Green Chemistry

Cutting-edge research for a greener sustainable future

rsc.li/greenchem

The Royal Society of Chemistry is the world's leading chemistry community. Through our high impact journals and publications we connect the world with the chemical sciences and invest the profits back into the chemistry community.

IN THIS ISSUE

ISSN 1463-9262 CODEN GRCHFJ 25(12) 4581-4864 (2023)



See Peiyuan Yao, Qiaging Wu, Dunming Zhu et al., pp. 4667-4673.

Image reproduced by permission of Peiyuan Yao from Green Chem., 2023, 25, 4667.



Inside cover

See Paweł Mateusz Nowak, pp. 4625-4640.

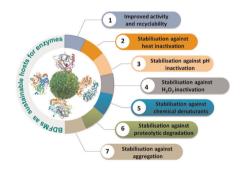
Image reproduced by permission of Paweł Mateusz Nowak from Green Chem., 2023. 25. 4625.

CRITICAL REVIEW

4591

Biomass-derived functional materials as carriers for enzymes: towards sustainable and robust biocatalysts

Meena Bisht,* Sarath Kumar Thayallath, Pranav Bharadwaj, Gregory Franklin and Dibyendu Mondal*



PERSPECTIVE

4625

What does it mean that "something is green"? The fundamentals of a Unified Greenness Theory

Paweł Mateusz Nowak



Editorial Staff

Executive Editor

Michael A. Rowan

Deputy Editor

Vikki Pritchard

Development Editors Bee Hockin, Andrea Carolina Ojeda Porras

Editorial Production Manager

Gisela Scott

Publisher

eanne Andres

Senior Publishing Editor

Robin Brabham

Publishing Editors

Catherine Au, Isobel Darlington, Konoya Das, Alexandre Dumon, Amy Lucas, Kieran Nicholson, Charlotte Pugsley, Hugh Ryan

Editorial Assistant

Daphne Houston

Publishing Assistant Robert Griffiths

For queries about submitted articles please contact Gisela Scott, Editorial Production Manager, in the first instance. E-mail green@rsc.org

For pre-submission queries please contact Michael A. Rowan, Executive Editor.

E-mail green-rsc@rsc.org

Green Chemistry electronic: ISSN 1463-9270 is published 24 times

a year by the Royal Society of Chemistry,

Thomas Graham House, Science Park, Milton Road, Cambridge, CB4 0WF, UK.

All orders, with cheques made payable to the Royal Society of Chemistry, should be sent to the Royal Society of Chemistry Order Department, Royal Society of Chemistry, Thomas Graham House, Science Park, Milton Road, Cambridge, CB4 0WF, UK

Tel +44 (0)1223 432398; E-mail orders@rsc.org

2023 Annual electronic subscription price: £2578; US\$4544. Customers in Canada will be subject to a surcharge to cover GST. Customers in the EU subscribing to the electronic version only will be charged VAT.

If you take an institutional subscription to any Royal Society of Chemistry journal you are entitled to free, site-wide web access to that journal. You can arrange access via Internet Protocol (IP) address at www.rsc.org/ip

Customers should make payments by cheque in sterling payable on a UK clearing bank or in US dollars payable on a US clearing bank.

Whilst this material has been produced with all due care, the Royal Society of Chemistry cannot be held responsible or liable for its accuracy and completeness, nor for any consequences arising from any errors or the use of the information contained in this publication. The publication of advertisements does not constitute any endorsement by the Royal Society of Chemistry or Authors of any products advertised. The views and opinions advanced by contributors do not necessarily reflect those of the Royal Society of Chemistry which shall not be liable for any resulting loss or damage arising as a result of reliance upon this material. The Royal Society of Chemistry is a charity, registered in England and Wales, Number 207890, and a company incorporated in England by Royal Charter (Registered No. RC000524), registered office: Burlington House, Piccadilly, London W1J 0BA, UK, Telephone: +44 (0) 207 4378 6556.

