Design and Characterization of a Low Temperature Plasma Reactor

M. Allain, J. Pippins III, S. Ambatipati

Introduction

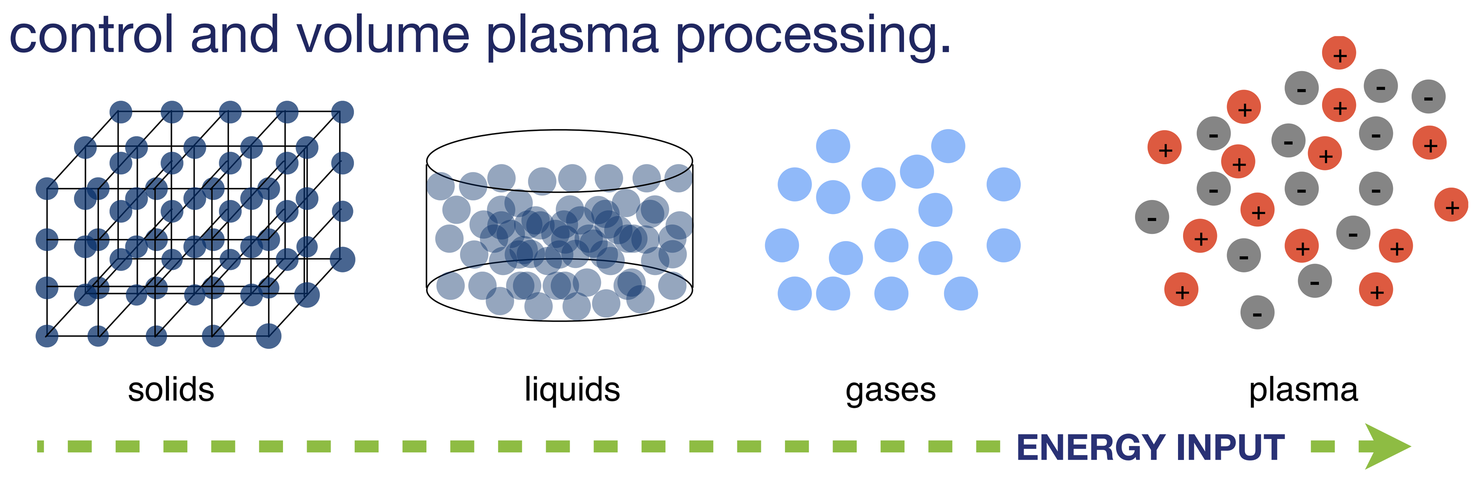
The effect of chemical processes and hydrocarbon production on atmospheric air quality is of increasing importance. Volatile organic compounds (VOCs) such as unburned hydrocarbons, organic solvent chemicals, toluene, benzene, and others, have adverse ecological effects. In addition, increasing attention is being placed on anthropogenic greenhouse gas emissions. Ultimately, researchers must look to recycling and utilization of these gases for viable solutions.

