“Fundamental Mechanisms, Predictive Modeling, and Novel Aerospace Applications of Plasma Assisted Combustion -*Laminar Flow Reactor and Nanoparticle Studies at Low to Intermediate Temperatures:* “

Program Overview

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MURI Kick-Off Meeting
The Ohio State University
Columbus, OH

November 4, 2009

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **04 NOV 2009**	2. REPORT TYPE	3. DATES COVERED **00-00-2009 to 00-00-2009**
4. TITLE AND SUBTITLE **Program Overview**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Pennsylvania State University,Department of Mechanical and Nuclear Engineering,University Park,PA,16802**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES **U.S. Government or Federal Rights License**		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**14**	

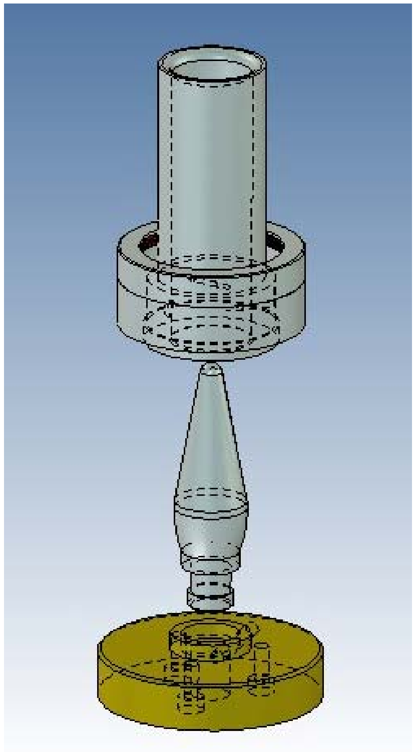
Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Examples of Combustion enhancement using rotating arc

Advantage of rotating arc

- Non-thermal plasma with relatively high temperature
- 3D expansion of 2D Glid arc
- Reduction of thermal damage
- Increased plasma volume coverage
- Applicable at High pressure

N_2 plasma rotating arc



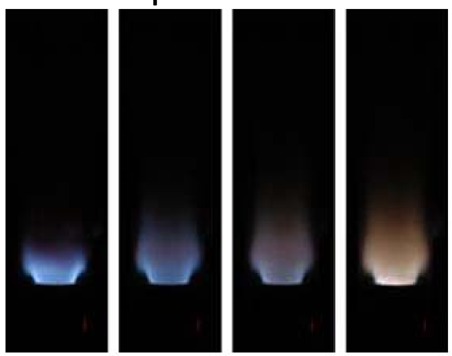
Rotating arc generator

Examples of Combustion enhancement using rotating arc

(Premixed methane/air flame)