Advertisement sales:

Tel +44 (0) 1223 432246; Fax +44 (0) 1223 426017; E-mail advertising@rsc.org

For marketing opportunities relating to this journal, contact marketing@rsc.org



Green Chemistry

Cutting-edge research for a greener sustainable future

rsc.li/greenchem

Green Chemistry focuses on cutting-edge research that attempts to reduce the environmental impact of the chemical enterprise by developing a technology base that is inherently non-toxic to living things and the environment.

Editorial Board

Chair

Professor Doctor Javier Pérez-Ramírez, ETH Zurich, Switzerland

Associate Editors

Professor Aiwen Lei, College of Chemistry and Molecular Sciences, The Institute for Advanced Japan Studies, Wuhan University, P. R. China

Dr Elsje A. Quadrelli, CNRS and CPE Lyon, France

Professor Magdalena Titirici, Imperial College London, UK Dr Keiichi Tomishige, Tohoku Univeristy,

Dr Keiichi Tomishige, Tohoku Univeristy, Japan

Members

Dr François Jérôme, University of Poitiers,

Professor Laurel Shafer, The University of British Columbia, Canada

Dr Helen Sneddon, University of York, UK Dr Tao Zhang, Dalian Institute of Chemical Physics, Chinese Academy of Sciences, China

Advisory Board

Paul Anastas, Yale University, USA Isabel Arends, TU Delft, The Netherlands Gregg Beckham, NREL, USA Asim Bhaumik, Indian Association for the Cultivation of Science, India Fabrizio Cavani, University of Bologna, Italy Yonas Chebude, Addis Ababa University, Ethiopia

James Clark, University of York, UK Avelino Corma, Universidad Politecnica de Valencia, Spain

Robert H Crabtree, Yale University, USA Paul Dauenhauer, University of Minnesota, USA

Pierre Dixneuf, University of Rennes, France James Dumesic, University of Wisconsin-Madison. USA

Peter Dunn, Pfizer, UK

Martin Eastgate, Bristol Myers Squibb, USA Karen Goldberg, University of Washington, USA

Buxing Han, Chinese Academy of Sciences, China

Mark Harmer, SAC Technologies, USA Milton Hearn, Monash University, Australia Steve Howdle, Nottingham University, UK Andrew J. Hunt, Khon Kaen University, Гhailand

Graham Hutchings, Cardiff University, UK Philip Jessop, Queen's University, Canada C. Oliver Kappe, University of Graz, Austria Shu Kobayashi, University of Tokyo, Japan Mihkel Koel, Tallinn University of Technology, Estonia

Burkhard Koenig, University of Regensburg, Germany

Michael Kopach, Eli Lilly and Company, USA Dhileep Krishnamurthy, Jubilant Ingrevia Limited, India

Walter Leitner, RWTH Aachen University, Germany

Chao-Jun Li, McGill University, Canada Bruce Lipshutz, University of California, USA Rafael Luque, University of Cordoba, Spain Doug MacFarlane, Monash University, Australia

Tomoo Mizugaki, Osaka University, Japan Regina Palkovits, RWTH Aachen, Germany Alvise Perosa, Universita Ca Foscari, Italy Martina Peters, Bayer AG, Germany Martyn Poliakoff, University of Nottingham, UK Colin Raston, Flinders University, Australia Roberto Rinaldi, Imperial College London, UK Robin D. Rogers, McGill University, Canada Gadi Rothenberg, University of Amsterdam, The Netherlands

Susannah Scott, University of California, USA Roger Sheldon, Delft University of Technology, The Netherlands

Christian Stevens, Ghent Univesity, Belgium Natalia Tarasova, Mendeleev University of Chemical Technology, Russia

Rajender Varma, US Environmental Protection Agency, USA

Peter Wasserscheid, Friedrich-Alexander Universität Erlangen-Nürnberg, Germany Tom Welton, Imperial College London, UK Kevin C. W. Wu, National Taiwan University, Taiwan

