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Johnson Matthey Highlights

A selection of recent publications by Johnson Matthey R&D staff and collaborators

NON-PEER REVIEWED FEATURE

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Robust Continuous Synthesis and *in situ* Deposition of Catalytically Active Nanoparticles on Colloidal Support Materials in a Triphasic Flow Millireactor

W. K. Wong, J. T. Y. Chin, S. A. Khan, F. Pelletier and E. C. Corbos, *Chem. Eng. J.*, 2022, **430**, (4), 132778

A triphasic flow millireactor for catalytic nanoparticle synthesis and facile *in situ* deposition onto colloidal support materials is presented. Colloidal deposition was chosen because it allows nanoparticles with complex shapes and compositions to be deposited on the support material. In comparison to batch-synthesised nanoparticles, those generated by flow synthesis demonstrated greater quality and consistency. The method is shown to be effective when using different support materials, including alumina, ceria and titania. The technique's versatility is also demonstrated for various nanoparticle types, such as tri-/bi-/mono-metallics.

Comparison Between the Thermal and Plasma (NTP) Assisted Palladium Catalyzed Oxidation of CH_4 using AC or Nanopulse Power Supply

F. De Rosa, C. Hardacre, W. G. Graham, G. McCullough, P. Millington, P. Hinde and A. Goguet, *Catal. Today*, 2022, **384–386**, 177

A palladium supported alumina catalyst was used to investigate the combustion of methane using three systems (thermocatalytic, plasma and plasma-catalyst). To compare the three systems, the authors looked for the presence of a synergistic effect between the heterogenous catalyst and the plasma. The specific input energy of each system was also examined. The plasma systems were shown to be less efficient than the thermal process. When an AC power supply was used, no synergistic effect was found for the plasma systems. However, a nanopulse power supply demonstrated more promise. When using a nanopulsed operation, energy requirements were reduced for both heterogenous and homogeneous configurations.

Gas-Phase Isomerisation of *m*-Xylene on Isoreticular Zeolites with Tuneable Porosity

N. Remperová, J. Přech, M. Kubů, K. Gołąbek, J. F. Miñambres, M.-F. Hsieh, A. Turrina and M. Mazur, *Catal. Today*, 2022, **390–391**, 78

The ADOR approach was used to synthesise aluminium-containing isoreticular zeolites with controllable pore sizes. The zeolites were used to study catalytic performance in gas-phase *m*-xylene isomerisation. The authors investigated phase purity, the crystallinity and interlayer distances, aluminium content, textural properties of prepared materials and their crystals morphology. Comparisons were made with standard ZSM-5 zeolite. IPC-2 (10- and 12-ring channels) exhibited the highest conversion and *p*-xylene yields. A drop in selectivity was observed in the presence of extra-large, 14-ring channels, a consequence of xylene disproportionation.

Evaluation Of Water States in Thin Proton Exchange Membrane Manufacturing using Terahertz Time-Domain Spectroscopy

D. F. Alves-Lima, X. Li, B. Coulson, E. Nesling, G. A. H. Ludlam, R. Degl'Innocenti, R. Dawson, M. Peruffo and H. Lin, *J. Membr. Sci.*, 2022, **647**, 120329

The unique structure of perfluorinated sulfonic-acid ionomers (used as materials in proton exchange membranes) supports their chemical/mechanical and water properties. An understanding of these properties is imperative for creating optimal membranes. The authors used terahertz time-domain spectroscopy to resolve molecular water states and retention properties inside Nafion membranes (**Figure 1**). They also developed a parametric-based algorithm for data analysis. The technique was applied to industrially relevant thin ionomers (13–70 µm), and results were reinforced

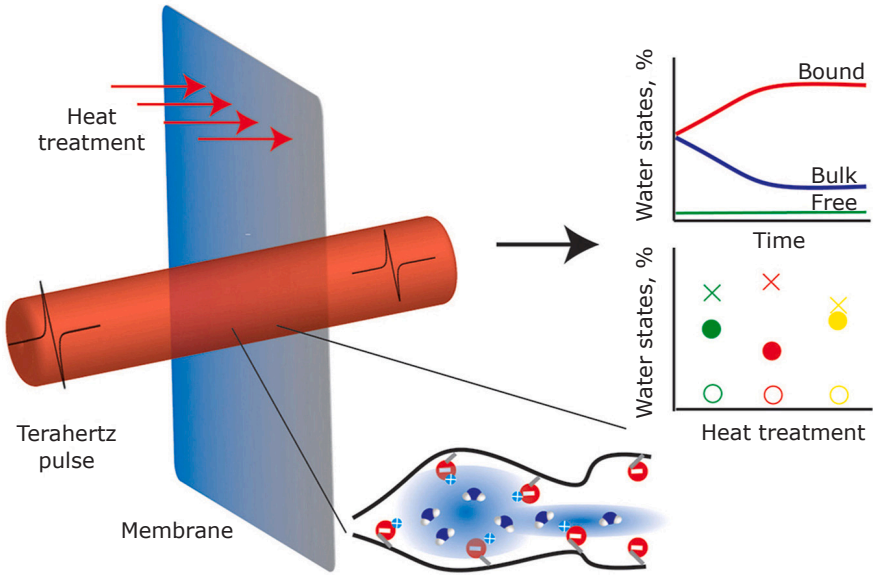

Fig. 1. Graphical abstract. Reprinted from D. F. Alves-Lima *et al.*, *J. Membr. Sci.*, 2022, **647**, 120329 under Creative Commons Attribution 4.0 International License (CC BY 4.0)

by prior demonstrations and conventional gravimetric analysis. The method showed sensitivity to membranes prepared under different processing conditions.

