Green & Sustainable Chemical Communication
綠色與永續化學通訊
2014年3月

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引言

本期通訊感謝甘魯生教授提供文章(新能源報導：電能源就在足下)與同儕分享，歡迎其他同仁踴躍投稿。本期的新聞輯要，可見到新能源的多個發展面向，文獻的部份以回顧論文為主，期望對大家有所助益。

根據報導，綠色化學帶來的市場效益預估由 2011 年的 28 億美元將升至 2020 年的 985 億。工研院副院長劉仲明博士在去年化學年會的綠色化學午餐交流會中表示，目前如未考慮綠色永續因子，很難獲創投基金挹注資金。學術界對這些訊息可能相對無感，但事實上我們培養出的人才很多將進入工業界，仍當思考如何增進學生的競爭力。前年至華盛頓參與 Green Chemistry and Engineering Conference，聽到國外的大廠表示如果在研究階段就已有綠色化學的考量，後續製程才容易進行。因此 Dow 與 Pfizer 在 conference 中發表他們為化學研發團隊舉辦的 workshop 內容，也聽到一些教授發表在課程上的努力。目前有十八所學校加入所謂的 Green Chemistry Commitment 教育聯盟，大部分的學校並不出名，但也包括兩所重量級的學校 UC Berkeley 與 University of Minnesota。至於我們在台灣有哪些努力的可能性呢？去年綠色化學午餐交流會上徐永源教授與鄭政峰教授提到綠色化學無所不包，或許鄰近地區可以跨校聯合幾個老師一起授課，而劉緒宗教授建議可向國科會化學中心提議各學術小組在年度聚會時，安排綠色化學方面的報告。以上資訊提供大家參考。

目錄

Webinars

1. ACS Webinar: "From Waste to Wealth Using Green Chemistry"

March 6, 2014

The amount of waste that modern society produces is astounding. Could it be put to better use? Dr. James Clark, Dr. Avtar Matharu and Dr. Jeff Eaves from the Green Chemistry Centre of Excellence profile different case studies on how modern technologies can be used to maximize the chemical potential of food and e-waste.

2. ACS Webinar: "Biodegradable Electronics"

March 17, 2014

Dr. John A. Rogers from Department of Chemistry, University of Illinois at Urbana-Champaign summarizes recent work on this physically 'transient' type of electronics, from basic advances in materials chemistry, to fundamental studies of dissolution reactions, to engineering development of complete sets of device components, sensors and integrated systems. An 'electroceutical' bacteriocide designed for treatment of surgical site infections provides an application example.

Conferences

1. ACS National Meeting in Dallas, TX

March 16-20, 2014

The ACS Green Chemistry Institute® put together a listing of some of the top sustainable and green chemistry events and symposia at the 247th ACS National Meeting & Exposition in Dallas: Green Chemistry and the Environment (ENVR), Transition Metal Catalysis in Green Chemistry (ORGN), Energy and Fuels from Biomass (ENFL), Sustainable Polymers, Processes and Product Applications (POLY), Green Chemistry: Theory and Practice (CHED), Biocatalysis and Enzyme Engineering (CATL), Carbon Catalysts (CATL), Catalysis Science: The Next Generation (CATL), Design and Self-Assembly of Bio-Inspired Nanocomposites Based on Renewable Building Blocks (CELL), Innovations in Carbon Dioxide Capture, Storage, Conversion, and Utilization (ENFL), Nanostructured Materials for Solar Energy Conversion and Storage (ENFL), Hydrothermal Carbonization of Municipal, Industrial and Agricultural Wastes and Innovative Applications of the Process Byproducts (ENVR), Nanotechnology for Sustainable Resources and

Environmental Science (ENVR), Research and Development in Processes for Waste Recycling and Metal Recover (I&EC),ACS Award for Affordable Green Chemistry: Symposium in Honor of Arthur Ragauskas (ENFL), Ronald Breslow Award for Achievement in Biomimetic Chemistry: Symposium in Honor of Samuel H. Gellman (ORGN), Special Session - “Biodegradable Electronics”

2. Next Steps in Green Chemistry Research Workshop

May 21-23, 2014

University of Toronto, Toronto, Canada

3. 18th Annual Green Chemistry & Engineering Conference

"Advancing Chemistry, Innovating for Sustianability"

June 17-19, 2014

North Bethesda, Maryland, USA

4. 13th Annual Green Chemistry in Education Workshop

July 12-18, 2014

University of Oregon, Oregon, USA

5. Gordon Research Seminar on Green Chemistry

"Applications for Sustainable Future"

July 26-27, 2014

Hong Kong, China

6. Gordon Research Conference on Green Chemistry

"Industrial Successes and Challenges"

July 27 - August 1, 2014

Hong Kong, China

7. 5th IUPAC Conference on Green Chemistry

August 17-21, 2014

Durban, South Africa

News

1. Solar Power Efficiencies Reach 16.2% with Perovskites (ABX_3)

C&EN reported the recent major advances of perovskite solar cells. Unlike many other types of photovoltaics, in perovskites, it's all about the chemistry; precursor synthesis, cell assembly, and device customization are all mediated by ordinary chemistry methods, underscoring the prominent role chemists can play in this field. Current endeavors include tailoring chemical compositions to further boost electrical output, improving processing methods and stability. Perovskite solar cells could be the ultimate low-cost solar power.

