# Temperature Inhibition of Methane Conversion in DBD Plasma-Driven Systems

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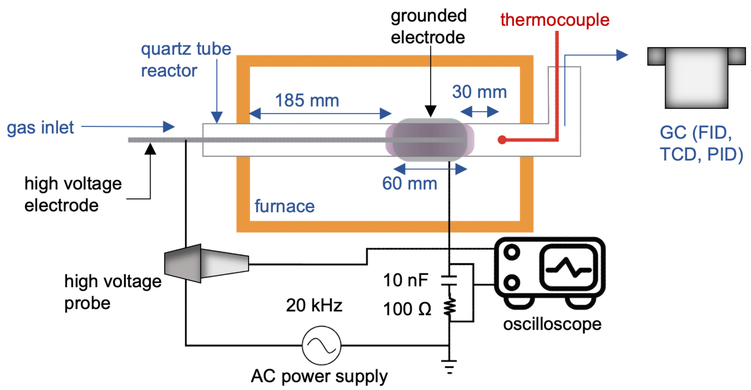
## Motivation

- Flaring of natural gas is a significant environmental and economic waste
- Non-thermal plasmas offer opportunity to react methane ($CH_4$) with nitrogen ($N_2$) on-site to form useful products


**Goal:**
**Understand how changing plasma reactor operating conditions affect plasma characteristics and reactions**

## Experimental Approach

- Cylindrical flow-through reactor with an integrated dielectric barrier discharge (DBD)
- Plasma characterized using electrical measurements
- Reaction products characterized using gas chromatography (GC)

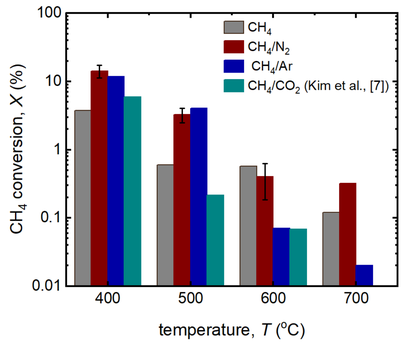


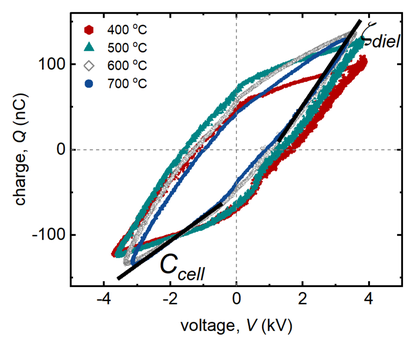

*Schematic of the reactor setup for electrical characterization of the plasma and product formation analysis*

**Reaction of interest:**

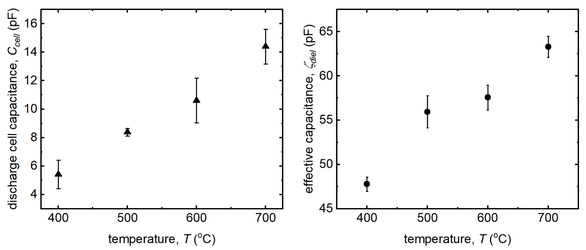
**$N_2 + CH_4 \rightarrow$ N-C Products**

## Results




- Increased temperature inhibits $CH_4$ conversion for DBD plasma-driven reactions
- Increased temperature also leads to anticlockwise rotation of Lissajous curve and change from typical parallelogram shape of DBD to almond shape

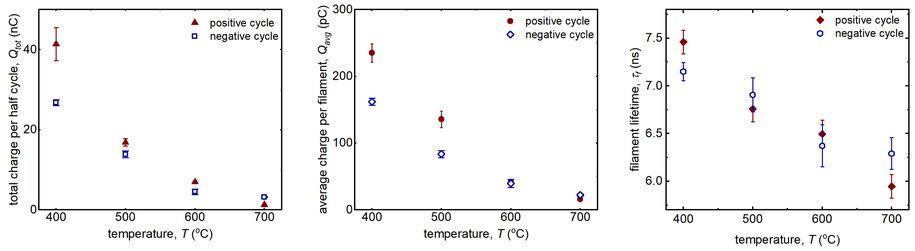



- Discharge cell ($C_{cell}$) and effective ($\zeta_{diel}$) capacitance both increase with temperature
- Increase in $C_{cell}$ much larger than attributable to temperature-dependent dielectric constant

- Total charge per half-cycle, average charge per filament, and filament lifetime have inverse relationship with increasing temperature
- Temperature-dependent change in DBD plasma mode from filamentary to diffuse could inhibit conversion

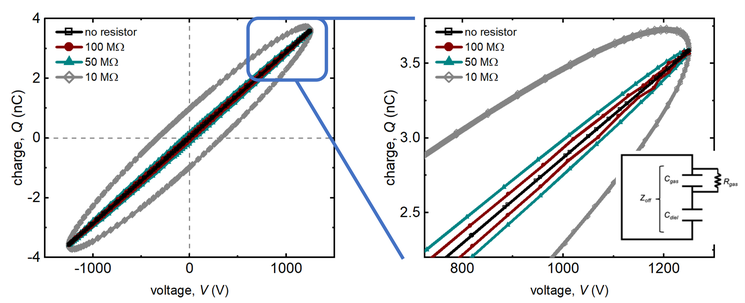
$$Q_{tot} = \sum_{i=1}^{N_f} \left[ \int_{t_{f,i}} I_i \, dt \right]_i \qquad Q_{avg} = \frac{Q_{tot}}{N_f}$$

$$\tau_f = \frac{\sum_{i=1}^{N_f} t_{f,i}}{N_f}$$

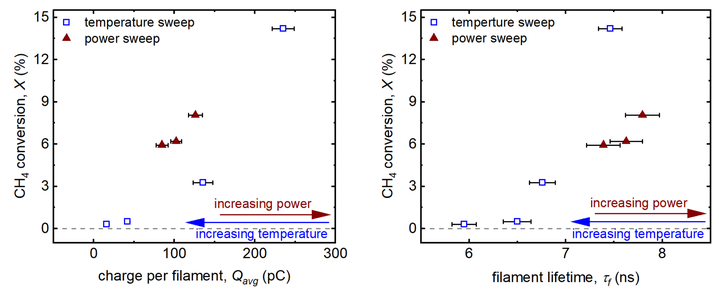



*Experimental conditions: 50 sccm flow rate (1-1 $N_2$/$CH_4$), 10 W power, 1 atm pressure*

## Results




- LTspice© simulations explain the observed Lissajous curve behaviors is likely due to an increase in conductivity of the gas prior to breakdown
- Positive correlation between average charge per filament and filament lifetime with conversion in both temperature and power sweep




**Reduced gas density at higher temperature likely leads to change to a diffuse plasma mode that could inhibit $CH_4$ conversion**

## Conclusions

- Increase in temperature leads to inhibition of $CH_4$ conversion in DBD reactor
- Pre-ionization of gas likely creates environment where $CH_4$ reactions with other species are inhibited
- Potential correlations between plasma characteristics and $CH_4$ conversion could guide operating design

## Acknowledgements

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