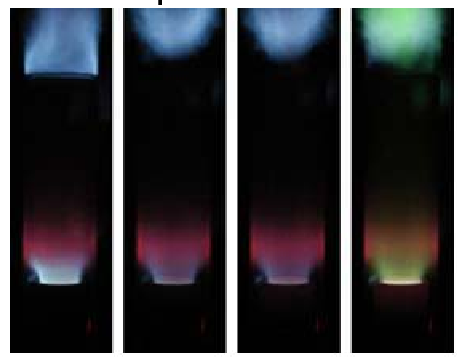
Type I

ϕ = 0.57



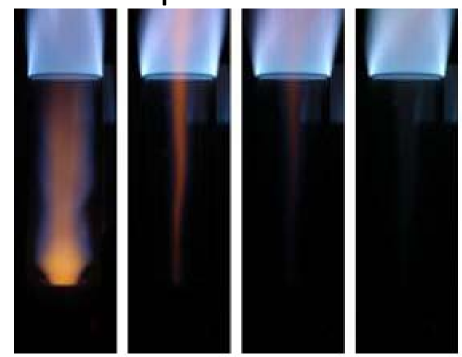
Increase of input power

ϕ = 1.27



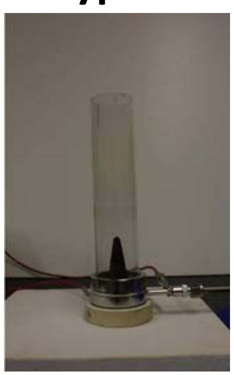
Increase of input power

ϕ = 1.87

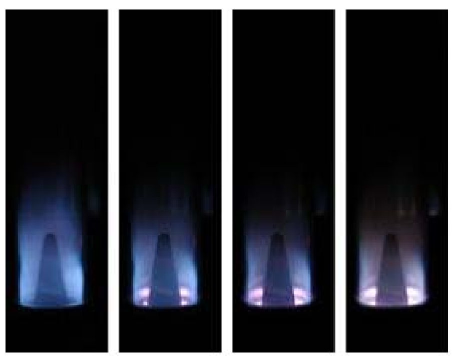


Increase of input power

Type 2

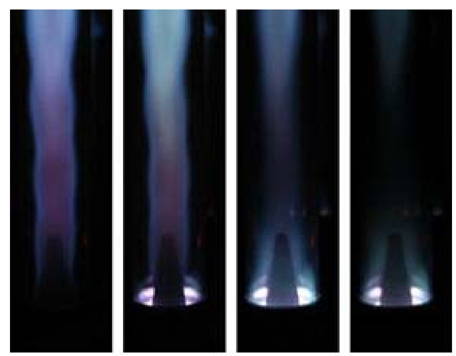


ϕ = 0.77



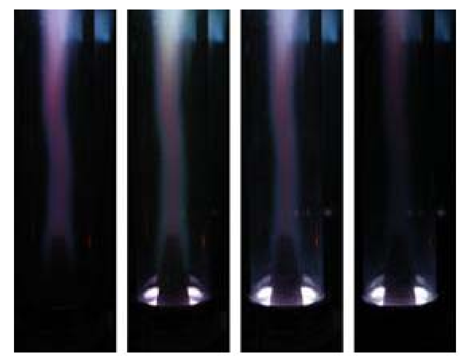
Increase of input power

ϕ = 1.27



Increase of input power

ϕ = 1.87



Increase of input power

Main tasks

1. *Reaction Kinetics studies* **with spatially controlled Plasma Discharges**

2. *Effect of nanoparticle* **coupling with plasma enhanced combustion in flow reactors and flames**

Objectives

-Development and validation of detailed ***low-temperature plasma fuel oxidation and ignition mechanisms***, including surrogate fuels

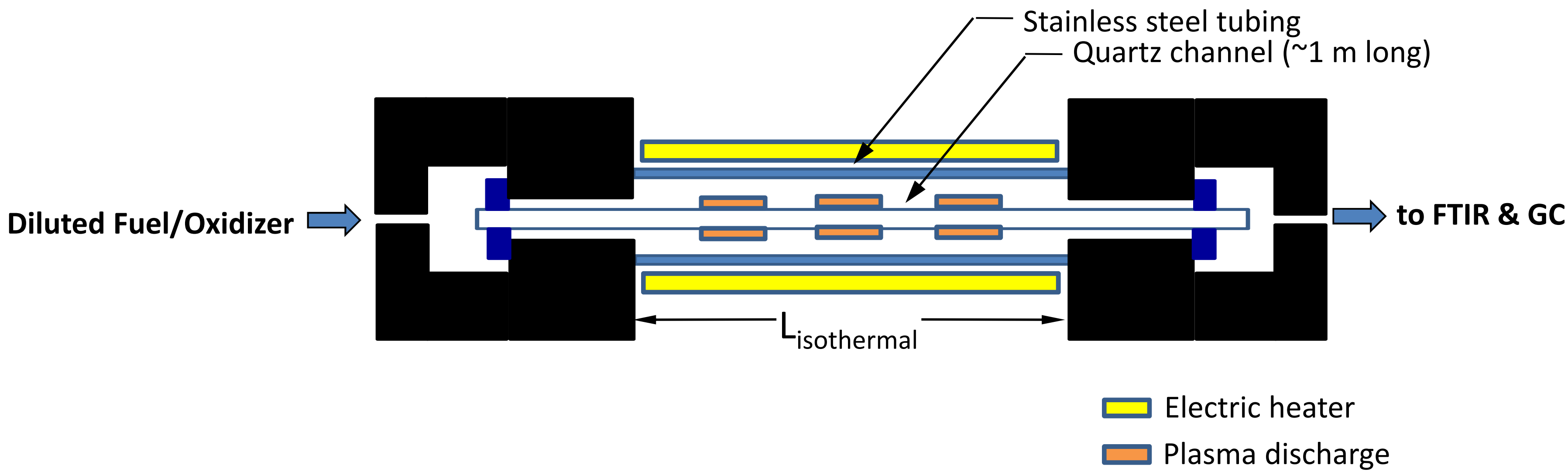
-Development of ***reduced plasma chemical fuel oxidation, ignition, and flameholding mechanisms*** which can readily be incorporated into predictive multi-dimensional reacting flow codes

-Identification of ***specific processes critical to the enhancement of basic combustion phenomena*** by nonequilibrium plasmas, in particular processes involving radical and/or excited metastable species.

