensing properties including high sensitivity (gauge factor of 90), wide sensing range (~80% strain), and fast response (52 ms). These properties, combined with high stretchability (870%) and excellent stability (>2000 cycles), allowed the sensor to precisely detect full-range human motions from large joint motions to subtle physiological signals. Moreover, the strain sensor had spontaneous self-healing capability at room temperature with high healing efficiencies of 97.7%, while the healing process could substantially be accelerated by the natural sunlight (24 h → 0.5 h). The healed sensor possessed comparable stretchability, sensing performance, and accurate monitoring ability of subtle body signals with the original sensor. The biomimetic self-healing functionality along with skin-like sensing properties makes it attractive for next-generation wearable electronics.



KEYWORDS: *strain sensor, carbon nanofiber, sensing performance, self-healing, motion monitoring*

1. INTRODUCTION

Flexible sensors as the key component of wearable electronic devices are recently attracting enormous attention, which have been demonstrated in personal health monitoring,[1−3] body motion detection,[4,5] artificial skin,[6,7] human−machine interface,[8,9] etc. Skin-like features have always been highly desirable for strain sensors.[10] To this end, sensitivity and sensing range are the two primary parameters to be considered in assessing the sensing performance of a strain sensor. The former represents the response ability of a flexible strain sensor to subtle strain variation, while the latter directly determines the requirements for conducting networks: high sensitivity originates from drastic electrical network deformation under subtle strains, whereas wide sensing range should keep conductive pathways from destruction until large strains are applied.[14] Consequently, it seems to be challenging to integrate high sensitivity and wide sensing range in one single flexible strain sensor.

To address this issue, considerable efforts have been made with varied successes. One strategy is to combine multiple conductive networks and utilize their different ductility to control the growth of microcracks. For example, Peng et al.[15]

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Charge-Boosting Strategy for Wearable Nanogenerators Enabled by Integrated Piezoelectric/Conductive Nanofibers

Jing Yan, Yuebin Qin, Mengfei Li, Yixia Zhao, Weimin Kang,* and Guang Yang*

Cite This: ACS Appl. Mater. Interfaces 2022, 14, 55039−55050 Read Online

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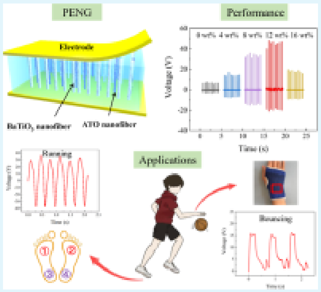
ABSTRACT: The surface charge density enhancement by incorporating conductive paths into organic/inorganic piezoelectric composites is considered to be an effective way to achieve high-performance piezoelectric nanogenerators (PENGs). However, it is challenging to boost the charge density of aligned piezoelectric nanofibers due to the difficulty in efficiently building well-distributed conductive paths in their dense structure. In this work, a charge boosting strategy was proposed for enhancing the surface charge density of aligned piezoelectric nanofibers, that is, synchronously preparing piezoelectric/conductive hybrid nanofibers to realize the effective conductive paths for transferring the underlying charges to the surface of the PDMS/$BaTiO_3$ composites. To this end, antimony-doped tin oxide (ATO) conductive nanofibers and barium titanate ($BaTiO_3$) piezoelectric nanofibers with the same preparation conditions were selected and synchronously prepared by the polymer template electrospinning technology, followed by the calcination process. Benefiting from the well-distributed conductive paths for transferring the charges, the open-circuit voltage and short-circuit current of a PENG with 12 wt% ATO in hybrid nanofibers reached 46 V and 14.5 μA (30 kPa pressure), respectively, which were much higher than the pristine $BaTiO_3$-based PENG. The high piezoelectric performance of the developed PENGs guaranteed their great potential applications in powering wearable microelectronics and monitoring human activity. This charge boosting strategy via the piezoelectric/conductive hybrid nanofibers may inspire the further development of high-performance energy harvesting technology.