http://cen.acs.org/articles/92/i8/Tapping-Solar-Power-Perovskites.html

2. A High-Energy-Density Sugar Biobattery Based on a Synthetic Enzymatic Pathway

Enzymatic fuel cells containing a 15% (wt/v) maltodextrin solution have an energy-storage density of 596 Ah kg^{-1}, which is one order of magnitude higher than that of lithium-ion batteries. Sugar-powered biobatteries could serve as next-generation green power sources, particularly for portable electronics. The enzymes are cheaper than the metals used in conventional batteries, and the bio-battery is also fully biodegradable. For the battery to get onto the market, the researchers must tackle two other challenges: increasing power density and lifetime.

http://www.rsc.org/chemistryworld/2014/01/sweet-success-bio-battery-sugar-power-phones

3. Chemical Treatment Could Cut Cost of Biofuel

By adding a dash of dilute sulphuric acid to a colourless, herbal-smelling liquid made by biomass, γ-valerolactone (GVL), chemists from the University of Wisconsin-Madison have invented a process that easily extracts sugars from lignin and cellulose fibres without costly enzymes.

http://www.nature.com/news/chemical-treatment-could-cut-cost-of-biofuel-1.14545

4. Approach Helps Identify New Biofuel Sources That Don't Require Farmland

The next generation of biodiesel may come from bacteria—rather than crops.

https://communities.acs.org/community/science/sustainability/green-chemistry-nexus-blog/blog/2014/02/10/approach-helps-identify-new-biofuel-sources-that-don-t-require-farmland

5. Green Energy's Environmental Impacts

Planned solar energy farms that would occupy hundreds of acres of pristine desert land present a new set of environmental challenges. Trampled desert biocrusts are one of the consequences to contemplate in the quest to implement sustainable energy technologies.

http://cen.acs.org/articles/91/i50/Green-Energys-Environmental-Impacts.html

6. Plastic Shopping Bags Make a Fine Diesel Fuel

Plastic shopping bags, an abundant source of litter on land and at sea, can be converted into diesel, natural gas and other useful petroleum products, researchers report.

http://www.sciencedaily.com/releases/2014/02/140212132853.htm

7. Simple Catalyst Pair Transforms Excess Glycerol Into Useful Compounds

A one-pot, two-catalyst reaction turns leftover glycerol from biodiesel production into chemicals of value.

http://cen.acs.org/articles/92/web/2014/02/Simple-Catalyst-Pair-Transforms-Excess.html

8. Now Open: $50K Green Chemistry Research Grant for Reduction of Amides

ACS GCI Pharmaceutical Roundtable's Medicinal Chemistry group is seeking to fund a one year R&D program targeting the identification and development of alternatives to the commonly employed stoichiometric hydride-based reagents or transition-metal catalyzed silane reductions, with a focus on substrates that are widely applicable to the pharmaceutical industry. Proposals are invited from public and private institutions of higher education worldwide. This collaborative project is intended for a student within the selected Principal Investigator's research group. One grant in the amount of $50,000 will be awarded to support execution of research for a period of 1 year. Deadline for receipt of proposals is **June 4th, 2014 at 5 PM EDT (GMT-4).**

Reviews and Papers

Solvent

Solvents for Sustainable Chemical Processes

Green Chem., **2014**, *16*, 1034-1055 **DOI:** 10.1039/C3GC42302F

The properties and some key applications of solvents such as (1) supercritical fluids (SCFs), (2) gas-expanded liquids (GXLs) and organic-aqueous tunable solvents (OATS), (3) water at elevated temperature (WET), and (4) switchable solvents like reversible ionic liquids (RevILs) are discussed in this review. Each system offers a unique set of properties to enable alternative strategies for varied applications. These applications range from chemical transformations, product separation, catalyst recycling, nanomaterial processing, and CO_2 capture. For each application, however, the common thrust is to enable greener and sustainable solutions for chemical processes.

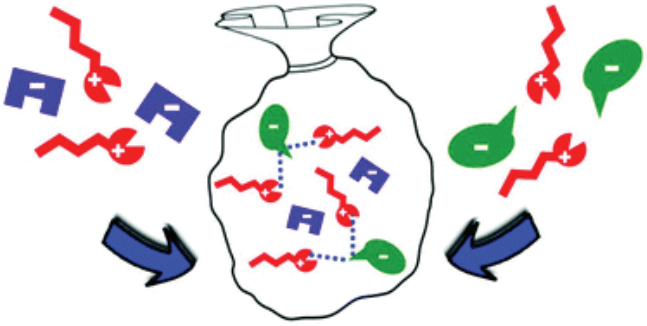
Are Ionic Liquids a Proper Solution to Current Environmental Challenges?

