



# 化工进展

## Chemical Industry and Engineering Progress

Vol.41 No.10  
2022年10月

**ATW 安特威**  
助您安心享受美好生活

**全金属三偏心蝶阀**

**双向密封、零泄漏**

- 双向VI级密封，100000次以上开关寿命
- 密封环可以互相更换
- 全数字化生产，远程可视、实时可控
- 大幅延长使用寿命，降低维修成本

助您安心享受美好生活

智能蝶阀柔性产线

扫码获取更多产品案例

广告

ISSN 1000-6613  
 10>  
9 771000 661225



主办 | 中国化学会  
 化学工业出版社有限公司



## 目 次

### 特约评述

微波强化酯交换反应制备生物柴油研究进展 ..... 朱长辉, 朱文超, 罗嘉, 田保河, 孙佳琳, 邹志云(5145)

### 化工过程与装备

- 国内外聚烯烃流化床技术专利分析 ..... 张雅群, 朱佩, 熊进苏, 孙丽娟, 叶文莹, 孙婧元(5155)  
乙烯装置急冷系统设计及优化方法 ..... 辛江, 张来勇, 赵唯, 隋蕾(5169)  
边界压力波动对液膜端面机械密封空化及性能的影响 ..... 张金亚, 张家祥, 沈宗沼, 陈逸(5175)  
操作参数对三相卧螺离心机油水砂分离性能影响模拟及实验分析 ..... 朱明军, 胡大鹏(5188)  
费托合成水相副产物混合醇分离: 馏分切割工艺设计及控制 ..... 黄洋, 张稼骏, 李家腾, 夏铭, 许春建(5200)  
基于热流逸效应的燃煤电厂烟气二氧化碳分离系统 ..... 曾成, 卢苇, 蒙仕达, 覃日帅(5214)  
四产品 Kaibel 隔壁精馏塔分离丙二醇混合物的模拟与节能分析 ..... 李腾, 张雨新, 林子昕, 别海燕, 安维中(5221)  
高性能柔性环路热管设计与热特性分析 ..... 徐光明, 邵博, 李南茜, 赵晨阳, 郑宿正, 陆燕(5228)  
耦合溴化锂吸收式制冷与有机朗肯循环的合成气深冷分离工艺 ..... 李丹, 杨思宇, 钱宇(5236)  
应用于换热网络优化的并行双层 RWCE 算法 ..... 刘洪彬, 崔国民, 周志强, 肖媛, 张冠华, 杨其国(5247)

### 能源加工与技术

- 多孔介质中  $\text{CO}_2\text{-CH}_4$  水合物置换的影响因素及强化机理研究进展 .....  
张学民, 张山岭, 李鹏宇, 黄婷婷, 尹绍奇, 李金平, 王英梅(5259)  
质子交换膜燃料电池仿真模型研究进展 ..... 李政翰, 涂正凯(5272)  
可再生能源在化工生产及其公用工程系统中的应用 ..... 孙志伟, 伍联营, 胡仰栋, 张伟涛(5297)  
农业生物质与塑料共热解技术进展 ..... 谢腾, 赵立欣, 姚宗路, 霍丽丽, 贾吉秀, 张沛祯, 田利伟, 傅国浩(5306)  
骨架结构醚基支链型羧酸在铝电解电容器中的应用 ..... 刘康洪, 许孙洁, 薛瑄武, 原鲜霞(5316)  
高温质子交换膜燃料电池电堆稳定性分析与优化 ..... 姬峰, 郑博文, 罗若尹, 杜玮, 邓呈维, 杨声, 刘志强(5325)  
化学链空分联合化学链制氢的煤制甲醇过程参数优化与分析 .....  
周怀荣, 马迎文, 王可, 李红伟, 孟文亮, 谢江鹏, 李贵贤, 张栋强, 王东亮, 赵永臣(5332)  
高含有机硫天然气的净化研究与探索 ..... 冷南江, 马国光, 张涛, 雷洋, 彭豪, 熊祚帅, 陈玉婷(5342)  
中试装置内水合物注抑制剂的分解规律 ..... 王云飞, 孙长宇, 喻西崇, 王清, 李清平, 陈光进(5354)  
全可视化反应釜内二氧化碳水合物的生成分解特征 ..... 毛港涛, 李治平, 王凯, 丁垚(5363)  
动力学抑制剂与乙二醇协同作用下甲烷水合物再生成 ..... 隋金昊, 王智, 梁璇玑, 张烜玮, 朱羽墨, 宋尚飞, 史博会, 宫敬, LOU Xia(5373)  
丝瓜络固定化米根霉催化光皮树油制备生物柴油 ..... 纪淑兰, 李迅, 王飞(5381)

