

Ignition and Extinction Voltages of a Low Pressure Capacitively Coupled Plasma of Air

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April 25, 2016

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Quick Introduction to Plasmas

What is a Plasma?

"A plasma is a quasineutral gas of charged and neutral particles which exhibits collective behavior"¹

- Frequently referred to as fourth state of matter
- Consists of (singly or more) ionized nuclei and electrons



Figure 1: Glow Discharge

¹Francis F. Chen. *Introduction to plasma physics and controlled fusion*.
2nd ed. Vol. 1. Springer, 1984, p. 2. ISBN: 978-1-4419-3201-3. DOI:
10.1007/978-1-4757-5595-4.

Why Study Plasmas?

Plasmas are the most abundant type of normal matter in the universe and are present in stars, galaxies, and interstellar media

- Theory – Meeting of fluid dynamics and electrodynamics
- Industry – Numerous uses including materials processing
- Exploration – Space travel and satellites

Our Experiment

Experimental Setup

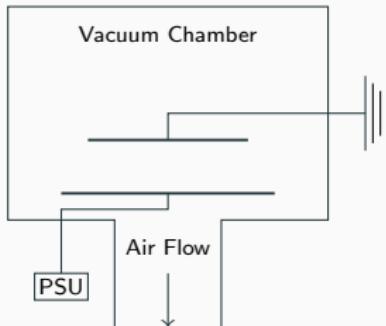
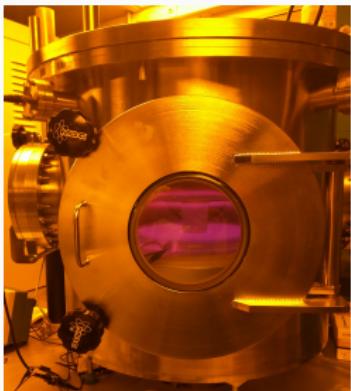
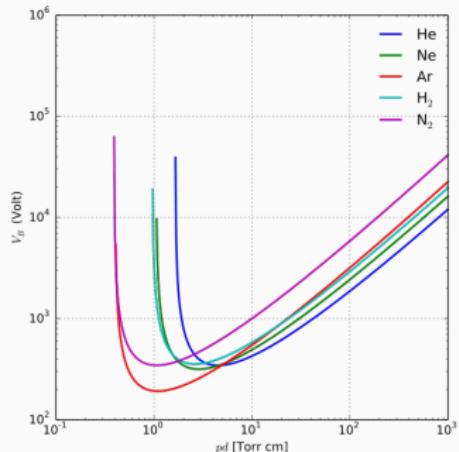


Figure 2: Plasma Chamber Image and Diagram

- Vacuum chamber at vacuum on order of 10^{-1} Torr
- Two “capacitor” plates connected to 13.56 MHz power supply
- Probe to measure voltage between two plates
- Manually recorded statistical uncertainties by max deviation from mean within interval

Expected Results



Expect breakdown (ignition) voltage to follow Paschen's Law:

$$V_B = \frac{Bpd}{\ln(Apd) - \ln[\ln(1 + \gamma_{se}^{-1})]} \quad (1)$$

Figure 3: Paschen's Curves
for Various Gases³

³Wikimedia Commons. *Paschen curves*. 2014. URL:
https://commons.wikimedia.org/wiki/File:Paschen_curves.svg

