Online LTP Seminar

September 21, 2021, 9:00 am EDT

Nitrogen Fixation as NO_x Using Non-equilibrium Atmospheric Pressure Plasmas Coupled with Heterogeneous Catalysis

Dr. Xuekai Pei

School of Electrical Engineering and Automation of Wuhan University,

China

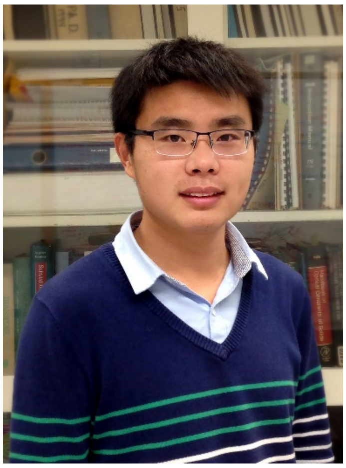
Nitrogen fixation, i.e. converting unreactive molecular nitrogen (N_2) into more reactive forms of nitrogen (N_r), is fundamental in the manufacture of nitrogen-based fertilizers. The dominant process currently is the high temperature and high-pressure catalytic formation of NH_3 from N_2 and H_2, commonly known as the Haber–Bosch (HB) process. However, the reliance of the HB process on fossil fuels and its associated high CO_2 emissions have spurred recent interest in finding more sustainable and environmentally benign alternatives. Fixation of nitrogen due to naturally occurring electrical discharges, such as lightning, is well known. Based on the same principle, reactive nitrogen produced from air by non-equilibrium atmospheric pressure plasmas has been recently proposed as an alternative technology for nitrogen fixation. However, a major challenge remains in reducing the energy cost of NO_x production in air plasmas to make the technology economically competitive.

We investigated the energy cost of NO_x production using four types of discharges: DBD, glow, spark and the Propeller Arc in air. Based on the results, we found the two key parameters controlling NO_x production efficiency to be the average electric field $\bar{E}$ and average gas temperature $\bar{T}$. Using these parameters, we define the dimensionless parameter χ, the normalized product of $\bar{E}$ and $\bar{T}$. This quantity appears to effectively correlate specific energy cost of NO_x production for the discharges we studied as well as results from the literature. The χ factor appears to serve as a simple, effective means of correlating NO_x production energy efficiency across a broad range of discharges. We also attempted to improve plasma energy efficiency for nitrogen fixation by adding heterogeneous catalysts. It appears that fluidizing catalyst particles in the gas flow is viable and worthy of further investigations. The lowest energy cost that we measured across the different types of discharges or/and coupled with heterogeneous catalysis is about 210 GJ/tN (2.9 MJ/mol).

Acknowledgments

Most of the work was done in Prof. David B. Graves lab at University of California-Berkeley, USA.

Short Bio



Xuekai Pei obtained his Ph.D. in Electrical Engineering in 2014 at Huazhong University of Science and Technology. Then he joined Leibniz Institute for Plasma Science and Technology (INP), Germany. In 2016, Dr. Pei became a Postdoc at the University of California, Berkeley and concentrated on Plasma Nitrogen Fixation until early 2021. Now he is a professor at the School of Electrical Engineering and Automation of Wuhan University, China. He has authored or co-authored over 30 peer-reviewed scientific articles with over 1000 citations. In 2019, He was honored with the Young Investigator Award (1st Place) of the International Plasma Chemistry Society for his work on nitrogen fixation by air plasma. He and his colleagues invented the 'Plasma Flashlight' which was reported by many news media such as Science, Time, Daily News, Daily Mail, ABC Radio etc.

His current research interests include the design and applications of atmospheric pressure nonthermal plasma sources, plasma diagnostics, and nitrogen fixation by plasma.