### 工业催化

- 乙炔选择性加氢催化剂研究进展 ..... 陈志强, 车春霞, 吴登峰, 温翯, 韩伟, 张峰, 许昊翔, 程道建(5390)  
分散型浆态床渣油加氢双金属催化剂研究进展 ..... 武世伟, 王廷, 侯焕娣, 申海平(5406)

碳包裹非贵金属催化剂的制备及其在催化加氢中的应用 ..... 王宏政, 马超凡, 颜伟, 何巍, 卢春山, 李小年(5416)

## 材料科学与技术

- 高熔体强度聚丙烯中长支链结构的分析与表征方法新进展 ..... 崔崑, 黄晋, 赵巧玲, 马志(5425)  
锂离子电池安全添加剂的研究进展 ..... 胡华坤, 薛文东, 蒋朋, 李勇(5441)  
碳基全固态离子选择性电极材料研究进展 ..... 王锡民, 魏潇然, 冯瑛, 黄国勇, 王春霞(5456)  
研磨法制备金属有机框架材料的新进展 ..... 张珂, 屈小虎, 朱元军, 林建英, 赵志换, 樊惠玲(5465)  
不同模式多功能柔性传感器研究进展 ..... 汪小钰, 胡平, 操齐高, 李世磊, 胡卜亮, 葛松伟, 杨帆, 陈波, 朱昕宇, 王快社(5474)  
磁性 $\text{Fe}_3\text{O}_4@\text{SiO}_2$ 介孔 $\text{SiO}_2$ 空心微球的制备及漆酶固定化 ..... 李群艳, 孙路瑶, 常其飞, 周运炉(5494)  
氮掺杂石墨烯/碳纳米管/无定形炭复合材料制备及其电化学性能 ..... 张燕, 王森, 赵佳辉, 冯宇, 米杰(5501)  
氨基功能化介孔超分子聚合物的温和构筑及其 $\text{CO}_2$ 吸附性能  
..... 邱明月, 李东娜, 刘书磊, 易群, 范海明, 李向远, 李剑川, 史利娟, 张鼎(5510)  
基于相变材料的锂离子电池热管理性能 ..... 尹少武, 康鹏, 韩嘉维, 张朝, 王立, 童莉葛(5518)  
基于聚异丁烯胺改性的耐甲醇溶胀新型薄膜复合膜 ..... 丁俊毅, 陈营东, 王书浩, 严文韬, 周勇, 高从堦(5530)

## 生物与医药化工

- 一株产低温脂肪酶酵母菌的鉴定及酶学性质 ..... 史程风, 贾冉冉, 阎振丽, 惠丰立(5541)

## 精细化工

- 磷-硼杂化预聚物嵌段水性聚氨酯纸张施胶剂的制备和性能  
..... 李婷, 杜少辉, 崔锦峰, 王仰辉, 李虎林, 郭润兰, 王蓬, 王振军, 郭军红, 杨保平(5549)  
低有机氯含量PAE基纸张湿强剂的制备及性能评价 ..... 宋英琪, 沈一丁, 刘勇兵, 党园园(5558)

## 资源与环境化工

- 膜技术分离稀土金属元素的研究进展 ..... 张逸, 刘东昊, 丁一刚(5567)  
硫酸盐还原菌法固定酸性矿山废水中重金属的研究进展 ..... 闻倩敏, 秦永丽, 郑君健, 韦巧艳, 张媛媛, 蒋永荣(5578)  
氮掺杂生物炭材料的制备及其在环境中的应用 ..... 鞠梦灿, 严丽丽, 简铃, 江思雨, 饶品华, 李光辉(5588)  
氮修饰木质素基超交联聚合物的制备及其放射性碘捕获 ..... 万欢爱, 邵礼书, 刘娜, 毛莉, 张林, 詹鹏, 陈介南(5599)  
低共熔溶剂预处理杨木水解渣拆解木质素 ..... 刘乾静, 陈晓森, 王芷, 史吉平, 李保国, 刘莉(5612)  
退役锂电池放电废水特征有机污染物解析 ..... 刘肖贝, 张西华, 熊梅, 赵赫(5619)  
适应多负载电池储能系统的拓扑结构优化重构方法 ..... 郑良天, 康丽霞, 黄贤坤, 刘永忠(5630)  
Ⅱ型无水磷石膏凝结硬化过程调控技术 ..... 张宇, 杨家豪, 刘瑜, 宋子玉, 何涵潇, 赵凤清(5637)  
磺酸修饰的金刚石掺杂磺化聚芳醚砜质子交换膜的制备与性能 ..... 王盟, 刘莉莉, 李娜, 胡朝霞, 陈守文(5645)  
高效重质石油降解菌群构建及降解性能评价 ..... 汪润民, 张晓东, 徐成华, 于丹丹, 余冉(5653)  
纳米片层铁锰双金属催化剂活化过一硫酸盐预处理烟草糖香料废水 ..... 薛雨微, 叶校圳, 曾静, 王永全, 洪俊明(5661)  
基于酸度系数( $\text{pK}_a$ )模型的胺法 $\text{SO}_2$ 捕集过程多目标效能分析 ..... 王东亮, 谢江鹏, 孟文亮, 李婧玮, 周怀荣(5669)  
可燃生活垃圾气化Ca-Fe复合金属氧化物的原位固硫性能  
..... 刘洋, 黄亚继, 董革新, 丁雪宇, 杨晓域, 王新宇, 张臻荣, 曹歌瀚, 李志远, 田新启(5677)  
基于深度时间序列特征融合的西安市2015—2020年供暖季雾霾重污染过程预警 ..... 王英, 冉进业, 张今, 杨鑫, 张浩(5685)