Green Chem., **2014**, Advance Article **DOI**: 10.1039/C3GC42096E

It is well known that ionic liquids (ILs) possess extraordinary characteristics, making them greener solvents with unique properties, which allow processes that would otherwise be difficult or impossible with common solvents to be carried out. In this review, we describe and discuss, in the light of possible future large scale applications, some fundamental studies showing the efficacy of ILs in several "hot" fields, from dissolution and transformation of biopolymers to extraction and capture of important inorganic components (metals) or pollutants (CO_2).

Mixing Ionic Liquids – "Simple Mixtures" or "Double Salts"?

Green Chem., **2014**, Advance Article **DOI**: 10.1039/C3GC41389F



In the third issue of the then new journal *Green Chemistry* (**2001**, *3*, 156–164), we published our first paper describing the physical properties of a few hydrophilic and hydrophobic ionic liquids (ILs) representing one of the first such studies to be published. To help celebrate the 15th anniversary of the Journal, we revisit the 'design' aspect of ILs by reviewing the growing area of what most are calling 'ionic liquid mixtures'. In 2001, designing IL properties meant essentially independent variation or synthesis of the cations and anions and determining what physical or chemical properties these liquid salts possessed. Recently, however, the mixing of ILs has been proposed and investigated as a way to add increased scope to the accessible properties of IL media. In this review, we question whether the same thinking and approach used for organic solvent mixtures should be applied to ILs simply because of the way they were made. Unlike organic solvent mixtures, IL compositions of varied ions, do not retain their individual nature, need not be made by simple mixing of two-ion salts, and preferential interactions of a given cation for a given anion are possible in these 3-ion, 4-ion, or higher order liquids. When two ILs are mixed together, one can't identify which ion is from which IL, and the chemistry is simply not based on the identity of the individual ILs, but on the ions comprising them and the interactions of each individual ion, independently of the counterion. Thus, we ask if it would not be better to consider these as unique ion combinations whose solvent properties are derived from the specific choice and abundance of each ion in the system. Through this review of the available literature, we support the concept of Double Salt Ionic Liquids (DSILs) and discuss the interactions involved in these systems, by examining their physicochemical properties and the novel applications they offer.

Bio-based Solvents: an Emerging Generation of Fluids for the Design of Eco-efficient Processes in Catalysis and Organic Chemistry

Chem. Soc. Rev., **2013**, *42*, 9550-9570 **DOI**: 10.1039/C3CS60241A

Biomass and waste exhibit great potential for replacing fossil resources in the production of chemicals. The search for alternative reaction media to replace petroleum-based solvents commonly used in chemical processes is an important objective of significant environmental consequence. Recently, bio-based derivatives

have been either used entirely as green solvents or utilized as pivotal ingredients for the production of innovative solvents potentially less toxic and more bio-compatible. This review presents the background and classification of these new media and highlights recent advances in their use in various areas including organic synthesis, catalysis, biotransformation, and separation. The greenness, advantages and limitations of these solvents are also discussed.

Glycerol: a Solvent and a Building Block of Choice for Microwave and Ultrasound Irradiation Procedures

Green Chem., **2014**, *16*, 1056-1065 **DOI**: 10.1039/C3GC41955J

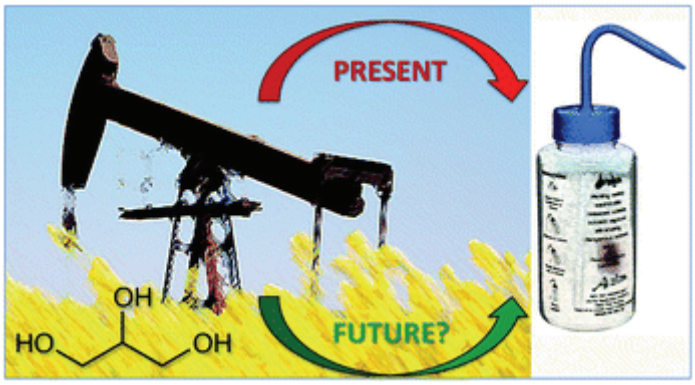
Glycerol has the potential to be both an excellent renewable solvent in modern chemical processes and a versatile building block in biorefineries. Both of these potential applications may be made easier and more convenient by microwave and/or ultrasound irradiation. As glycerol is a nontoxic, biodegradable compound, it will provide important environmental benefits to new platform products. Furthermore, significant markets in polymers, polyethers, fuel additives, nanoparticles and other valuable compounds may well be opened up by cutting down the high purification cost of glycerol. The aim of this review is to highlight the best literature examples of glycerol being used, either as a solvent or as a reagent, to give interesting results under microwave or ultrasound irradiation.

