Nitric oxide (NO) and temperature measurements in plasma-assisted NH_3 combustion

Background:

Industrial processes and manufacturing significantly contribute to greenhouse gas emissions, with 25% of CO_2 eq. emissions worldwide attributed to these sectors. While solutions leveraging decarbonized electricity are already in application, certain high-temperature industries (steel, glass, cement) and long-distance transportation, cannot readily replace hydrocarbon fuels by electricity. In the pursuit of decarbonization, alternative fuels like ammonia (NH_3) are being explored. NH_3 is energetically dense and its combustion does not produce CO_2, as shown below:

$$2\ NH_3 + 3/2\ O_2 \rightarrow 3\ H_2O + N_2$$

However, certain combustion regimes can lead to the formation of harmful pollutants for the environment and health: NH_3 (health), NO (health), and N_2O (greenhouse effect). NH_3 flames are also more prone to extinction than their hydrocarbon counterpart. Therefore, ammonia combustion poses challenges that require the use of a combustion promoter. The objective of this project is to solve these issues by employing Nanosecond Repetitively Pulsed (NRP) electrical discharges.

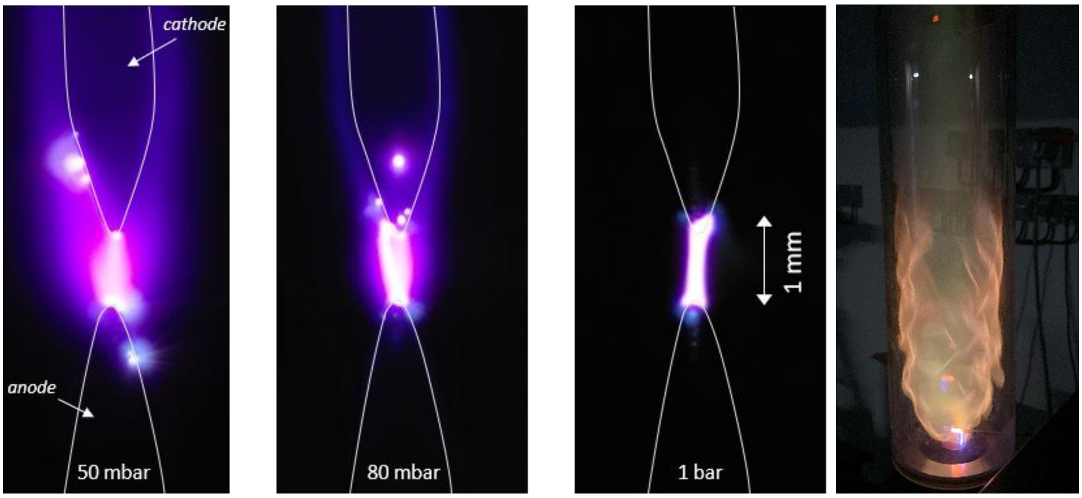

Figure 1 (Left) Transition from a "non-equilibrium spark" discharge at 50 mbar to a "thermal spark" discharge at 1 bar [5] ***(Right) NRP discharges applied in an NH_3 flame.***

Typical NRP discharges last 10 ns and are generated by voltage pulses of 10-30 kV at repetition rates of 10 to 100 kHz. Depending on the applied voltage and initial gas conditions, these NRP discharges can be formed in several regimes, see Figure 1. In hydrocarbon flames, these NRP discharges have been successfully used to stabilize flames of various carbon-based fuels up to powers of about 100 kW [1], [2]. Some studies have also demonstrated the possibility of reducing NO emissions [1]. However, these studies mainly focus on carbon-based fuels, and very few have addressed plasma-assisted combustion of NH_3 flames. Some promising results demonstrated NO_x reductions in NH_3 flames exhaust using NRP discharge [3], [4] but the underlying mechanism behind this reduction remains unexplained. Thus, the motivation of this internship is to elucidate the mechanism responsible for this reduction by performing quantitative measurements in a plasma-assisted flame, thereby bridging the knowledge gap and paving the way for further NOx emission reductions. The specific goal of this internship is to investigate this phenomenon through NO measurements in the plasma-assisted NH_3 burner at EM2C, utilizing Laser Absorption Spectroscopy (LAS) to quantify and map the 3D distribution of species and temperature in the burner.

Objective: The objective of this internship is to design a Laser Absorption Spectroscopy (LAS) system for simultaneous measurements of NO and temperature.

Task Description: The intern will be responsible for:

1. Literature review: Conduct a thorough review of existing LAS techniques for NO and temperature measurements in burners. The temperature measurements will be performed via an existing setup of H_2O laser absorption spectroscopy.
2. Sensor design: Design and develop a LAS sensor package capable of measuring NO and temperature in ammonia combustion environments.
3. Data analysis: Analyze the data obtained from the LAS measurements and draw conclusions about the combustion process, focusing on NO emissions, as well as temperature profiles. If time allows, the impact of the discharge regime will also be investigated.

Candidate profile:

We are seeking a candidate pursuing a Master's degree in a relevant field, such as plasma, combustion, or engineering. While not mandatory, knowledge of spectroscopy, combustion, and optical instrumentation would be a plus. Proficiency in programming languages like MATLAB or Python is also a desirable asset.

Organization:

The student will work within the plasma group at the EM2C laboratory, CentraleSupélec, primarily under the supervision of Nicolas Minesi and Sébastien Ducruix. The internship salary is ~1700€ gross (SMIC brut). The internship, initially set for 5 months, holds the potential for extension into a thesis. For more information, contact nicolas.minesi@centralesupelec.fr

Bibliography:

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