Ganapati D. Yadav, Institute of Chemical Technology, India

Hisao Yoshida, Kyoto University, Japan Suojiang Zhang, Institute of Process Engineering, Chinese Academy of Sciences, China

Julie Zimmerman, Yale University, USA Vânia Zuin, Federal University of São Carlos, Brazil

Information for Authors

Full details on how to submit material for publication in Green Chemistry are given in the Instructions for Authors (available from http://www.rsc.org/authors). Submissions should be made via the journal's homepage: rsc.li/greenchem

Authors may reproduce/republish portions of their published contribution without seeking permission from the Royal Society of Chemistry, provided that any such republication is accompanied by an acknowledgement in the form: (Original Citation)–Reproduced by permission of the Royal Society of Chemistry.

This journal is © The Royal Society of Chemistry 2023.

Apart from fair dealing for the purposes of research or private study for non-commercial purposes, or criticism or review, as permitted

tor not-commercial purposes, or crucism or review, as permitted under the Copyright, Designs and Patents Act 1988 and the Copyright and Related Rights Regulation 2003, this publication may only be reproduced, stored or transmitted, in any form or by any means, with the prior permission in writing of the Publishers or in the case of reprographic reproduction in accordance with the terms of licences issued by the Copyright Licensing Agency in the UK. US copyright law is applicable to users in the USA.

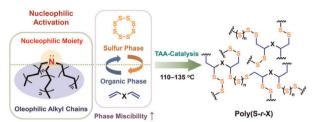
Registered charity number: 207890

COMMUNICATIONS

4641

Inverse vulcanization of elemental sulfur catalyzed by trialkyl amines

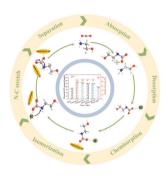
Jae Hyuk Hwang, Ji Mok Lee, Jong Hwi Seo, Guk Yun Noh, Wonmoo Byun, Seonggeon Kim, Woohwa Lee, Sungmin Park,* Dong-Gyun Kim* and Yong Seok Kim* Facile and Fast Inverse Vulcanization of Elemental Sulfur (ES) using Unreactive Crosslinkers under Eco-friendly Trialkyl Amines (TAAs) Catalysis



4647

Evaluation of hybrid amines and alcohol solvent with ion-exchange resin catalysts for energy-efficient CO₂ capture

Qiang Sun, Jia Xiong, Hongxia Gao,* Teerawat Sema, Wilfred Olson and Zhiwu Liang*



4656

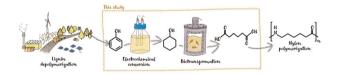
An electrochemical-enabled cascaded cyclization of enaminones with potassium thiocyanate and alcohols to access 2-alkoxythiazoles

Dandan Li,* Long Chen, Yang Jin, Xiaochen Wang, Long Liu, Yilin Li, Gongyuan Chen, Guanhao Wu, Yujie Qin, Leilei Yang, Mengke Wang, Lulu Zhao, Zhihong Xu and Jiangwei Wen*

4662

Integrated electrosynthesis and biosynthesis for the production of adipic acid from lignin-derived phenols

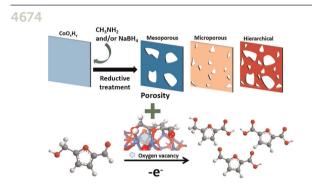
Micjel Chávez Morejón, Alexander Franz, Rohan Karande* and Falk Harnisch*



4667 One-pot biocatalytic cascade 8 examples (S)-IRED 97 to >99%ee Up to 100% conv. 1) Buchwald-Hartwig cyclization 2) deallylation

Chemo-enzymatic synthesis of chiral 3-substituted tetrahydroquinolines by a sequential biocatalytic cascade and Buchwald-Hartwig cyclization