Reaction Kinetics studies with spatially controlled Plasma Discharges

Approach

- Construct a ***laminar flow reactor*** for operation between a pressure range of 0.5 and 10 bar and a temperature range of ambient to 1000 K.
- Perform ***dilute hydrocarbon oxidation experiments*** in excess nitrogen or other diluents to minimize exothermicity of reaction and stretch the reaction spatially over a significant length.
- ***Perturb the reaction at different extents of reaction*** with a spatially defined plasma discharge.
- Measure ***temperature and product species*** by sample extraction and GC/FTIR analysis.
- Perform ***kinetic modeling of the reaction kinetics*** with sensitivity and Green's function analysis ($\partial Y_i(x)/\partial Y_j(x')$).



Schematic drawing of laminar (plug) flow reactor

-Operating temperature: up to 1000 K

-Operating pressure: 0.5 to 10 atm

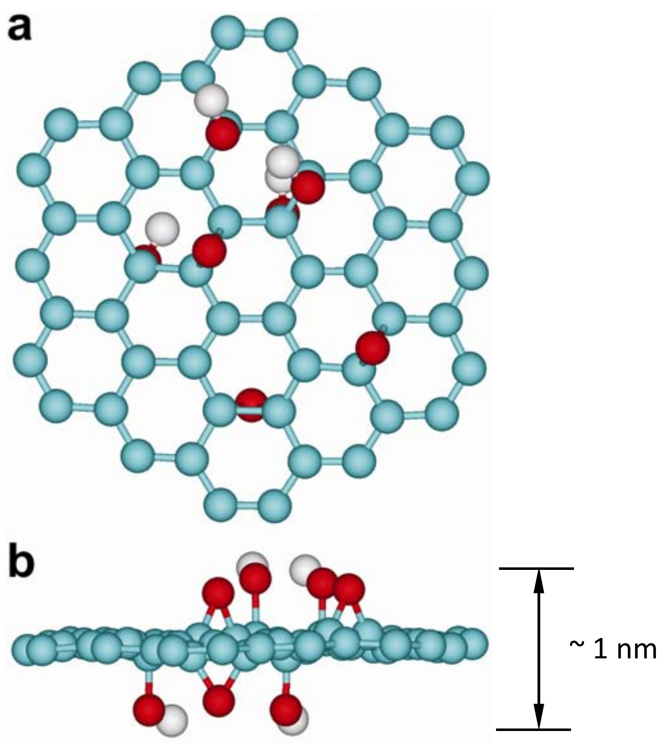
$$Residence\ time,\ \tau = \frac{V}{Q} = \frac{\left(\pi r^2 L_{isothermal}\right)}{Q_S\left(\frac{T}{273.15}\frac{1}{P}\right)}$$

Effect of nanoparticle coupling with plasma enhanced combustion in flow reactors and flames

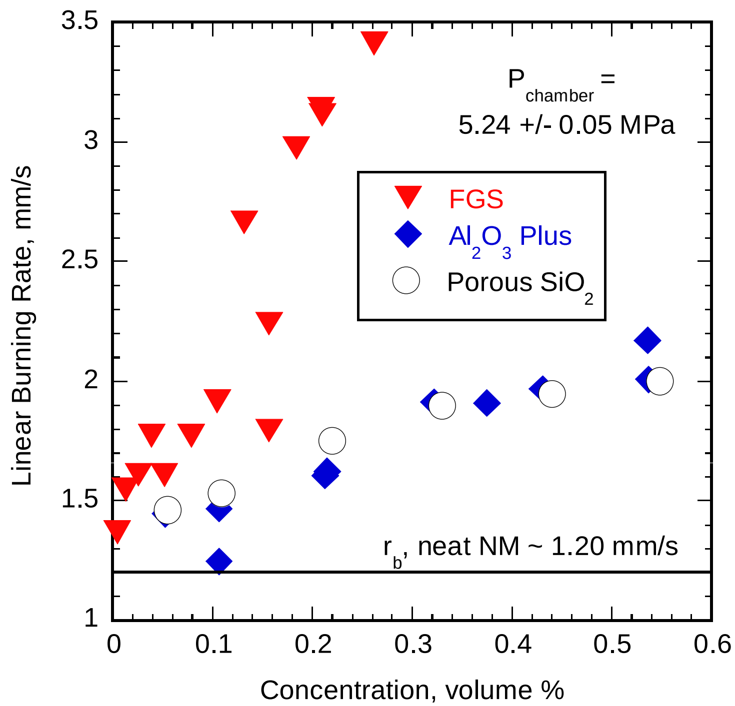
Motivation

- Nano-particles are known to be ionized more easily than molecules and atoms (due to lower ionization potential)
- MD simulation shows that strong (~10^7 V/cm) electric field is inherently self-generated in nano aluminum nano-particles at high temperature (~1100 K), providing a strong driving force for ion transport
- Nano-particles are chemically and catalytically active in plasma
- Functionalized nano-particles may enhance the effectiveness of plasma