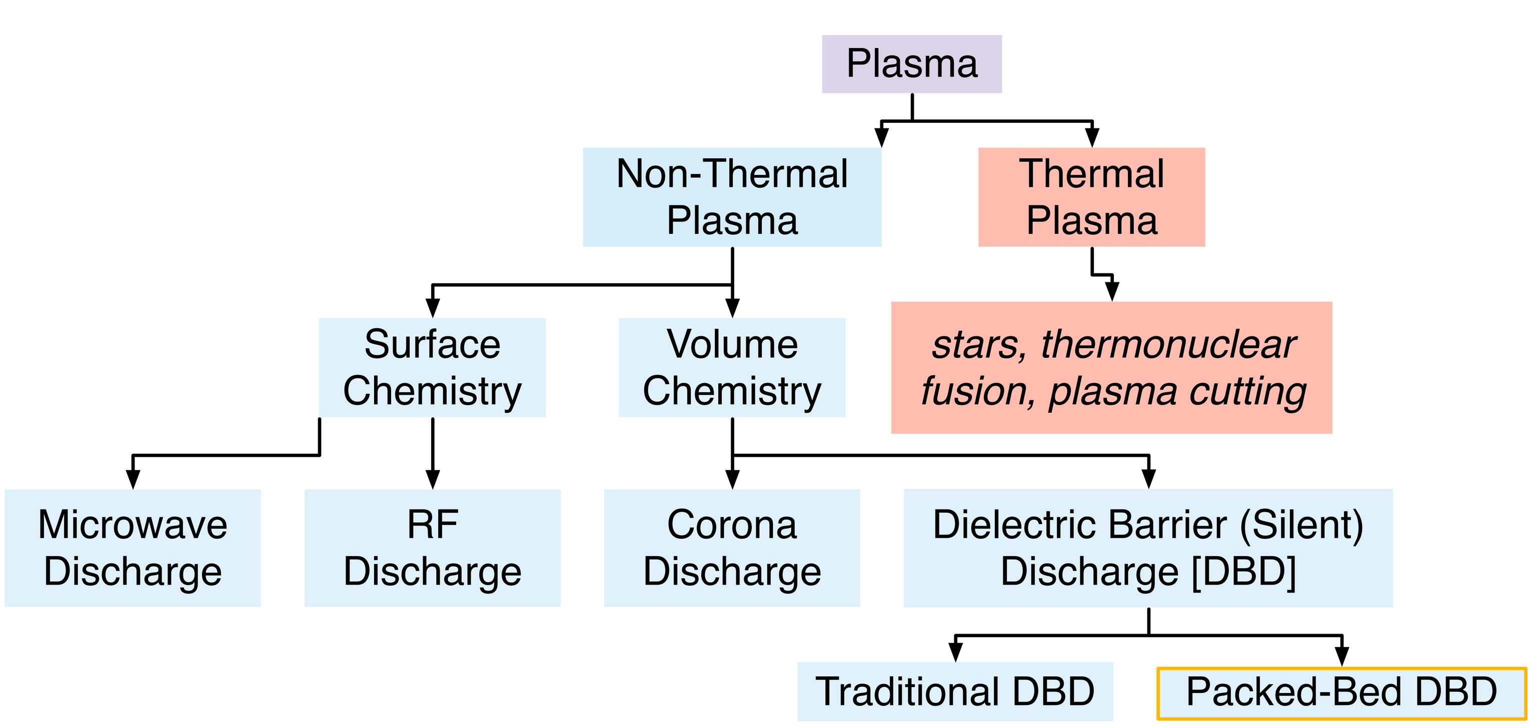
Recent research has proven plasma catalysis using low temperature plasmas an effective as well as efficient method of recycling for VOCs, nitrogen oxides, sulfur oxides, and even carbon dioxide. Also, with hydrocarbon VOCs, there is a great deal of potential in producing syngas, which is a widely used intermediate in synthesis fuel and ammonia production. Likewise, carbon dioxide could be dissociated into a more favorable carbon monoxide or elemental carbon.

Background Theory

Plasma is formed when energy input causes the electrons in a gas to be expelled from their orbitals, resulting in ionization of the gas. In low temperature (non-thermal) plasmas, electrical discharges are utilized to ionize gas. These discharges can be categorized by their characteristics, and behave very differently.