Glycerol Based Solvents: Synthesis, Properties and Applications

Green Chem., **2014**, *16*, 1007-1033 **DOI**: 10.1039/C3GC41857J

The most recent advances in the use of glycerol and glycerol derivatives as solvents are reviewed. There are an increasing number of examples of the use of glycerol itself as a reaction medium, solvent–reagent or a dispersive medium for a large variety of applications. In the case of glycerol derivatives, new synthetic methods, physico-chemical properties and application examples as solvents are revised. Recent

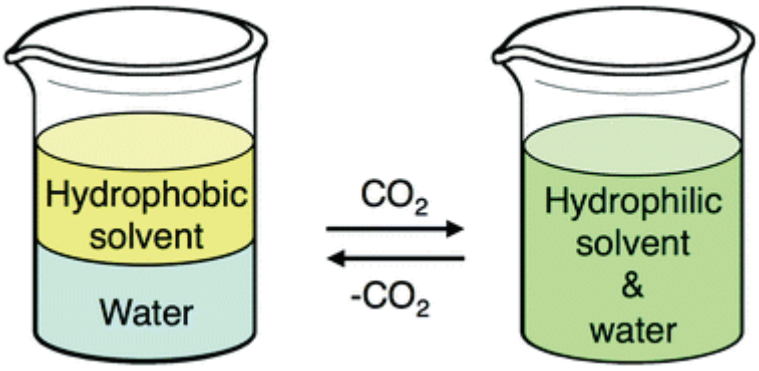
studies in the field of solvent classification, as well as solvent substitution issues, in connection with glycerol derivatives are also discussed in this review.



Design and Evaluation of Switchable-Hydrophilicity Solvents

Green Chem., **2014**, *16*, 1187-1197 **OI:** 10.1039/C3GC42164C

Switchable-hydrophilicity solvents (SHSs) are solvents that can switch reversibly between one form that is miscible with water to another that forms a biphasic mixture with water. For these SHSs, we use CO_2 at 1 bar as a stimulus for triggering the transformation to the water-miscible form and removal of CO_2 to achieve the reverse. We now report the identification of 13 new SHSs, including the first secondary amine SHSs, and a comparison of all known SHSs in terms of safety and environmental impacts. Amines which include another functional group, especially oxygen-containing groups, are less hazardous than alkylamines. Secondary amines can have improved switching speeds relative to tertiary amines. The variety of SHSs identified suggests that amine SHSs can be designed to have ideal properties for a given application.

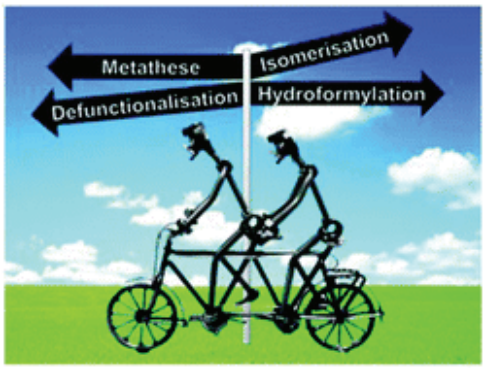


Synthesis

Towards Resource Efficient Chemistry: Tandem Reactions with Renewables

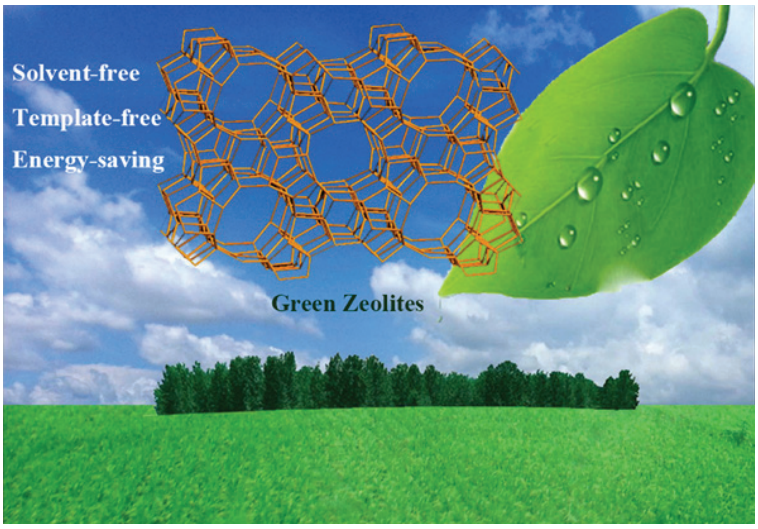
Green Chem., **2014**, *16*, 982-1006 **DOI**: 10.1039/C3GC41960F

In an economically expanding world new sustainable concepts have to be developed in order to overcome growing problems of resource availability. Merging different "Green principles" is a promising concept in this respect, *e.g.* the combination of tandem reactions and renewables. This review summarizes the trends in this field and demonstrates advantages and future demands. Four reactions, namely metathesis, hydroformylation, defunctionalisation and isomerisation, have been identified for transforming renewables in tandem reactions. Every reaction yields a reactive intermediate or secures a tailored selectivity in order to use the natural molecular structure of renewables.