KEYWORDS: *piezoelectric nanogenerator, conductive nanofiber, electrospinning, energy harvesting, motion monitoring*

1. INTRODUCTION

The piezoelectric nanogenerators (PENGs) that can convert mechanical vibration to electrical energy have been studied extensively as sustainable energy suppliers and self-powered sensors.[1,2] Since its invention by Prof. Wang in 2006, PENGs have received significant attention from various research fields due to their strong universality, small size, portability, high sensitivity, and durability.[3,4] Owing to their potential applications in energy harvesting, health diagnosis, motion monitoring, and so forth, PENGs must have good flexibility to respond to complex strains from bending, stretching, or twisting.[5] Based on the fact that most materials with relatively high piezoelectric coefficients are fragile ceramics and easily broken upon deformations, it is therefore necessary to embed piezoelectric ceramics into flexible polymers to develop

$BaTiO_3$) composite to improve its piezoelectric property, in which MWCNTs could form conductive paths reducing the internal resistance of the PENG for charge transfer, thus improving the output performance. By adding 1 wt% MWCNTs, the generated open-circuit voltage (V_{oc}) increased from 0.17 to 3.2 V under the continual bending/unbending cycles. Similarly, Sun et al.[11] reported a flexible PDMS/ZnO PENG with MWCNTs as the "nano-electrical bridge" among ZnO nanoparticles for transferring the induced charge. V_{oc} was as high as 7.5 V compared to 0.8 V for the control sample. Based on these research works, it can be concluded that conductive paths play an essential role in the charge transfer for the performance enhancement of organic/inorganic flexible PENGs.

Compared to their particle forms, regularly arranged

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Highly sensitive, direction-aware, and transparent strain sensor based on oriented electrospun nanofibers for wearable electronic applications

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ARTICLE INFO

Keywords:
Strain sensor
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Direction recognition
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ABSTRACT

Wearable strain sensors have made great progress in sensing performance, stretchability and durability. However, practical applications of these sensors are still quite challenging because they are incapable of detecting multi-degree-of-freedom strains due to the interference of multidirectional strains. Herein, a high-sensing-performance, direction-aware and transparent strain sensor is reported based on antimony-doped tin oxide oriented nanofiber (ATO-ONF) films prepared by electrospinning. The monolayer ATO-ONF strain sensor shows remarkable anisotropic sensing performance, namely GFs of 250 and 1.2 for the nanofiber orientation and its transverse directions, suggesting the realization of the unidirectional sensing capability of the strain sensor, *i.e.*, only responding to strains along the nanofiber direction. In addition, this strain sensor also exhibits high transparency with a light transmittance of ~ 80%, and excellent sensing performance including high sensitivity, high linearity, low hysteresis, good repeatability and durability (>2000 cycles). Based on these superior sensing properties, the direction-aware biaxial strain sensor is designed by orthogonally stacking ATO-ONF films, by which the predicted magnitude and direction of the tensile strains agree well with those of the actual strains. Furthermore, the multi-degree-of-freedom applications of direction-aware strain sensors in human motion monitoring and human–machine interaction are demonstrated, showing a great application potential in next-generation wearable electronics.

1. Introduction

Flexible strain sensors that convert mechanical deformations into measurable electrical signals have attracted tremendous attention and their potential applications in diverse fields were fully developed, such as human motion detection [1–4], soft robotics [5–7], personal health monitoring [8–10], and human–machine interaction [11–13]. According to working mechanisms, there are several types of flexible strain sensors, including resistive, capacitive, piezoelectric, and triboelectric sensors [14–17]. Owing to the advantages of ease of fabrication, good readability, and tunable sensitivity, resistive-type strain sensors exhibit a greater potential in wearable sensing devices. In most cases, directional recognition of multi-degree-of-freedom motions is essential for strain sensors, especially in some specific fields such as e-skin, direction indicators, *etc* [18,19]. However, although a great progress has been made in the sensing performance enhancement of wearable strain sensors [20–22], these strain sensors are only able to detect the strain in the preset direction without the ability of distinguishable detection of multiaxial strains originates from strong coupled variations of electrical resistance in the principal strain direction and the transverse direction. Therefore, once the off-axial strains occur, the electrical signals of the strain sensors will be affected, leading to inaccurate calculation of the strains.