Results

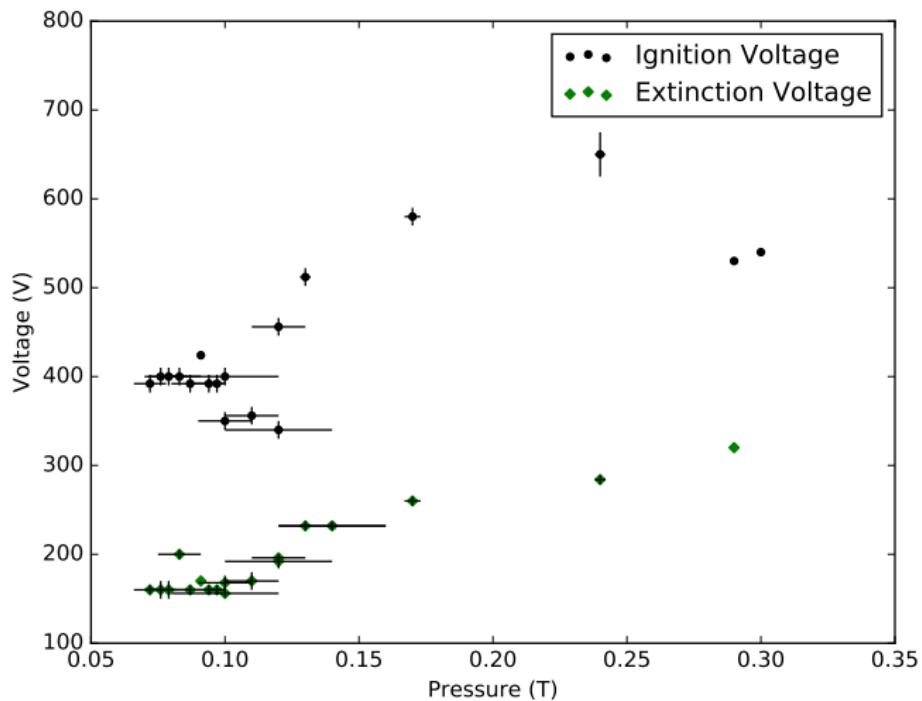


Figure 4: Obtained Ignition and Extinction Voltages

Results

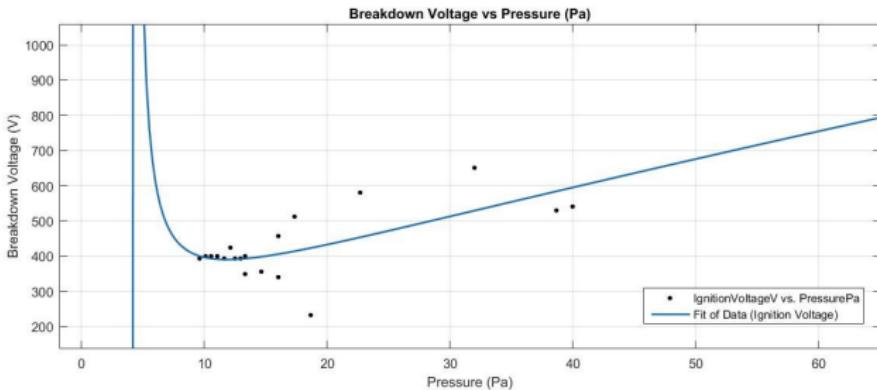


Figure 5: Obtained Fit

Results

Results suggestive of success in testing Paschen's Law, but not conclusive.

- Line of fit similar to known Paschen Curves.
- Attempted fit: $f(x) = \frac{Bx}{\log(Ax) - C}$

Coefficient	Experimental Value	Fit Value	Uncertainty
A	0.221	0.311	$\pm 5.61 \times 10^6$
B	48.7	32.9	± 23.5
C	0.223	0.301	$\pm 1.80 \times 10^7$

- Goodness-of-fit measurement: $(\frac{\chi^2}{\nu}) \approx 0.37$

Discussion

Results suggestive of success in testing Paschen's Law, but not conclusive.

- $\alpha = \frac{1}{\lambda}$ applicable approximation
- Conducted most testing in "risky" region (< 1 Torr)
- Inhomogeneous electric field (plate size, inconsistent dielectric).

Future Improvements

- Use same size electrode
- Use one sort of dielectric (hang top electrode)
- Increase pressure range
- Improve statistical uncertainties by automated data acquisition
- Explore inductively coupled plasmas