CO2 Dissociation using a Catalytic Dielectric Barrier Discharge

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**Motivation**
As concerns about excessive CO2 production increase, economical ways of converting CO2 into commercially useful feedstock gases or into molecules that have less of a greenhouse effect are of broad interest. The Versatile Atmospheric dielectric barrier discharge experiment (VADER) is designed to create a high density, non-thermal, cool plasma with high-energy electron tail that preferentially excites vibrational CO2 states and subsequently drives CO2 dissociation. The energy cost per dissociation, even in a non-thermal plasma is still prohibitively high. Here we present baseline measurements of the energy cost per dissociation as a function of discharge frequency, inlet gas temperature, gas flow rate and gas mixture. We will also present energy cost per dissociation measurements when one of the DBD electrodes is covered with a UV photocatalyst. The fraction of CO2 dissociated is measured with a real-time Residual Gas Analyzer (RGA) and the densities of vibrational energy states are measured in situ through optical emission spectroscopy.

**The Versatile Atmospheric DBD ExpeRiment (VADER)**

- HV Power Supply
- Oscilloscope
- Laser System
- Laser injection
- Function Generator
- Capillary tubes
- Roughing Pump
- Pressure gauge
- Spectrometer
- Computer
- Gas exhaust to RGA

**System Features**
- Variable Frequency: 0 - 10 kHz
- Voltage: 0-20 kV (p-p)
- Fully adjustable electrode gap
- Varied dielectric materials – BN, quartz glass, MACOR and Lava
- Pressure: 0.001 to 2 ATM
- Gas mixtures
- Variable voltage pulse shape
- Variable electrode geometry
- Variable gas temperatures

**Diagnostics**
- Emission spectroscopy For electron density and temperature
- Residual gas analyzer
- Real time conversion rates
- Power measurements
- Dissociation efficiency

**Ar Optical Emission for measuring the Plasma Electron Density**

Ongoing experiments are focused on obtaining plasma electron density measurements from the Stark broadening of Ar emission lines. The Stark broadening is determined by fitting a measured Ar emission line (red line) and fitting it with a model function that includes the different line broadening effects (blue line): Doppler, Van Der Waals, Stark, etc. and then comparing the calculated Stark broadening to the theoretical calculations for the density dependent Stark broadening.

**Future Work**
- Additional experimental CO2 decomposition runs, pushing the boundaries of the VADER system.
- Completion of the Ar optical emission spectroscopy fitting program and exploring the effects of source parameters on the electron density.
- Determine the electron temperatures the plasma through line ratio techniques developed by other groups.

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**Calibration of the RGA measurements with a Gas Chromatograph**

GC calibration data no catalyst
- GC 266.4 177.6 200 yes 100
- GC 266.4 177.6 200 no 100
- GC 177.6 266.4 200 yes 100
- GC 177.6 266.4 200 no 100
- RGA O2 177.6 200 yes 100
- RGA O2 177.6 200 no 100
- GC O2 177.6 266.4 100 yes 100
- GC O2 177.6 266.4 100 no 100
- RGA O2 177.6 266.4 100 yes 100
- RGA O2 177.6 266.4 100 no 100
- GC 266.4 177.6 200 yes 100
- RGA CO 266.4 177.6 200 yes 100
- RGA CO 266.4 177.6 200 no 100

GC calibration data w/ catalyst
- GC 266.4 177.6 200 yes 100
- GC 266.4 177.6 200 no 100
- GC 177.6 266.4 200 yes 100
- GC 177.6 266.4 200 no 100
- RGA O2 177.6 200 yes 100
- RGA O2 177.6 200 no 100
- GC O2 177.6 266.4 100 yes 100
- GC O2 177.6 266.4 100 no 100
- RGA O2 177.6 266.4 100 yes 100
- RGA O2 177.6 266.4 100 no 100
- GC 266.4 177.6 200 yes 100
- RGA CO 266.4 177.6 200 yes 100
- RGA CO 266.4 177.6 200 no 100
- GC 177.6 266.4 200 yes 100
- GC 177.6 266.4 200 no 100
- RGA O2 177.6 266.4 100 yes 100
- RGA O2 177.6 266.4 100 no 100

**Energy per molecule (eV/molec)**

- Frequency (kHz)
- Energy per molecule (eV/molec)

**Counts**

- Pressure: 0.001 to 2 ATM
- Gas mixtures
- Variable voltage pulse shape
- Variable electrode geometry
- Variable gas temperatures

**Temperature Comparisons (°C)**

- Frequency (kHz)
- Energy per molecule (eV/molec)

**Catalyst Comparisons (TiO2)**

- Frequency (kHz)
- Energy per molecule (eV/molec)

**Flow Rate Comparisons (SCCM)**

- Frequency (kHz)
- Energy per molecule (eV/molec)

**Gas Mix Comparisons (%CO2, %CO, %Ar)**

- Frequency (kHz)
- Energy per molecule (eV/molec)

**Fixed Volume box**

- Reactor zone
- Gas exhaust to RGA
- Gas feed
- Quartz glass
- Pressure gauge

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