A CO_2 free future: Sustainable hydrogen and carbon nanomaterials production in methane plasma

Keywords: Climate change, sustainability, energy, methane, CO_2, spectroscopy, laser

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Project Description

Fossil fuels provided the cheap energy that catalysed global development in the previous two centuries. This "cheap" energy came at the expense of environmental effects, such as the growth of anthropogenic CO_2 emissions leading to climate change. To limit warming to 2.0 degrees, the Paris accord requires a 90% reduction in CO_2 emissions by 2050. Despite this, there are currently few economic incentives for the petrochemical industry to reduce their emissions. In this project, we will investigate a route in which CO_2-neutral hydrogen is produced by "decarbonisation" of methane with renewable energy whilst an economic benefit is created by the co-production of high-value carbon that can be used as a construction material.

Methane pyrolysis in plasma occurs at temperatures above 1400 K, producing solid carbon and hydrogen as products. During plasma pyrolysis, a range of carbon structures can be formed. Some of these carbon structures are valuable (nanotubes, graphene flakes, etc.), and contribute positively to the overall process economics. However, the process that leads to the formation of these valuable carbon structures is complex and depends on the energy and species transport through the reactor. In this project, we will investigate total methane pyrolysis to optimise and control the value of the carbon products and at the same time economically producing hydrogen. We will generate understanding of reactor transport and energy dissipation using in-situ laser diagnostics to quantify reactor temperature and to observe carbon nucleation and growth.

PhD candidate requirements

Applicant **must** be from a Chinese University. Candidate should graduate in 2021 with a Master's degree in either physics, chemistry, chemical engineering, mechanical engineering, or other engineering or physical science disciplines. Preference will be given to students with knowledge or experience in laser diagnostics, plasma chemistry or physics, or hydrocarbon chemistry. Due to the funding through the CSC programme, we will preferentially select candidates from "Double First class" universities, although other strong applicants are encouraged to apply. A high level of English speaking and writing ability is essential.

Recent publications from PI and CI

- van Rooij, G. J. *et al* (2015) *Taming microwave plasma to beat thermodynamics in CO2 dissociation*, Faraday Discussions, 183 233-248 **121 Citations**
- Butterworth, T., Elder, R. & Allen, R. (2016) *Effects of particle size on CO_2 reduction and discharge characteristics in a packed bed plasma reactor*. Chemical Engineering Journal. 293, 55-67. **63 Citations**
- Butterworth, T. & Allen, R. (2017) *Plasma-catalyst interaction studied in a single pellet DBD reactor: Dielectric constant effect on plasma dynamics.* Plasma Sources Sci. Technol. 26, 065008 **40 Citations**
- Bekerom, D. C. M., van Rooij, G. J. *et al* (2019) *The importance of thermal dissociation in CO_2 microwave discharges investigated by power pulsing and rotational Raman scattering*, Plasma Sources Sci. Technol. 28 055015 **21 Citations**
- Butterworth, T., Amyay, B., vd Bekerom, D. et al. (2019) *Quantifying methane vibrational and rotational temperature with Raman scattering,* J. Quant. Spectrosc. Radiat. Transf., 236, 106562 **5 Citations**
- Adamovich, I., Butterworth, T., Orriere, T., Pai, D., Lacoste, D., Cha, M.S. (2019) *Nanosecond Second Harmonic Generation for Electric Field Measurements with Temporal Resolution Shorter than Laser Pulse Duration,* J. Phys. D: Appl. Phys. 53 145201 **4 Citations**
- Butterworth, T., vd Steeg, A., vd Bekerom, D., Minea. T., Righart. T., v Rooij, G. J. (2020)*, Plasma induced vibrational excitation of CH4 – a window to its mode selective processing, Plasma Sources Sci. Technol.* 29 095007 **0 Citations – recent publication**
- Butterworth, T., Cha, M. S. (Accepted) *Electric field measurement in electric-field modified flame,* Proceedings of the Combustion Symposium. **In process of publication**

More information on the CSC programme can be found here: https://www.maastrichtuniversity.nl/china-csc-scholarships

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