Green Routes for Synthesis of Zeolites

Chem. Rev., **2014**, *114*, 1521–1543**DOI:** 10.1021/cr4001513



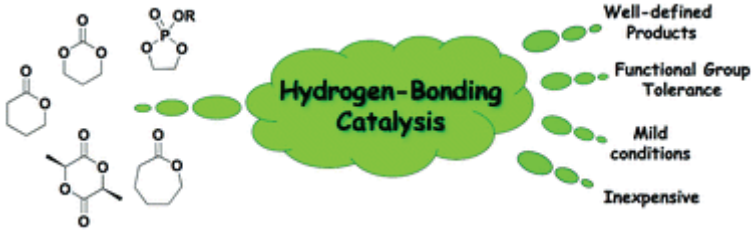
Catalysis

Hydrogen-Bonding Organocatalysts for Ring-Opening Polymerization

Green Chem., **2014**, Advance Article **DOI**: 10.1039/C3GC41806E

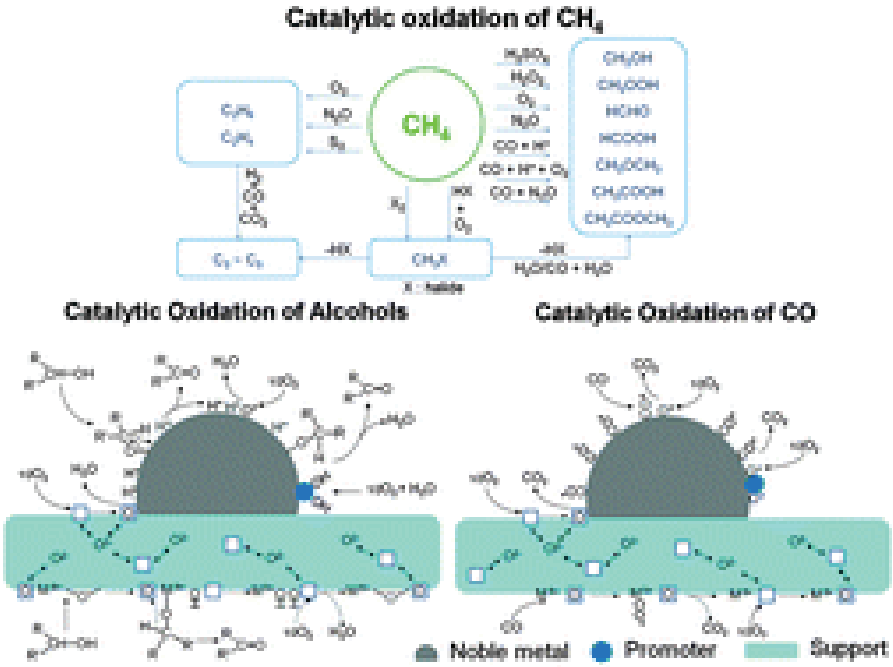
In the ring-opening polymerization (ROP) of cyclic esters and carbonates, hydrogen-bonding organocatalysis offers an interesting alternative to metal-based

and enzymatic catalysis to access biocompatible and biodegradable polymers. The design of catalysts, strategies of activation and mechanistic elucidations are highlighted. Recent developments with functionalized monomers for applications in nanomaterials and biomedicine have opened perspectives to broaden the scope of future catalytic systems. In the field of sustainable chemistry, hydrogen-bonding structures devoted to ROP have become a full-fledged class of catalysts.



Recent Advances in Heterogeneous Selective Oxidation Catalysis for Sustainable Chemistry

Chem. Soc. Rev., **2014**, Advance Article **DOI**: 10.1039/C3CS60282F

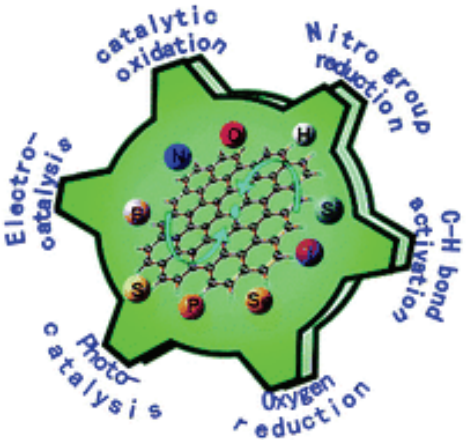


Oxidation catalysis not only plays a crucial role in the current chemical industry for the production of key intermediates such as alcohols, epoxides, aldehydes, ketones and organic acids, but also will contribute to the establishment of novel green and sustainable chemical processes. This review is devoted to dealing with selective oxidation reactions, which are important from the viewpoint of green and sustainable chemistry and still remain challenging. Actually, some well-known highly challenging chemical reactions involve selective oxidation reactions, such as the

selective oxidation of methane by oxygen. On the other hand some important oxidation reactions, such as the aerobic oxidation of alcohols in the liquid phase and the preferential oxidation of carbon monoxide in hydrogen, have attracted much attention in recent years because of their high significance in green or energy chemistry. This article summarizes recent advances in the development of new catalytic materials or novel catalytic systems for these challenging oxidation reactions. A deep scientific understanding of the mechanisms, active species and active structures for these systems are also discussed. Furthermore, connections among these distinct catalytic oxidation systems are highlighted, to gain insight for the breakthrough in rational design of efficient catalytic systems for challenging oxidation reactions.