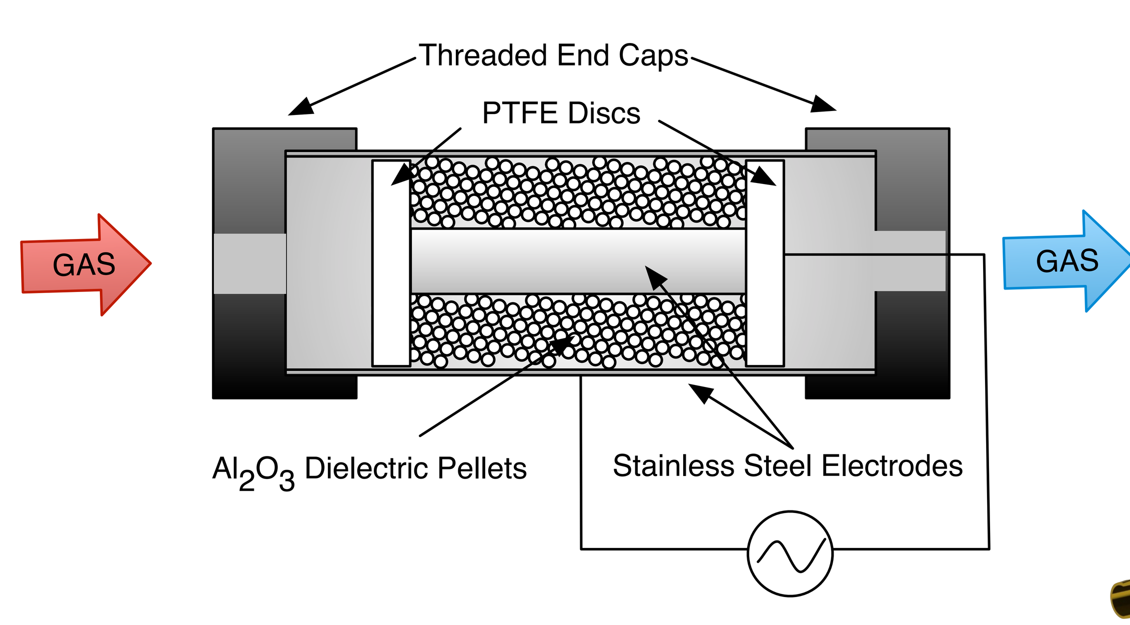
Packed-bed reactors are one type of dielectric barrier discharge, and serve to distribute discharges throughout a reactor volume, so they are advantageous for pollution control and volume plasma processing.