责任编辑：奚志刚

英文顾问：郭梅芳, 金仁村, 李保庆, 龙秉文, 王运东

## Contents

### Invited review

- Recent advances in microwave-intensified transesterification for biodiesel preparation ..... ZHU Changhui, ZHU Wenchao, LUO Jia, TIAN Baohe, SUN Jialin, ZOU Zhiyun (5145)

### Chemical processes and equipment

- Analysis on the patent information of polyolefin fluidized bed technology ..... ZHANG Yaqun, ZHU Pei, XIONG Jinsu, SUN Lijuan, YE Wenying, SUN Jingyuan (5155)  
Design and optimization method of quench system in ethylene plant ..... XIN Jiang, ZHANG Laiyong, ZHAO Wei, SUI Lei (5169)  
Influence of boundary pressure fluctuation on cavitation and performance of liquid film end face mechanical seal ..... ZHANG Jinya, ZHANG Jiaxiang, SHEN Zongzhao, CHEN Yi (5175)  
Simulation and experimental analysis of the influence of operating parameters on oil-water-sand separation performance of three-phase decanter centrifuge ..... ZHU Mingjun, HU Dapeng (5188)  
Separation of mixed alcohols from Fischer-Tropsch aqueous by-product: design, optimization and control of fraction cutting ..... HUANG Yang, ZHANG Jiajun, LI Jiateng, XIA Ming, XU Chunjian (5200)  
Thermal-transpiration-effect-based carbon dioxide separation system for flue gas from coal-fired power plant ..... ZENG Cheng, LU Wei, MENG Shida, QIN Rishuai (5214)  
Simulation and energy-saving analysis for separating propylene glycol mixtures via four-product Kaibel dividing wall column ..... LI Teng, ZHANG Yuxin, LIN Zixin, BIE Haiyan, AN Weizhong (5221)  
Design and thermal characteristics analysis of a high-performance flexible loop heat pipe ..... XU Guangming, SHAO Bo, LI Nanxi, ZHAO Chenyang, ZHENG Suzheng, LU Yan (5228)  
Syngas cryogenic separation process combined with lithium bromide absorption refrigeration and organic Rankine cycle ..... LI Dan, YANG Siyu, QIAN Yu (5236)  
Parallel double-layer RWCE algorithm for heat exchanger network optimization ..... LIU Hongbin, CUI Guomin, ZHOU Zhiqiang, XIAO Yuan, ZHANG Guanhua, YANG Qiguo (5247)

