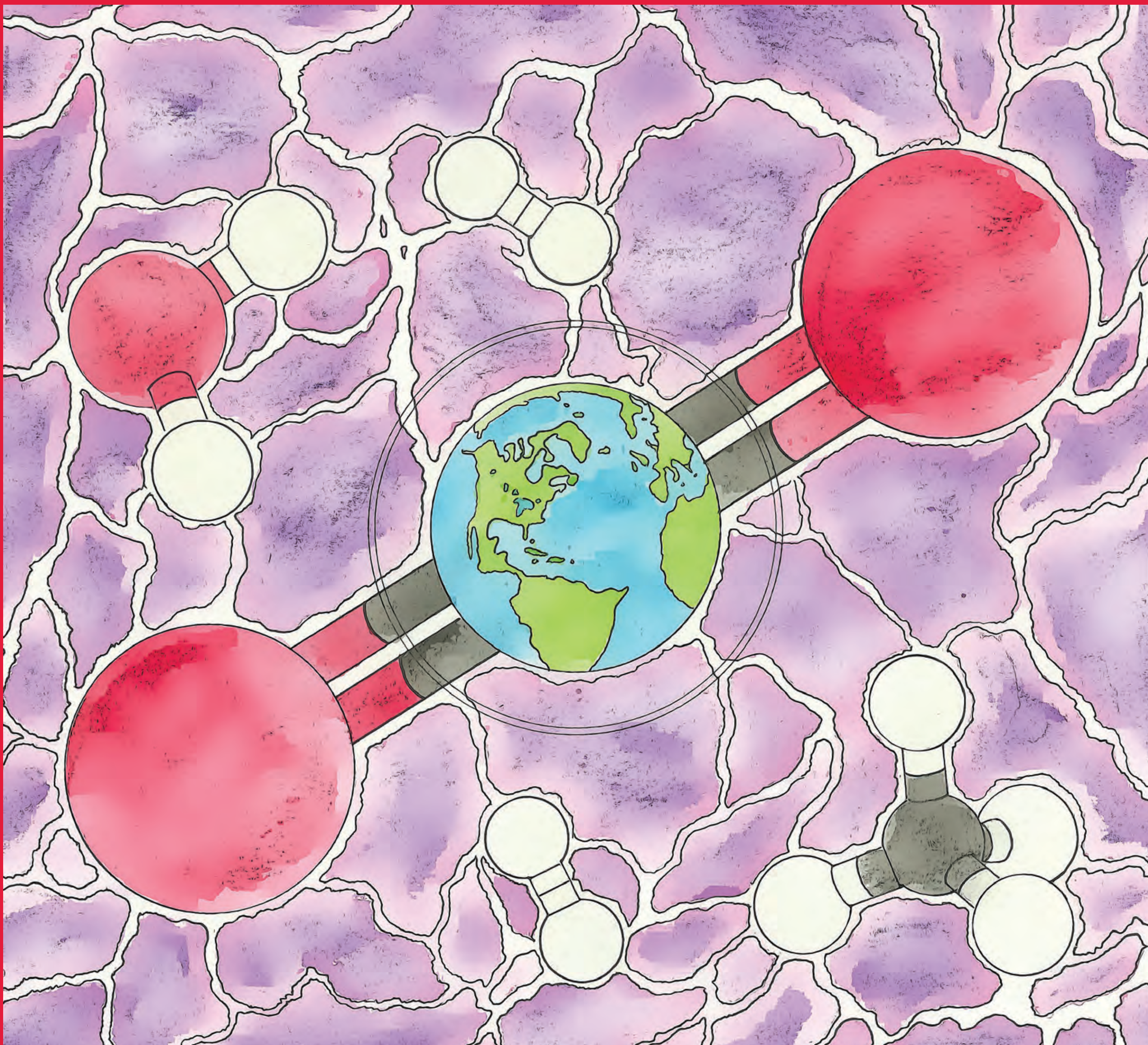
Volume 14 | Number 6 | June 2017

www.plasma-polymers.org

PLASMA PROCESSES AND POLYMERS



Special Issue:
Plasma Conversion

Guest Editors:
Tomohiro Nozaki | Annemie Bogaerts | Xin Tu | Richard van de Sanden

WILEY-VCH

DOI: 10.1002/ppap.201790061

PLASMA PROCESSES AND POLYMERS

EDITORIAL

Special issue: Plasma Conversion

With growing concern of energy and environmental issues, the combination of plasma and heterogeneous catalysts receives special attention in greenhouse gas conversion, nitrogen fixation and hydrocarbon chemistry. Plasma gas conversion driven by renewable electricity is particularly important for the electrification of the chemical industry, which is currently dominated by water electrolysis, producing CO_2-free renewable hydrogen. Meanwhile, electrochemical conversion of CO_2, CH_4 and other gaseous materials has yet to be successful because the material and energy conversion efficiency as well as productivity of the electrochemical processes greatly depend on the electrolyte material in terms of the solubility of gaseous materials and mass transport capability, which needs to be dramatically improved.