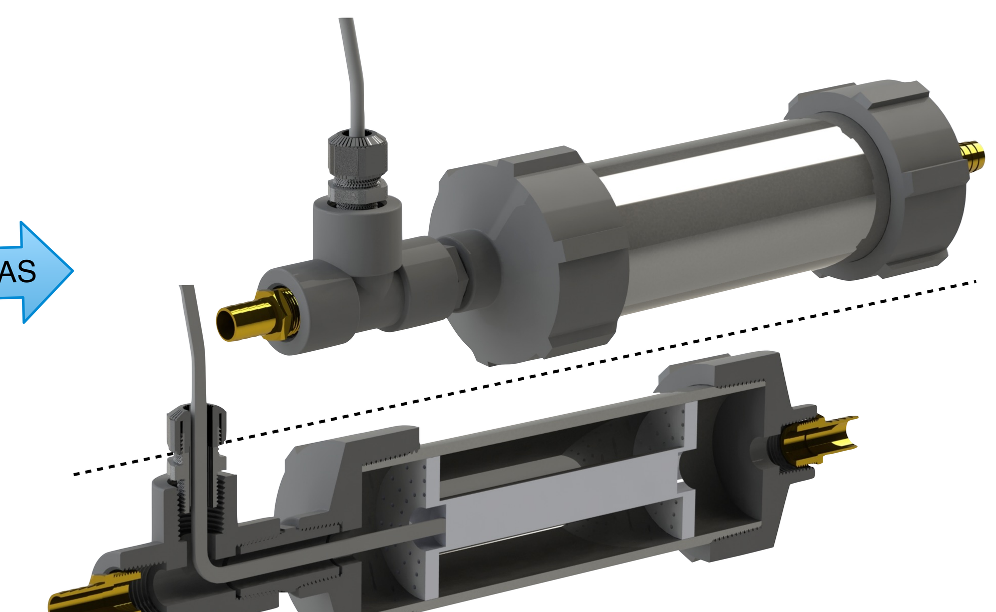




Design and Assembly

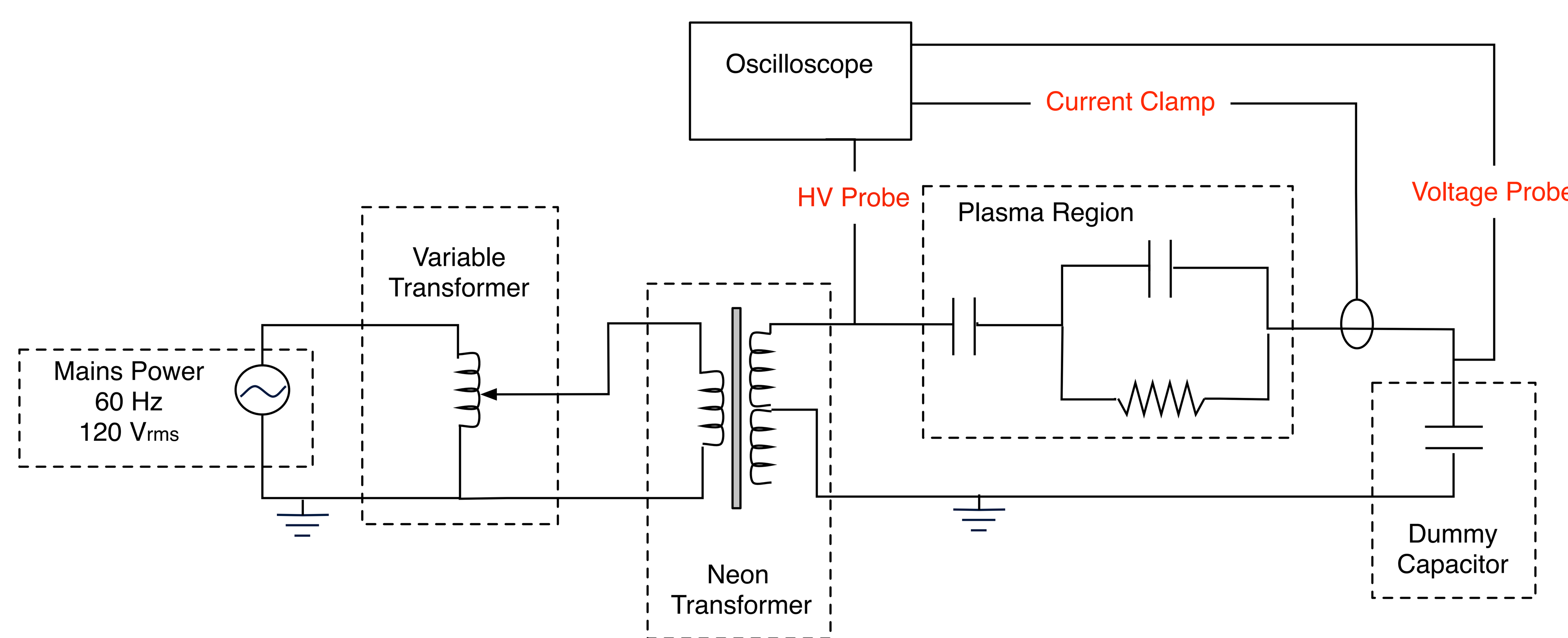
The apparatus was designed with the common experimental configuration of coaxial electrodes (two concentric cylindrical electrodes). The plasma discharge area was filled with alumina dielectric pellets. An additional demonstration unit was made from glass in order to visualize the discharges.





main reactor assembly

Power was provided by a repurposed neon transformer (12 kV_{RMS}, 60 Hz), driven by a variable autotransformer. Due to the center-tap ground of the transformer, only one-half of the full potential of the tranformer could be utilized while maintaining measurement accuracy. Actual discharge power is measured by the Lissajous figure technique, integrating the charge on a dummy capacitor with the voltage on the reactor. The circuit can be seen below.