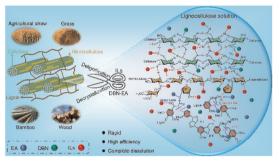
Zefei Xu. Jinhui Feng, Peivuan Yao, * Qiaging Wu* and Dunmina Zhu*



Room-temperature fabrication of defective CoO_xH_v nanosheets with abundant oxygen vacancies and high porosity as efficient 5-hydroxymethylfurfural oxidation electrocatalysts

Ruyi Zhong, Puwei Wu, Qi Wang, Xiting Zhang, Lei Du, Yunhua Liu, Huakang Yang, Meng Gu, Z. Conrad Zhang, Limin Huang* and Siyu Ye*

4685



Robust ionic liquid/ethanolamine-superbase solvents enable rapid, efficient and mild dissolution of lignocellulosic biomass

Yang Wang, Huan Wang, Lan Chen, Weitao Wang, Zhaohui Yang, Zhimin Xue* and Tiancheng Mu*



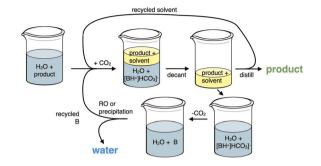
Eco-friendly cellulose nanofibrils with high surface charge and aspect ratio for nanopaper films with ultrahigh toughness and folding endurance

Da Zhang, Kexia Jin, Khak Ho Lim, Suyun Jie, Wen-Jun Wang and Xuan Yang*

4705

A CO₂-responsive method for separating hydrophilic organic molecules from aqueous solutions: solvent-assisted switchable water

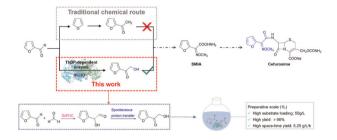
Vanessa Saab Liberato, Tatiana Felix Ferreira, Alex Redmond MacDonald, Bernardo Dias Ribeiro, Maria Alice Zarur Coelho and Philip G. Jessop*



4713

Biosynthesis of 2-furylhydroxymethylketone, an intermediate of cefuroxime, from furfural and formaldehyde using a ThDP-dependent enzyme

Xianghe Zhang, Hao Wei, Xinlin Wei, Tengteng Qi, Xinrui Zong, Zixi Liu, Jie Qin, Xiuzhen Gao,* Gengxiu Zheng* and Qinyuan Ma*



4723

High-purity polypropylene from disposable face masks *via* solvent-targeted recovery and precipitation

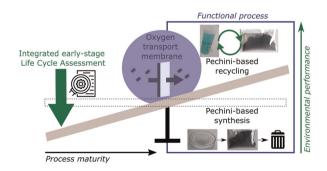
Jiuling Yu, Aurora del Carmen Munguía-López, Victor S. Cecon, Kevin L. Sánchez-Rivera, Kevin Nelson, Jiayang Wu, Shreyas Kolapkar, Victor M. Zavala, Greg W. Curtzwiler, Keith L. Vorst, Ezra Bar-Ziv and George W. Huber*



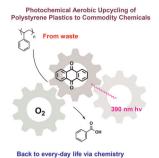
4735

Recycling process development with integrated life cycle assessment – a case study on oxygen transport membrane material

Melanie Johanning, Marc Widenmeyer,* Giamper Escobar Cano, Vanessa Zeller, Sebastian Klemenz, Guoxing Chen, Armin Feldhoff and Anke Weidenkaff



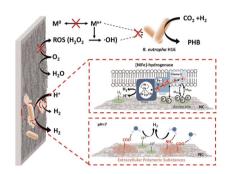
4750



Photochemical aerobic upcycling of polystyrene plastics to commodity chemicals using anthraquinone as the photocatalyst

Nikolaos F. Nikitas, Elpida Skolia, Petros L. Gkizis, Ierasia Triandafillidi and Christoforos G. Kokotos*

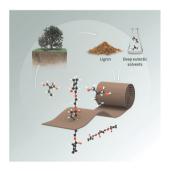
4760



Efficient CO₂ conversion by biocompatible N-doped carbon nanosheets coupled with Ralstonia eutropha: synergistic interactions between microbial and inorganic catalysts