Functionalized graphene sheet colloids enhance fuel combustion!



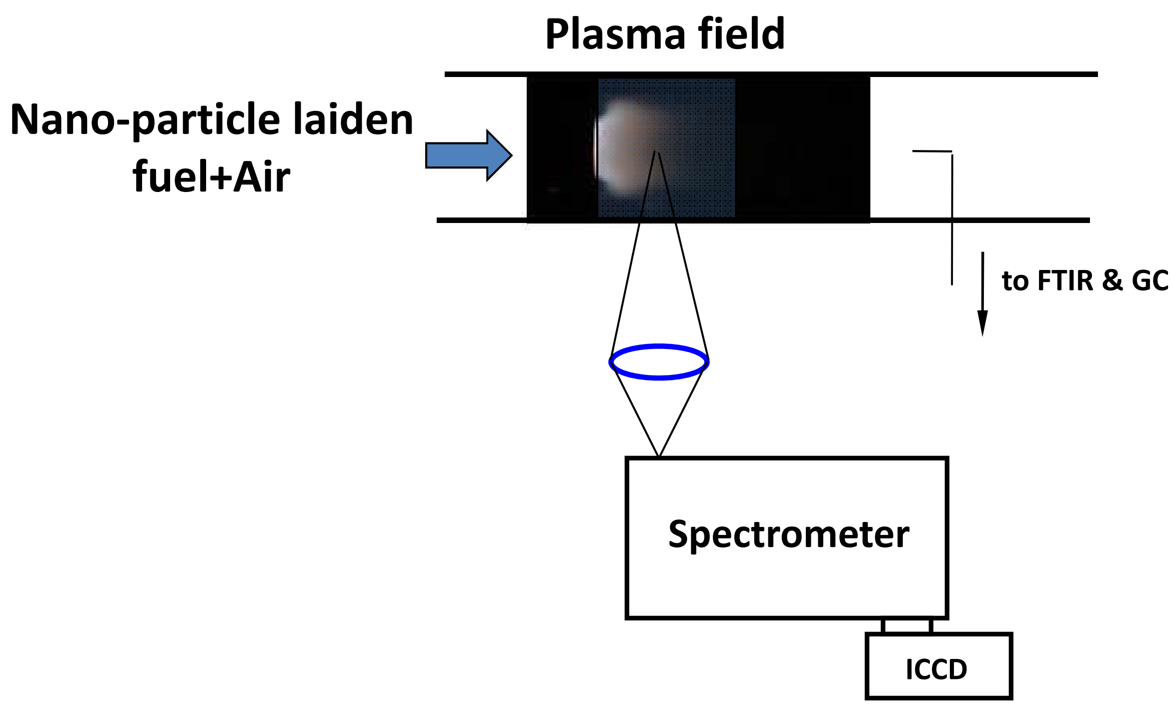
(a) An overhead view and (b) edge-on view of a functionalized graphene sheet



Linear burning rate of nitromethane and catalyst support additive mixtures as a function of volume concentration

Approach

- Studies will be conducted to investigate ***the effects of nanoparticles on the plasma characteristics and reaction kinetics***, e.g., lowering the energy for breakdown and provide significant surface area for surface charge and kinetic interactions.
- Particles will be selected that increase the electron density, act as catalysts, and contain significant additional energy content.
- Various ***metallic and nonmetallic nanoparticles*** (e.g., aluminum, iron, graphene, composite thermites) will be studied.
- The nanoparticles will be entrained into the carrier gas flow through passage of the carrier gas through an electrostatic levitation chamber prior to entering the reactor. For liquids, a nebulizer will be used to create a fine aerosol. Volume fractions of the nanoparticles will be maintained to less than 0.1%.
- Experiments will be conducted ***in flow reactors and flames***.



Schematic drawing of a setup laminar flow reactor to investigate the effect of nano-particle coupling with plasma enhanced combustion in flames

Thank you!