As for fuel processing, the majority of reactions are categorized as uphill (endothermic) reactions where energy input is indispensable due to the conservation of energy. Ideally, such energy should be supplied by low temperature heat while plasma-generated reactive species promote initiation reactions. One promising approach is the use of vibrationally excited molecules which enhance the probability of chemisorption onto the catalyst surfaces. The role of vibrational species has been well investigated through molecular beam studies. However, the way to create such species has not been studied yet. Non-thermal plasma creates an oversaturated amount of vibrational species even at low temperature, showing great promises towards low temperature plasma catalysis of stable molecules. Furthermore, vibrational species uniquely create reaction pathways in homogeneous reactions via stepwise energy transfer gradually populating higher vibrational levels which eventually leads to the dissociation of stable molecules such as CO_2.

The special issue entitled "*Plasma Conversion*" consists of three review articles and 11 original research papers, focusing on the state-of-the-art plasma technology that is used for enhancing homogeneous/heterogeneous plasma catalytic conversion of greenhouse gases, nitrogen fixation and hydrocarbon chemistry. Review articles include the new catalyst synthesis approach using nonthermal plasma processes and the potential application of such unique catalysts is introduced (Rahimpour et al.) [1]. CH_4 and CO_2 reforming is one of the hot topics in plasma catalysis and research has been conducted mostly by experimental approaches. Bogaerts et al. discuss CH_4 reforming and CO_2 splitting and various mixtures from a modeling perspective, paying special attention to plasma chemistry and the role of plasma-generated vibrationally excited molecules [2]. Reactions involving vibrationally excited species need to be explored further and a numerical approach is truly beneficial providing insightful information towards the reaction mechanisms. Liquefaction of CH_4 is to produce higher hydrocarbons via CH_4 polymerization at ambient conditions (not for cryogenic methane condensation) [3]. Carbon containing liquid fuels such as gasoline and diesels produced via renewable electricity improve transportability and storage of renewable energy. Two research papers are related to heterogeneous plasma catalysis of CH_4 and CO_2 where nonthermal plasma is combined with Ni-supported reforming catalysts [4,5]. Research was conducted experimentally and plasma induced synergistic effects are highlighted. Van Rooij and Bongers discuss the homogeneous CO_2 conversion with warm discharge, or low pressure microwave plasma [6,7]. Special emphasis on the vibrationally excited CO_2 chemistry and CO_2 dissociation by the latter mechanism is discussed. A novel heterogeneous plasma catalysis approach of CO_2, where nonthermal plasma is combined with an oxygen permeating solid electrolyte membrane, is presented by Mori [8]. O_2 is extracted directly from the plasma reaction field, and thus the CO_2 conversion and energy efficiency were greatly improved. Moreover, CO_2 microwave plasma diagnostics by optical emission spectroscopy [9], diagnostics plasma-catalyst interfacial phenomena [10], and atomistic simulations of plasma catalytic interactions [11] are included in the collection of this special issue. Three other papers focus on ammonia synthesis with atmospheric pressure plasma combined with heterogeneous catalysts [12–14].

Finally we would like to thank all contributors to this special issue and the editorial staff of *Plasma Processes and Polymers* for their great support. We hope that this issue contributes to exploring the new frontiers of plasma chemistry, and also to promoting the interdisciplinary interaction among the plasma science, chemical catalysis and surface science community, as well as other science specialists.