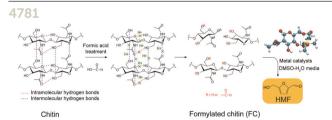
Jiani Yao, Youzhi Li, Siyuan Xiu, Shujie Zheng, Ying Huang, Zijing Zhou, Yang Hou, Bin Yang, Lecheng Lei and Zhongjian Li*

4769



A lignin-based membrane fabricated with a deep eutectic solvent

Abaynesh Yihdego Gebreyohannes, Sandra L. Aristizábal, Liliana Silva, Eyad A. Qasem, Stefan Chisca, Lakshmeesha Upadhyaya, Daniyah Althobaiti, João A. P. Coutinho and Suzana P. Nunes*



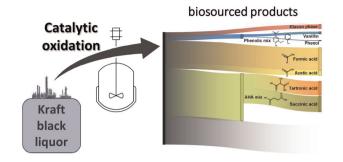
Efficient conversion of chitin into 5-hydroxymethylfurfural via a simple formylation step under mild conditions

Chunxiao Gong, Zhaoyang Ju, Kuichuan Sheng and Ximing Zhang*

4793

Potential of catalytic oxidation of kraft black liquor for the production of biosourced compounds

Léa Vilcocq,* Nicolas Chaussard, Antonio Hernández Mañas, Olivier Boyron, Manel Taam, Frédérique Bertaud, Pascal Fongarland and Laurent Djakovitch*



4808

Sustainable polar aprotic/poly-deep eutectic solvent systems for highly efficient dissolution of lignin

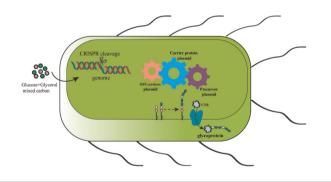
Qiaoling Liu, Yang Wang, Jing Bian, Ming-Fei Li, Jun-Li Ren, Xiang Hao* and Feng Peng*



4818

Sustainable production of a polysaccharide-based glycoprotein by simultaneous conversion of glucose and glycerol in engineered Escherichia coli

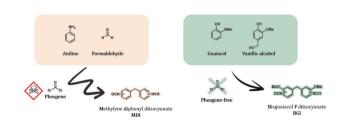
Yuhui Wang, Xiaohan Wang, Guozhen Ma, Lijie Xie, Dan Liu, Yanling Wang, Xinyu Zhao, Yingying Su, Andrei V. Perepelov, Peng Ding, Xiao Zhang, Bo Xu, Bin Liu* and Di Huang*



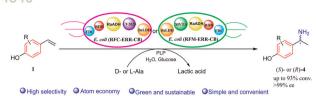
4833

Lignin-based bisguaiacol diisocyanate: a green route for the synthesis of biobased polyurethanes

Sébastien Lemouzy, Aliénor Delavarde, Frédéric Lamaty, Xavier Bantreil, Julien Pinaud and Sylvain Caillol*



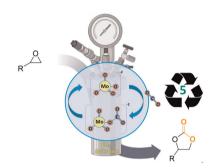
4840



Biocatalytic formal regio- and enantioselective Markovnikov hydroamination of aryl alkenes to chiral amines

Qi Jin, Jingqi Zhang, Shuangping Huang, Lili Gao, Honghong Chang and Jiandong Zhang*

4849



Molybdate ionic liquids as halide-free catalysts for CO₂ fixation into epoxides

Nicola Bragato, Alvise Perosa, Maurizio Selva, Giulia Fiorani* and Roberto Calmanti*

CORRECTION

4861

Correction: Sustainable pathway to furanics from biomass via heterogeneous organo-catalysis

Sanny Verma, R. B. Nasir Baig, Mallikarjuna N. Nadagouda, Christophe Len and Rajender S. Varma*