Doped Graphene for Metal-Free Catalysis

Chem. Soc. Rev., **2014**, Advance Article **DOI**: 10.1039/C3CS60401B



Graphene has attracted increasing attention in different scientific fields including catalysis. *Via* modification with foreign metal-free elements such as nitrogen, its unique electronic and spin structure can be changed and these doped graphene sheets have been successfully employed in some catalytic reactions recently, showing them to be promising catalysts for a wide range of reactions. In this review, we summarize the recent advancements of these new and interesting catalysts, with an emphasis on the universal origin of their catalytic mechanisms. We are full of hope for future developments, such as more precisely controlled doping methods, atom-scale surface characterization technology, generating more active catalysts *via* doping, and finding wide applications in many different fields.

Gold Nanoparticle (AuNPs) and Gold Nanopore (AuNPore) Catalysts in Organic Synthesis

Org. Biomol. Chem., **2014**, Advance Article **DOI**: 10.1039/C3OB42207K

Organic synthesis using gold has gained tremendous attention in last few years, especially heterogeneous gold catalysis based on gold nanoparticles has made its place in almost all organic reactions, because of the robust and green nature of gold catalysts. In this context, gold nanopore (AuNPore) with a 3D metal framework is giving a new dimension to heterogeneous gold catalysts. Interestingly, AuNPore

chemistry is proving better than gold nanoparticles based chemistry. In this review, along with recent advances, major discoveries in heterogeneous gold catalysis are discussed.

Metal-Free Oxidation/Coupling

Metal-Free Allylic/Benzylic Oxidation Strategies with Molecular Oxygen: Recent Advances and Future Prospects

Green Chem., **2014**, Advance Article **DOI**: 10.1039/C3GC42135J

The selective oxo-functionalization of hydrocarbons under mild conditions with molecular oxygen as the terminal oxidant continues to be a hot topic in organic synthesis and industrial chemistry. Though many oxidation protocols in combination with transition metal salts, enzymes, organometallic catalysts, or organocatalysts have been summarized recently, a review that focuses solely on the metal-free allylic/benzylic oxidation strategies with molecular oxygen is still unavailable. This critical review will summarize recent significant advances achieved in this important field under the scope of green chemistry, which covers the promising applications and brief mechanistic profiles involving three kinds of efficient catalysts, namely *N*-hydroxyimides, homogeneous/heterogeneous light-sensitive molecules, and heteroatom-doped carbon materials, and concerns the sustainability of these methods, as well as predicts the potential utilization of available but unreported analogous catalysts or catalytic systems in this field. Special emphasis will also be placed on the burgeoning metal-free strategies with visible light irradiation from the long-term greenness and sustainability of these oxidation processes due to their established appealing performances under ambient conditions.

To Be or Not to Be Metal-Free: Trends and Advances in Coupling Chemistries

Org. Biomol. Chem., **2014**, *12*, 10-35 **DOI**: 10.1039/C3OB41768A

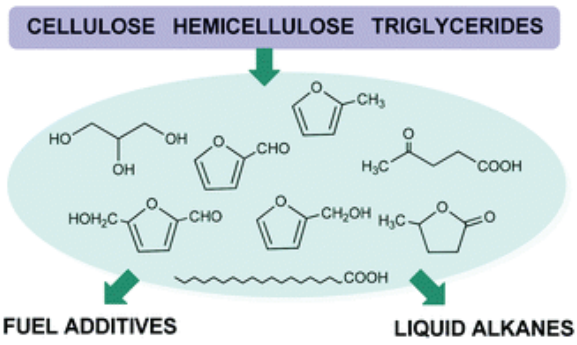
Coupling reactions have been part of several extensive studies in order to develop innovative and greener protocols that can generate a wide range of compounds with applications in pharmaceuticals, agrochemicals and biologically active compounds. Metal-free couplings are an important and increasingly trendy field that has attracted

a significant deal of interest in recent years, generating a lot of controversy on the issue of whether metal free is really free. Aside from focusing on such a controversial topic itself, this contribution aims to provide a brief introduction on coupling chemistry to point out the transition of this technology from metal-catalyzed to metal-free. This is followed by a range of key selected synthetically useful metal-free processes and a brief commentary on the current debate of whether metal-free reactions are really metal-free and the required experiments for a full understanding of a metal-free coupling process.

Conversion of Biomass

Conversion of Biomass Platform Molecules into Fuel Additives and Liquid Hydrocarbon Fuels