Guest Editors:
Tomohiro Nozaki
Department of Mechanical Engineering, Tokyo Institute of Technology, Tokyo, Japan
Email: tnozaki@mech.titech.ac.jp

Annemie Bogaerts
Research Group PLASMANT
Department of Chemistry, University of Antwerp, Wilrijk-Antwerp, Belgium
Email: annemie.bogaerts@uantwerpen.be

Xin Tu
Department of Electrical Engineering and Electronics, University of Liverpool, Liverpool, UK
Email: xin.tu@liverpool.ac.uk

Richard van de Sanden
Dutch Institute for Fundamental Energy Research (DIFFER),
Department of Applied Physics,
University of Technology, Eindhoven, The Netherlands
Email: M.C.M.vandeSanden@differ.nl

Reviews

1. H. Taghvaei, M. Heravi, M. R. Rahimpour, Synthesis of supported nanocatalysts via novel non-thermal plasma methods and its application in catalytic processes, *Plasma Process Polym.* **2017**, *14*, e1600204
2. A. Bogaerts, C. De Bie1, R. Snoeckx, T. Kozák, Plasma based CO_2 and CH_4 conversion: A modeling perspective, *Plasma Process Polym.* **2017**, *14*, e1600070
3. R. Snoeckx, A. Rabinovich, D. Dobrynin, A. Bogaerts, A. Fridman, Plasma based liquefaction of methane: The road from hydrogen production to direct methane liquefaction, *Plasma Process Polym.* **2017**, *14*, e1600115

Dry reforming – Hybrid

4. D. Mei, B. Ashford, Y.-L. He, X. Tu, Plasma-catalytic reforming of biogas over supported Ni catalysts in a dielectric barrier discharge reactor: Effect of catalyst supports, *Plasma Process Polym.* **2017**, *14*, e1600076
5. S. Kameshima, K. Tamura, R. Mizukami, T. Yamazaki, T. Nozaki, Parametric analysis of plasma-assisted pulsed dry methane reforming over Ni/Al_2O_3 catalyst, *Plasma Process Polym.* **2017**, *14*, e1600096

Homogeneous CO_2 conversion

6. N. den Harder, D. C. M. van den Bekerom, R. S. Al, M. F. Graswinckel, J. M. Palomares, F. J. J. Peeters, S. Ponduri, T. Minea, W. A. Bongers, M. C. M. van de Sanden, G. J. van Rooij, Homogeneous CO_2 conversion by microwave plasma: Wave propagation and diagnostics, *Plasma Process Polym.* **2017**, *14*, e1600120
7. W. Bongers, H. Bouwmeester, B. Wolf, F. Peeters, S. Welzel, D. van den Bekerom, N. den Harder, A. Goede, M. Graswinckel, P. W. Groen, J. Kopecki, M. Leins, G. van Rooij, A. Schulz, M. Walker, R. van de Sanden, Plasma-driven dissociation of CO_2 for fuel synthesis, *Plasma Process Polym.* **2017**, *14*, e1600126
8. S. Mori. L. L. Tun, Synergistic CO_2 conversion by hybridization of dielectric barrier discharge and solid oxide electrolyser cell, *Plasma Process Polym.* **2017**, *14*, e1600153

Diagnostics

9. T. Silva, N. Britun, T. Godfroid, R. Snyders, Understanding CO_2 decomposition in microwave plasma by means of optical diagnostics, *Plasma Process Polym.* **2017**, *14*, e1600103
10. Z. Jia, X. Wang, F. Thevenet, A. Rousseau, Dynamic probing of plasma-catalytic surface processes: oxidation of toluene on CeO_2, *Plasma Process Polym.* **2017**, *14*, e1600114
11. E. C. Neyts, K. M. Bal, Effect of electric fields on plasma catalytic hydrocarbon oxidation from atomistic simulations, *Plasma Process Polym.* **2017**, *14*, e1600158

NH_3 Hybrid

12. A. Gómez-Ramírez, A. M. Montoro-Damas, J. Cotrino, R. M. Lambert, A. R. González-Elipe, About the enhancement of chemical yield during the atmospheric plasma synthesis of ammonia in a ferroelectric packed bed reactor, *Plasma Process Polym.* **2017**, *14*, e1600081
13. L. Wang, Y. Yi, Y. Guo, Y. Zhao, J. Zhang, H. Guo, Synergy of DBD plasma and Fe-based catalyst in NH_3 decomposition: Plasma enhancing adsorption step, *Plasma Process Polym.* **2017**, *14*, e1600111
14. H.-H. Kim, Y. Teramoto, A. Ogata, H. Takagi, T. Nanba, Atmospheric-pressure nonthermal plasma synthesis of ammonia over ruthenium catalysts, *Plasma Process Polym.* **2017**, *14*, e1600157