### Energy processes and technology

- Research progress on influencing factors and strengthening mechanism of CO<sub>2</sub>-CH<sub>4</sub> hydrate replacement in porous media system ..... ZHANG Xuemin, ZHANG Shanling, LI Pengyu, HUANG Tingting, YIN Shaoqi, LI Jinping, WANG Yingmei (5259)  
Research progress of simulation models of proton exchange membrane fuel cell ..... LI Zhenghan, TU Zhengkai (5272)  
Application status of renewable energy in chemical production and its utilities system ..... SUN Zhiwei, WU Lianying, HU Yangdong, ZHANG Weitao (5297)  
Progress in co-pyrolysis technology of agricultural biomass and plastics ..... XIE Teng, ZHAO Lixin, YAO Zonglu, HUO Lili, JIA Jixiu, ZHANG Peizhen, TIAN Liwei, FU Guohao (5306)  
Application of ether-based branched carboxylic acid with skeleton structure in aluminum electrolytic capacitor ..... LIU Kanghong, XU Sunjie, XUE Xuanwu, YUAN Xianxia (5316)  
Analysis and optimization of a HT-PEMFC stack ..... JI Feng, ZHENG Bowen, LUO Ruoyin, DU Wei, DENG Chengwei, YANG Sheng, LIU Zhiqiang (5325)  
Optimization and analysis of coal-to-methanol process by integrating chemical looping air separation and hydrogen technology ..... ZHOU Huairong, MA Yingwen, WANG Ke, LI Hongwei, MENG Wentiang, XIE Jiangpeng, LI Guixian, ZHANG Dongqiang, WANG Dongliang, ZHAO Yongchen (5332)  
Research and exploration on purification of natural gas with high organic sulfur content ..... LENG Nanjiang, MA Guoguang, ZHANG Tao, LEI Yang, PENG Hao, XIONG Zuoshuai, CHEN Yuting (5342)  
Analysis of the methane hydrate decomposition characteristics through inhibitor injection method by using a pilot scale reactor ..... WANG Yunfei, SUN Changyu, YU Xichong, WANG Qing, LI Qingping, CHEN Guangjin (5354)  
Analysis of the characteristics of the formation and dissociation of carbon dioxide hydrate in the fully visualized reactor ..... MAO Gangtao, LI Zhiping, WANG Kai, DING Yao (5363)  
Paired KHI-MEG for synergistic inhibition of methane hydrate reformation ..... SUI Jinhao, WANG Zhi, LIANG Xuanji, ZHANG Xuanwei, ZHU Yumo, SONG Shangfei, SHI Bohui, GONG Jing, LOU Xia (5373)  
Immobilization of *Rhizopus oryzae* onto loofah sponge as a whole-cell biocatalyst to preparation of biodiesel from *Comus wilsoniana* fruit oil ..... JI Shulan, LI Xun, WANG Fei (5381)

### Industrial catalysis

- Advances in catalysts for selective hydrogenation of acetylene ..... CHEN Zhiqiang, CHE Chunxia, WU Dengfeng, WEN He, HAN Wei, ZHANG Feng, XU Haoxiang, CHENG Daojian (5390)  
Research progress of dispersed bimetallic catalysts for slurry-phase hydrocracking of residue ..... WU Shiwei, WANG Ting, HOU Huandi, SHEN Haiping (5406)  
Preparation of carbon encapsulated non-noble metal catalysts and their application in catalytic hydrogenation ..... WANG Hongzheng, MA Chaofan, YAN Wei, HE Wei, LU Chunshan, LI Xiaonian (5416)

## Materials science and technology

- New progress in analysis and characterization of long chain branched structure in high melt strength polypropylene ..... CUI Kun, HUANG Jin, ZHAO Qiaoling, MA Zhi (5425)  
Research progress of safety additives for lithium ion batteries ..... HU Huakun, XUE Wendong, JIANG Peng, LI Yong (5441)  
Studies on all solid-state ion-selective electrodes based on carbon derived materials ..... WANG Ximin, WEI Xiaoran, FENG Ying, HUANG Guoyong, WANG Chunxia (5456)  
Progress in preparation of metal-organic framework materials by grinding ..... ZHANG Ke, QU Xiaohu, ZHU Yuanjun, LIN Jianying, ZHAO Zhihuan, FAN Huiling (5465)  
Latest research progress of multifunctional flexible sensors with different modes ..... WANG Xiaoyu, HU Ping, CAO Qigao, LI Shilei, HU Boliang, GE Songwei, YANG Fan, CHEN Bo, ZHU Xinyu, WANG Kuaishe (5474)  
Synthesis and laccase immobilization of magnetic  $\text{Fe}_3\text{O}_4@\text{SiO}_2$  mesoporous  $\text{SiO}_2$  hollow microspheres ..... LI Qunyan, SUN Luyao, CHANG Qifei, ZHOU Yunlu (5494)  
Preparation and electrochemical properties of nitrogen-doped graphene/carbon nanotubes/amorphous carbon composites ..... ZHANG Yan, WANG Miao, ZHAO Jiahui, FENG Yu, MI Jie (5501)  
Facile construction of amino-functionalized mesoporous supramolecular polymers for  $\text{CO}_2$  adsorption ..... QIU Mingyue, LI Dongna, LIU shulei, YI Qun, FAN Haiping, LI Xiangyuan, LI Jianchuan, SHI Lijuan, ZHANG Ding (5510)  
Thermal management performance of lithium-ion battery based on phase change materials ..... YIN Shaowu, KANG Peng, HAN Jiawei, ZHANG Chao, WANG Li, TONG Lige (5518)  
Methanol swelling-resistant novel TFC membrane based on polyisobutylene amine modification ..... DING Junyi, CHEN Yingdong, WANG Shuhao, YAN Wentao, ZHOU Yong, GAO Congjie (5530)