In order to meet application requirements of specific areas that need to quantitatively determine sophisticated strains, designing a single strain sensor with the reliable direction recognition capacity is indispensable. So far, several efforts have been made to achieve decoupled electrical properties *via* unique anisotropic structural design, which effectively avoids the interference among various stimuli for realizing multidirectional sensing. One strategy of preparing these direction-aware strain sensors is to design stiffness-variant stretchable matrices combined with a cross-shaped conductive network [23]. The resultant strain sensors could efficiently distinguish the strains of various directions with high selectivity (*i.e.*, a maximal difference in gauge factor (GF) of > 20 between the orthogonal axes). Another strategy is to design anisotropic structures of the sensing elements for anisotropic electromechanical behaviors. The first demonstration of this strategy was re-

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Toward high-performance multifunctional electronics: Knitted fabric-based composite with electrically conductive anisotropy and self-healing capacity

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ARTICLE INFO

Keywords:
Multifunctional electronics
Anisotropic conductive composite
Electro-heater
Strain sensor
Self-healing function

ABSTRACT

Textile-based electronics characterizing easy integration into textile garments and good wearability have received considerable attentions. However, it is still a huge challenge to integrate multiple functions into single electronic device, especially for those having different even opposite requirements in electrical properties. In this work, an anisotropic electrically conductive composite was prepared by encapsulating conductive knitted fabric (CKF) into polyurethane (PU). Based on anisotropic electrical conductivity, i.e., extremely low and stable resistivity in the coursewise direction and significant variation of resistivity in the walewise direction during tensile strains, the composite could efficiently integrate the electro-heating and strain-sensing functions that required opposite electrical properties. When applied for electro-heating applications in the coursewise direction, the CKF/PU composite exhibited fast thermal response, ultrahigh electric-thermal conversion (140 °C at 4 V), and stable electrothermal performance under a large strain (40%) or after long-term use (>1000 stretching cycles). When applied for strain-sensing applications in the walewise direction, the composite showed good sensing performances, including high sensitivity (GF of −8.1 at a 5% strain), low hysteresis, good reproducibility and stability (>1000 cycles), which enabled the device as a wearable sensor to accurately detect human joint movements and subtle motions. Furthermore, the self-healing function was exploited for the CKF/PU electronic device, by which the abnormal sensing property could be fully repaired at human body temperature. This work may shed new light on the future development of high-performance multifunctional wearable electronics with the anisotropic conducting feature.

1. Introduction

Wearable electronics featuring high flexibility and stretchability have attracted tremendous attention due to their great potentials in diverse fields, such as artificial skin [1–3], human activity detection [4,5], health monitoring [6,7], and human–machine interactions [8,9]. Compared with conventional electronics that are almost rigid, flexible wearable electronics are able to work under stretching, bending, and torsion states, effectively meeting the demands for wearing [10,11]. Textiles as a common necessity in human life have flexible, breathable, structurally controllable, and industrial-scale producible features [12], which allow them to be ideal materials/supports for wearable electronics. Nevertheless, a majority of the wearable electronics are monolithic films in geometry and thus they are integrated into smart textiles by attaching to the textiles rather than being a part of the textile structure, which may result in easy performance deterioration and uncomfortable feeling for human body [13–15]. In contrast, textile-based wearable electronics are easily woven into complex fabrics during the weaving process and become a part of the cloths themselves. This characteristic offers the benefits unparalleled by other electronic materials [16,17]. One common approach for achieving textile-based electronics is to coat conductive components onto existing fabrics [18,19]. However, the coated textiles are usually faced with a challenge of cycling stability and durability. Because most conductive materials do not have strong interactions with the fabrics, large deformation and long-term use easily change the state of the conducting path, resulting in the deterioration of electronic functionalities [14,20]. Another way to achieve textile-based electronics is to weave or knit 1D conductive filaments or yarns into a 2D textile pattern [21,22]. Compared with the former coating method, the latter would offer higher strain durability, better long-term stability, and independently designed textile style. Therefore, this approach has a great potential in the electronic textile field.

Textile-based electronics have been applied in various fields,