# CAE-Based Design and Optimization of a Plasma Reactor for Hydrocarbon Processing

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## Introduction

Plasma reactors can be applied to the conversion of waste, biomass and fuel to synthesis gas ($H_2$ + $CO_2$) with efficiencies as higher as 90-95% and low energy demand.

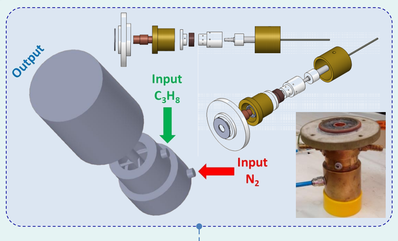
**Design optimization**

Fluid flow, chemical reactions and electromagnetic field at the electrode dictate the system stability.

**Objective**

Apply a multi-step approach for the investigation of the main physics involved in a rotating gliding arc (RGA) discharge reactor used for hydrocarbon processing.

## Method

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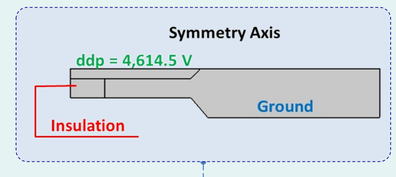
Flow field

$$\rho(\mathbf{u}\cdot\nabla)\mathbf{u} = \nabla\cdot\left[-p\mathbf{I} + \mu\left(\nabla\mathbf{u} + \nabla\mathbf{u}^T\right) - \frac{2}{3}\mu(\nabla\cdot\mathbf{u})\mathbf{I}\right] + \mathbf{F}$$
$$\nabla\cdot(\rho\mathbf{u}) = 0$$




Electrostatics

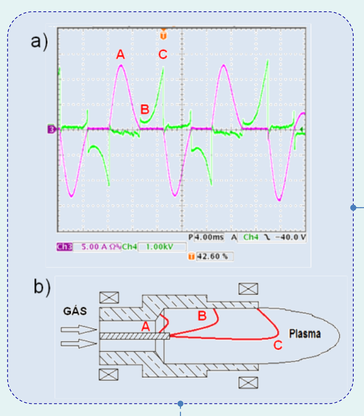
$$E = -\nabla V$$
$$\nabla\cdot(\varepsilon_0\varepsilon_r\mathbf{E}) = \rho_v$$

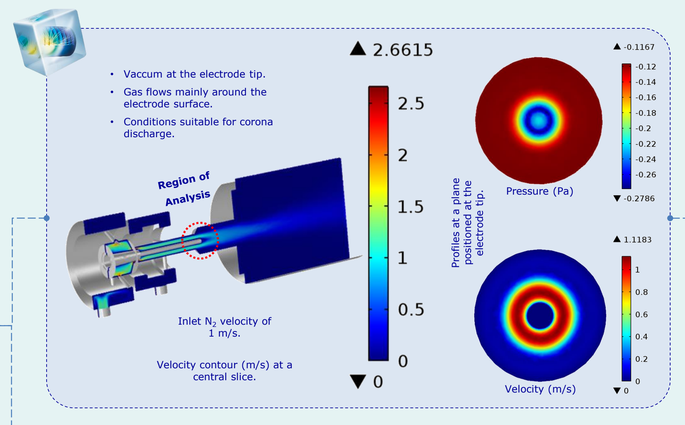
Chemical Equilibrium with Applications → Chemical composition of $N_2$ at the electrode region.

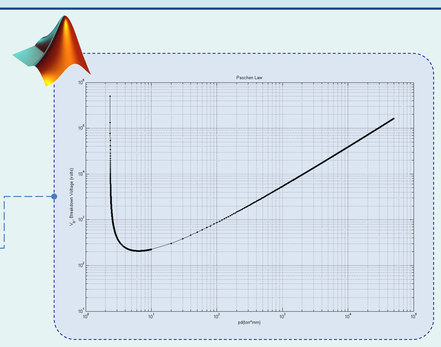
Home-made code (Pashen's and Peek's law) → Breakdown voltage at the electrode as a function of pressure and gap length.

## Results

Transitory discharge (thermal/non-thermal plasma). High electron density and energy at moderate temperature. Once the discharge is ignited, it moves pushed by the flowing gas. The movement of the arc increase the voltage demanded to sustain the process. The maximum voltage required corresponds to the breakdown value.

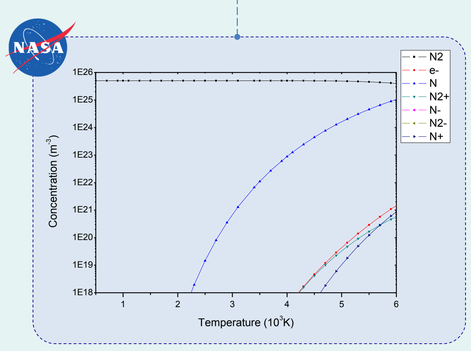


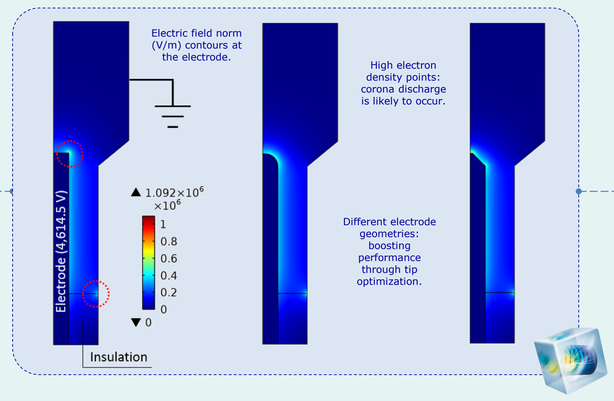



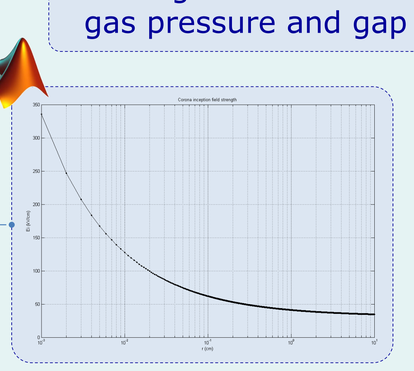

Pashen's law allows the prediction of the breakdown voltage as a function of the gas pressure and gap length.

The pressure and electric fields are predicted through COMSOL simulations. This is the core of our workflow.




NASA's CEA allow the prediction of $N_2$ composition at the thermal region.




An enhanced electric field develops at the electrode tip depending on the geometry. Peek's law allows the prediction of corona discharge.

## Conclusions

Rotating gliding arc (RGA) reactors can be efficiently used for chemical reactions aiming hydrocarbon reforming for syngas production.

A complex interation of different physics dictates the performance of the equipment.

CAE tools can be used for design and optimization.

We have used a workflow, with COMSOL Multiphysics at the core, for phenomenological understanding and application design of RGA reactors.

This procedure will help us to translate the technology developed at laboratory bench scale to real field applications.

## References

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