Green Chem., **2014**, *16*, 516-547 **DOI**: 10.1039/C3GC41492B



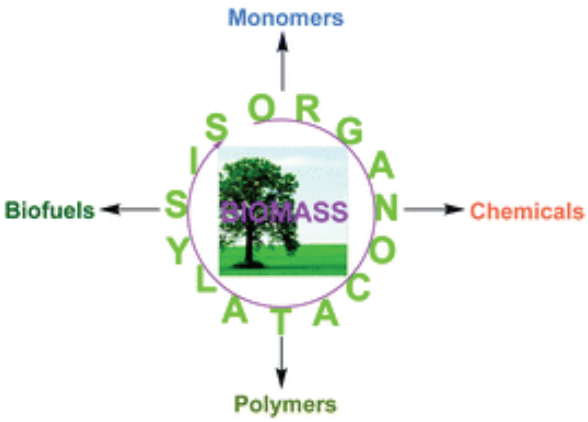
In this work some relevant processes for the preparation of liquid hydrocarbon fuels and fuel additives from cellulose, hemicellulose and triglycerides derived platform molecules are discussed. Thus, it is shown that a series of platform molecules such as levulinic acid, furans, fatty acids and polyols can be converted into a variety of fuel additives through catalytic transformations that include reduction, esterification, etherification, and acetalization reactions. Moreover, we will show that liquid hydrocarbon fuels can be obtained by combining oxygen removal processes (*e.g.* dehydration, hydrogenolysis, hydrogenation, decarbonylation/descarboxylation *etc.*) with the adjustment of the molecular weight *via* C–C coupling reactions (*e.g.* aldol condensation, hydroxyalkylation, oligomerization, ketonization) of the reactive platform molecules.

Organocatalysis in Biorefining for Biomass Conversion and Upgrading

Green Chem., **2014**, *16*, 964-981 **DOI**: 10.1039/C3GC41934G

Organocatalysis using small-molecule organic compounds as catalysts has risen to prominence in organic synthesis and polymer synthesis. However, its application in biorefining for catalytic biomass conversion and upgrading into sustainable chemicals, materials, and biofuels has come to light only recently. This emergence of applying organocatalysis for biorefining has not only broadened the scope of

organocatalysisand offered metal-free “greener” alternatives for biomass conversion and upgrading, it has also showed some unique activity and selectivity in such transformations as compared to metal-mediated processes. This review captures highlights of this emerging area by focusing on utilization of organocatalytic means for catalytic conversions of cellulose, glucose and fructose, upgrading of furaldehydes, and organocatalytic polymerization of biomass feedstocks.



Green Industrial Chemical Processes

Green Chemistry in the Fine Chemicals and Pharmaceutical Industries

Org. Process Res. Dev., **2013**, *17* (12), pp 1479–1484 **DOI**: 10.1021/op400258a

Biocatalysis is the main green chemistry technology adopted by the fine chemicals and pharmaceutical industries to manufacture chemicals with higher yield. Heterogeneously catalyzed processes using supported metal or molecular catalysts are still an exception. Reviewing the actual development of green chemistry in these important segments of the chemical enterprise, we investigate the reasons behind such a delay in innovation. Finally, we consider whether green metrics developed by chemists is actually purposeful to management, and find that this concept needs to be streamlined to include simple financial metrics quantifying the impact of prevention on the company’s bottom line.

Green Analytical Chemistry

The 12 Principles of Green Analytical Chemistry and the Significance Mnemonic of Green Analytical Practices

Trends Anal. Chem., **2013**, 50, 78-84 **DOI**: 10.1016/j.trac.2013.04.010

The current rapid development of green analytical chemistry (GAC) requires clear, concise guidelines in the form of GAC principles that will be helpful in greening laboratory practices. The existing principles of green chemistry and green engineering need revision for their use in GAC because they do not fully meet the needs of analytical chemistry. In this article we propose a set of 12 principles

consisting of known concepts (i.e. reduction in the use of reagents and energy, and elimination of waste, risk and hazard) together with some new ideas (i.e. the use of natural reagents), which will be important for the future of GAC.

Green Chromatography

J. Chromatogr. A, **2013**, *1307*, 1-20 **DOI**: 10.1016/j.chroma.2013.07.099

Analysis of organic compounds in samples characterized by different composition of the matrix is very important in many areas. A vast majority of organic compound determinations are performed using gas or liquid chromatographic methods. It is thus very important that these methods have negligible environmental impact. Chromatographic techniques have the potential to be greener at all steps of the analysis, from sample collection and preparation to separation and final determination. The paper summarizes the approaches used to accomplish the goals of green chromatography. While complete elimination of sample preparation would be an ideal approach, it is not always practical. Solventless extraction techniques offer a very good alternative. Where solvents must be used, the focus should be on the minimization of their consumption. The approaches used to make chromatographic separations greener differ depending on the type of chromatography. In gas chromatography it is advisable to move away from using helium as the carrier gas because it is a non-renewable resource. GC separations using low thermal mass technology can be greener because of energy savings offered by this technology. In liquid chromatography the focus should be on the reduction of solvent consumption and replacement of toxic and environmentally hazardous solvents with more benign alternatives. Multidimensional separation techniques have the potential to make the analysis greener in both GC and LC. The environmental impact of the method is often determined by the location of the instrument with respect to the sample collection point.