Biotechnological Synthesis of Pd-based Nanoparticle Catalysts

C. Egan-Morriss, R. L. Kimber, N. A. Powell and J. R. Lloyd, *Nanoscale Adv.*, 2022, **4**, (3), 654

Palladium nanoparticles supported on microbial cells (bio-Pd) offer a more sustainable alternative to palladium nanoparticles generated *via* conventional chemical synthesis. However, the intrinsic activity and selectivity of bio-Pd needs to be enhanced to make it commercially viable. Bacteria, such as dissimilatory metal-reducing bacteria, have historically been used to produce bio-Pd. Recently, bio-bimetallic nanoparticles have been introduced, which can significantly enhance the catalytic properties of bio-Pd. To further enhance these properties, bio-Pd can be integrated into biocatalytic processes using systems biology. In this review, the authors examine enzymatic metal reduction processes that can be bioengineered to control the shape, size and cellular location of bio-Pd to improve its catalytic properties.

Site-Selective d^{10}/d^0 Substitution in an S = ½ Spin Ladder $Ba_2CuTe_{1-x}W_xO_6$ ($0 \leq x \leq 0.3$)

C. Pughe, O. H. J. Mustonen, A. S. Gibbs, M. Etter, C. Liu, S. E. Dutton, A. Friskney, N. C. Hyatt, G. B. G. Stenning, H. M. Mutch, F. C. Coomer and E. J. Cussen, *Inorg. Chem.*, 2022, **61**, (9), 4033

The hexagonal perovskite Ba_2CuTeO_6 has a spin ladder geometry of Cu^{2+} cations. The authors substituted Te^{6+} d^{10} by W^{6+} d^0 in Ba_2CuTeO_6 to produce a $Ba_2CuTe_{1-x}W_xO_6$ solid solution (x = 0–0.3). The substitution of W^{6+} for Te^{6+} was nearly exclusively observed on the corner-sharing site within the spin ladder rather than the face-sharing site between ladders. The intraladder interactions (J_{rung} and J_{leg}) were shown to be directly tuned by site-selective doping. As W^{6+} increased, the system changed from a spin ladder to isolated spin chains. This was demonstrated by modelling the magnetic susceptibility data, which also showed that the relative intraladder interaction strength (J_{rung}/J_{leg}) was modified by the d^0 orbitals.

Renewable Butadiene: A Case for Hybrid Processing *via* Bio- and Chemo-Catalysis

S. Rodgers, F. Meng, S. Poulston, A. Conradie and J. McKechnie, *J. Cleaner Prod.*, 2022, **364**, 132614

Technoeconomics and greenhouse gas emissions of renewable butadiene production using a hybrid biocatalytic route with black liquor were investigated and compared to two chemocatalytic routes using forestry residues and pulpwood. A novel aerobic gas fermentation platform was employed. Integrated supercritical water gasification and aerobic gas fermentation produces acetaldehyde, followed by chemocatalytic upgrading. One route passes through an ethanol intermediate, the other has propene as an intermediate. The hybrid bio/chemo-catalytic route was found to be profitable using the nominal technoeconomic inputs, producing a net present value of US$2.8 million and minimum selling price of US$1367 tonne^{-1}.

Enzymatic Epoxidation of Long-Chain Terminal Alkenes by Fungal Peroxygenases

E. D. Babot, C. Aranda, J. Kiebist, K. Scheibner, R. Ullrich, M. Hofrichter, A. T. Martínez and A. Gutiérrez, *Antioxidants*, 2022, **11**, (3), 522

Unspecific peroxygenases (UPOs) were explored to selectively epoxidise terminal alkenes. After

optimisation of reaction parameters (cosolvent, cosubstrate and pH), UPOs from *Cyclocybe (Agrocybe) aegerita, Marasmius rotula, Coprinopsis cinerea, Humicola insolens* and *Daldinia caldariorum* were found to catalyse the epoxidation of long-chain terminal alkenes from C12:1 to C20:1. Alkenols and other hydroxylated derivatives of the alkenes were also formed. Peroxygenases therefore have potential as an interesting and green alternative to the existing technologies for epoxidising long-chain terminal alkenes.

A Cell Design for Correlative Hard X-ray Nanoprobe and Electron Microscopy Studies of Catalysts under *in situ* Conditions

J. E. Parker, M. Gomez-Gonzalez, Y. Van Lishout, H. Islam, D. Duran Martin, D. Ozkaya, P. D. Quinn and M. E. Schuster, *J. Synchrotron Rad.*, 2022, **29**, 431

A specially developed system incorporating a commercially available gas-cell chip assembly within an X-ray nanoprobe beamline was used to investigate the redox behaviour of platinum nanoparticles supported on ceria under typical lean and rich diesel-exhaust conditions. The system may also be applied to a wide range of other solid–gas reactions. Complimentary *in situ* TEM and X-ray nanoprobe studies could be carried out under identical conditions. The same cell can be used and easily transferred between instruments, a major advantage which raises the possibility of studying the same particles under identical conditions (gas flow, pressure, temperature) using multiple techniques.

Intensified Liquid-Liquid Extraction of Biomolecules using Ionic Liquids in Small Channels

Y.-V. Phakoukaki, P. O'Shaughnessy and P. Angeli, *Sep. Purif. Technol.*, 2022, **282**, (B), 120063

Intensified extraction of amino acid L-tryptophan from aqueous solution into an ionic liquid was carried out in small channels. The study demonstrated the possibility of replacing conventional organic solvents with ionic liquids. A mechanism is proposed for ionic liquid and extractant combination. Hydrodynamic properties of the liquid-liquid plug flow in small channels were investigated. High mass transfer coefficients in comparison to mixer-settlers and organic solvents, respectively, were found.