## Biochemical and pharmaceutical engineering

- Identification of a cold-adapted lipase-producing yeast and its enzyme characterization ..... SHI Chengfeng, JIA Ranran, YAN Zhenli, HUI Fengli (5541)

## Fine chemicals

- Preparation and properties of waterborne polyurethane paper sizing agents with phosphorus-boron hybrid prepolymer blocks ..... LI Ting, DU Shaohui, CUI Jinfeng, WANG Yanghui, LI Hulin, GUO Runlan, WANG Peng, WANG Zhenjun, GUO Junhong, YANG Baoping (5549)  
Preparation and performance evaluation of PAE-based paper wet strength agent with low organochlorine content ..... SONG Yingqi, SHEN Yiding, LIU Yongbing, DANG Yuanyuan (5558)

## Resources and environmental engineering

- Research progress of membrane technology for the separation of rare earth elements ..... ZHANG Yi, LIU Donghao, DING Yigang (5567)  
Research advances in the fixation of heavy metals in acid mine wastewater by sulfate reducing bacteria ..... WEN Qianmin, QIN Yongli, ZHENG Junjian, WEI Qiaoyan, ZHANG Yuanyuan, JIANG Yongrong (5578)  
Preparation of nitrogen-doped biochar and its environmental applications ..... JU Mengcan, YAN Lili, JIAN Ling, JIANG Siyu, RAO Pinhua, LI Guanghui (5588)  
Preparation of nitrogen modified lignin-based hyper-cross-linked polymers and their radioactive iodine capture ..... WAN Huan'ai, SHAO Lishu, LIU Na, MAO Li, ZHANG Lin, ZHAN Peng, CHEN Jienan (5599)  
Deep eutectic solvent pretreatment of poplar hydrolysis residue for lignin separation ..... LIU Qianjing, CHEN Xiaomiao, WANG Zhi, SHI Jiping, LI Baoguo, LIU Li (5612)  
Analysis on the characteristic organic pollutants from discharge wastewater of spent lithium batteries ..... LIU Xiaobei, ZHANG Xihua, XIONG Mei, ZHAO He (5619)  
Optimal reconfiguration method for topology of battery energy storage systems adapting to multiple load demands ..... ZHENG Liangtian, KANG Lixia, HUANG Xiankun, LIU Yongzhong (5630)  
Regulating technology of setting and hardening process of anhydrite-II phosphogypsum ..... ZHANG Yu, YANG Jiahao, LIU Yu, SONG Ziyu, HE Hanxiao, ZHAO Fengqing (5637)  
Preparation and properties of sulfonate modification nano-diamonds doped sulfonated poly(aryl ether sulfone) proton exchange membranes ..... WANG Meng, LIU Lili, LI Na, HU Zhaoxia, CHEN Shouwen (5645)  
Construction and performance evaluation of high efficiency heavy oil degradation consortium ..... WANG Runmin, ZHANG Xiaodong, XU Chenghua, YU Dandan, YU Ran (5653)  
Pretreatment of tobacco sugar flavoring wastewater by nano layered iron-manganese bimetallic catalysts activating peroxymonosulfate ..... XUE Yuwei, YE Xiaozhen, ZENG Jing, WANG Yongquan, HONG Junming (5661)  
Multi-objective capacity and heat analysis of amine-based  $\text{SO}_2$  capture process from acidity coefficient ( $pK_a$ ) model ..... WANG Dongliang, XIE Jiangpeng, MENG Wenliang, LI Jingwei, ZHOU Huairong (5669)  
*In-situ* sulfur fixation performance of Ca-Fe composite metal oxides during gasification of combustible municipal solid waste ..... LIU Yang, HUANG Yaji, DONG Xinxin, DING Xueyu, YANG Xiaoyu, WANG Xinyu, ZHANG Zhenrong, CAO Gehan, LI Zhiyuan, TIAN Xinqi (5677)  
Prediction of heavy haze pollution episodes based on deep feature fusion of pollutant and meteorological time series in Xi'an during 2015—2020 heating season ..... WANG Ying, RAN Jinye, ZHANG Jin, YANG Xin, ZHANG Hao (5685)

**Executive Editor:** XI Zhigang

**English Consultant:** GUO Meifang, JIN Rencun, LI Baoqing, LONG Bingwen, WANG Yundong