Green Materials and Devices

"Green" Electronics: Biodegradable and Biocompatible Materials and Devices for Sustainable Future

Chem. Soc. Rev., **2014**, *43*, 588-610 **DOI**: 10.1039/C3CS60235D

"Green" electronics represents not only a novel scientific term but also an emerging area of research aimed at identifying compounds of natural origin and establishing economically efficient routes for the production of synthetic materials that have applicability in environmentally safe (biodegradable) and/or biocompatible devices. The ultimate goal of this research is to create paths for the production of human- and

environmentally friendly electronics in general and the integration of such electronic circuits with living tissue in particular. Researching into the emerging class of “green” electronics may help fulfill not only the original promise of organic electronics that is to deliver low-cost and energy efficient materials and devices but also achieve unimaginable functionalities for electronics, for example benign integration into life and environment. This Review will highlight recent research advancements in this emerging group of materials and their integration in unconventional organic electronic devices.

新能源報導：電能源就在足下

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每次經過院內體育館，都會抬頭看健身室內，一排同仁們正在踩、跑、拉地使用著健身器具，那努力、專注和堅持的樣子確實是一幅優美的畫面，當下心裡想著，若那些以血肉之軀發出的動能量，在鍛鍊的同時也能產生電力就更為理想了。雖然全國有非常多的健身房及俱樂部，但好像沒聽說過有運動器材附帶發電的功能。好消息是自腳踏式壓電平板問世之後，以身體的動能量在不刻意的情況下發電更接近了現實。

壓電式(piezoelectric)平板是英國人 Laurence Kemball-Cook 在 2009 年(時年 22 歲)製造出來的產品，他成立了一個公司叫 Pavegen Systems，自任執行長。壓電效應並不是新發現，若運用到實際發電時，其效率及耐用程度是大問題。2008 年耶誕節期間(12 月 10 日至 12 月 25 日)東京車站前鋪了四塊 45 公分見方的「發電地板」(日本 Sound power 公司產品)供行人踩踏進行發電，此地板的功率為每踏二步可產生 0.5 瓦的電力。Pavegen 所製出的壓電板則是每踏一步(壓下約 0.5 公分)平均就可發電 5 瓦！其中 5%讓此板上指示燈發亮，以回饋反應及表示運作正常，其餘則存入鋰電池或啟動其他小型電器(如壁燈)。因此 Pavegen 對這發電板的效率非常自豪。Kemball-Cook 先生應邀演講時常做的第一件事就是請全體聽眾起立跳一下，然後告訴大家這一跳產生多少電力。言下之意即為永續能源就在大家的腳下。

Pavegen 將這項產品的技術部份列為機密，但強調產品非常環保。發電板表面的材料是回收的輪胎，底座是可回收再利用的聚合物(recycled polymer)。內部的電機零件是由無毒性物質組成。基於這種聲明可猜測是無鉛壓電材料，傳統的壓電陶瓷則含鉛。Pavegen 想讓大眾瞭解他的產品十分環保，其製造過程合乎綠色化學原則。

Pavegen 的壓電板相當耐用，可浸在水裡而不失其功能。Kemball-Cook 先生曾透露這個產品可以承受一位 300 公斤的女士穿著細跟高跟鞋踩在上面。現實生活中幾乎沒有這樣的人，相信只是一句玩笑話。不過他用機器模擬證明了這一點，顯示 Pavegen 壓電板非常耐重壓，在各種天候下也經得起人們長期及不斷的踩踏。

Pavegen 在 2012 年在倫敦 West Ham 地下鐵車站走廊上裝了二行，每行各六塊壓電板進行一次個案研究。此車站是通往奧林匹克運動大

會的重要運輸點。奧運期間人潮洶湧，測試結果十分亮眼，得到 BBC 的青睞而做了好幾個專題報導。使得 Pavegen 聲名大噪。次年同樣的試驗也出現在巴黎世界馬拉松的賽事上，Pavegen Systems 從此得到許多社會團體的肯定。Kemball-Cook 先生也受到 TEDx 邀請，分別在美國棕櫚泉、英國倫敦、德國柏林及 Rio+20 世界高峰會(巴西里約熱內盧)等地以及聯合國會員大會上發表演講。由此可見 Pavegen 壓電板已受到普遍的重視和認同。

根據加拿大 British Columbia 大學一份報告稱 8 塊 Pavegen 壓電板要價美金 30,800 元，這還未包括運費、鋪裝、維護及報廢處置的費用。裝設地點是該大學新建的學生活動中心。據統計在中午 12 至 2 點尖峰時間，這 8 塊壓電板被踩踏每小時高達 1,900 次，離峰時間(上午 8 到 12 時；下午 2 至 5 時)每小時也有 700 次。總計每工作日可發電 56 仟瓦，相當於 560 個 100 瓦光電燈泡用電，同時可減少產生二氧化碳 1.28 公斤/工作日。若將電賣給 British Columbia 電力公司，估計五年可回本。

發電量也許不大，但請注意這只是區區 8 塊板子的輸出，應用到小型電器可說綽綽有餘。例如 Pavegen 在海灘上的小木屋走到裝了 4 塊板子，遊客偶爾經過就在板子上頭跳個幾下，在三天內所產出的電力，就能將 1,000 支手機充飽電！而且重點是，人類的活動不會因為沒有設板子就停下，所以人類腳踏的動能不用白不用，取捨之間的選擇是不言而喻的了。

(網路搜索關鍵字：Pavegen Systems, Laurence Kenball-Cook,東京車站發電地板)