Experimental Procedure

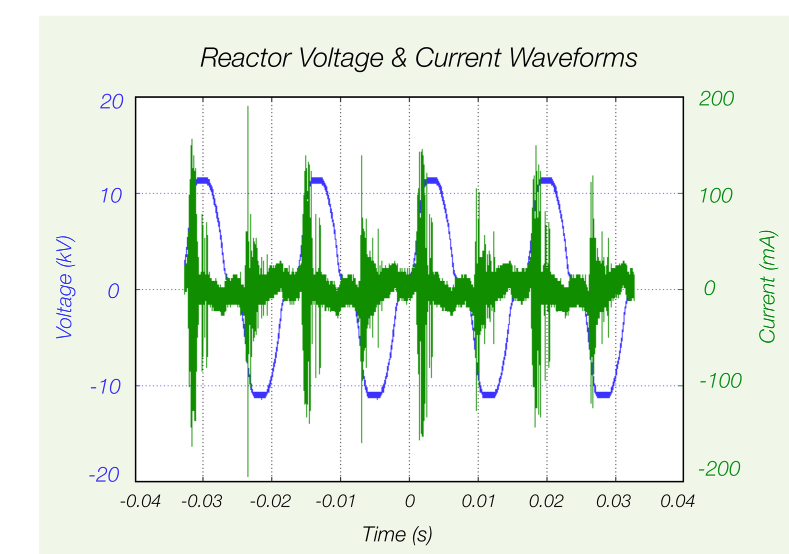
Initially, the reactor was energized in stagnant air. Later, carbon dioxide was processed in the reactor and sent for analysis. Discharge power was analyzed continuously via the Lissajous figure technique.

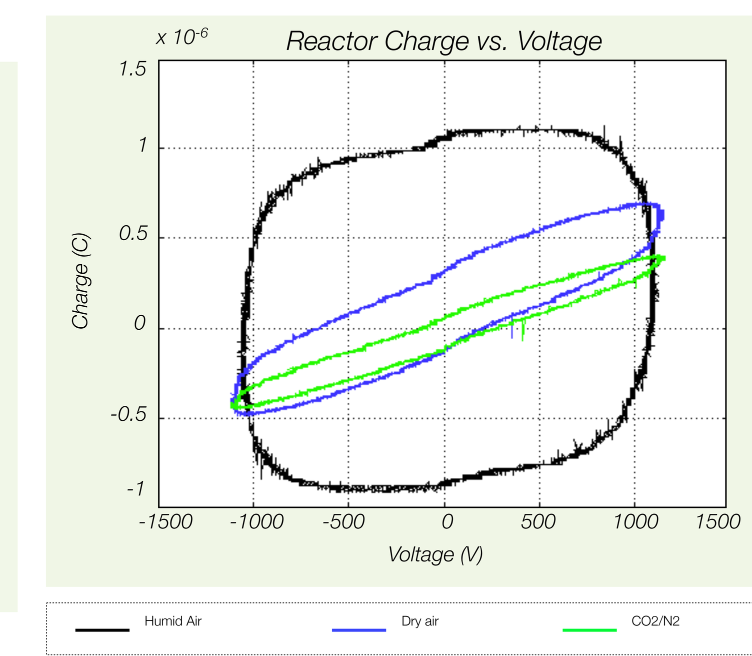
Additionally, the reactor was examined for particulate removal. A sealed chamber was filled with an organic smoke (incense), and plasma was utilized to oxidize the particulate.

Results and Analysis

Discharge power efficiency reached as high as 20% in stagnant air. However, the efficiency dropped to as low as 0.3% with carbon dioxide and nitrogen filling the reactor. At a specific energy density (SED) of 15 J/L, no measurable changes occurred in the feed gas. However, maximum applied potential, an arc discharge was formed, and both methane and carbon monoxide were observed as products.

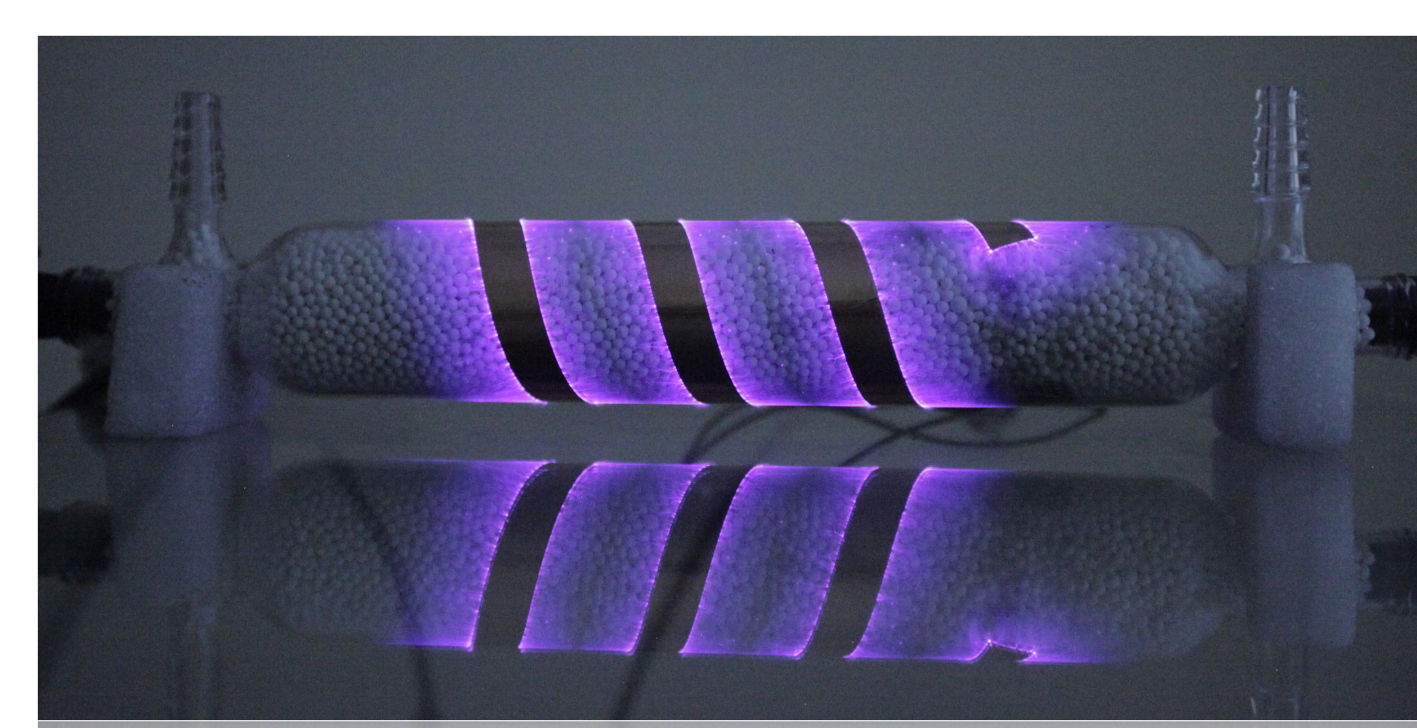
The apparent plasma power, based on Lissajous figure measurements, increases with increasing oxygen concentration. This is most likely due to increased electron mobility of oxygen. With dry air as the feed gas, efficiency increased to 1.5 %. Moisture content has a significant effect on plasma performance and efficiency. Power consumption is significantly higher in humid air.





Recommendations

Adaptability is the key to optimization in a lab-scale reactor. A more dedicated power supply would allow for frequency analysis, and more permanent connections and fixtures would increase experimental efficiency. Additionally alumina is a modest dielectric, and higher permittivity dielectrics, such as barium titanate, show more promise for depollution, although they are difficult to acquire or manufacture.



demonstration reactor, glass container, copper electrodes

R3 Sciences 1424 S. Hugh Wallis Rd. Lafayette, LA 70508 **T** 337-291-2778 **F** 337-291-2781 allain.mitch@gmail.com jp3@lusfiber.net