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Title: Plasma chemistry of water and other liquids

Project #1

PI: Gregory Fridman

Budget: $40,000/year

Duration: 2 years

NEED AND RELEVANCE

Medical, food processing, and AG industries require high volume of plasma treatment of liquids at low energy cost. These treatments also frequently occur in presence of high organic load, hindering the oxidation-based inactivation mechanisms.

GOALS

- Develop water treatment and droplet cluster formation system for surface treatment, disinfection, and drying.
- Understand mechanism of droplet/cluster formation and plasma interaction with these droplets and clusters.
- Understand mechanisms of oxidative and non-oxidative disinfection in presence of organic load and transition between them.

APPROACH

Tune plasma parameters and plasma temperature to optimize existing systems, analyze water chemistry and cluster/droplet formation dynamics. Apply different plasma parameters and analyze their effect on disinfection of various organisms of interest in medicine, food processing, and AG industries: *E.coli*, *Salmonella*, and *Listeria*.

OUTCOMES AND DELIVERABLES

- High volume flowing liquid treatment system and water mist treatment system with high yield of disinfectant.
- Mechanistic understanding of non-oxidative disinfection in presence of organic load.
- Mechanistic understanding of oxidative disinfection.
- Proposed approach for scale-up of DBD-based misting system and GlidArc-based high-throughput system.

Waste-to-Energy and Water Treatment: Scaling Up to Industrial Size Gliding Arc Plasma

Project #2

PI: Alexander Rabinovich

Budget: $40,000

Duration: 1 year

NEED AND RELEVANCE

Non-equilibrium gliding arcs in reverse vortex (Tornado) flow (GAT) at low power level (1-3kW) are proved to be a highly efficient plasma stimulators of several plasma chemical and plasma catalytic processes, including hydrogen/syngas generation from municipal wastes, biomass, coal and organic wastes, exhaust gas cleaning, fuel desulfurization and water treatment. Large scale application and commercialization of this technology require scaling-up of the non-equilibrium GA to a power of at least 300kW, which corresponds to H2/syngas production on the power level up to 30MW.

GOALS

Effective non equilibrium operation of GAT requires cold secondary electron emission mechanism of providing electrons to the gliding non equilibrium arc channel. Non equilibrium GAT regime is limited by transition from cold secondary electron emission to hot and highly erosive thermionic emission taking place at elevated currents and powers. Identification of maximum current level (and related levels of plasma power) preventing transition to thermionic emission at different arc motion modes is a major scientific goal of the project.Further increase of GAT power can be provided by increase of voltage and special multistage configuration of GAT reactor. Identification of optimal schemes of combining single plasma units into complex GAT plasma configurations without losing required level of plasma non equilibrium is a major engineering goal of the project.

APPROACH

Measurement of V-I characteristics, electrodes erosion, inner electrodes temperature

Analysis of different scale-up schemes; reverse vortex and series connection

OUTCOMES AND DELIVERABLES

Identification of maximum current level (and related levels of plasma power) preventing transition to thermionic emission at different arc motion modes.

Identification of optimal schemes of combining single plasma units into complex GAT plasma configurations without losing the required level of plasma non equilibrium

Title: Planar plasma jet: characterization, diagnostics and surface interaction

Project #3

PI: Danil Dobrynin

Budget: 120K

Duration: 3 years

NEED AND RELEVANCE

In this project, a new planar He plasma jet will be characterized. Uniformity of the jet, reactive chemistry in the gas phase and delivery of reactive species into a liquid sample will be studied for future evaluation of possible applications of this discharge in the areas of surface treatment and especially plasma medicine.

GOALS

Quantitative characterization of planar He plasma jet uniformity and reactive chemistry

- imaging of the discharge dynamics and development and quantification of plasma uniformity
- measurements of electric fields inside the plasma chamber, during propagation and at the treated surface
- spatially resolved spectroscopy to determine plasma characteristics (temperature)
- spatially resolved measurements of OH generation in gas phase and its delivery into liquid (OH and H_2O_2)

APPROACH

In order to achieve the goals of the project, the following techniques will be utilized:

- fast imaging using 4Picos ICCD camera with gating down to 0.2 ns synchronized with the power supply for time-resolved imaging of the jet development and propagation;
- high-resolution optical emission and absorption spectroscopy using imaging spectrometer
- liquid phase absorption spectroscopy and possibly fluorescence spectroscopy.

OUTCOMES AND DELIVERABLES

The outcomes of the project will provide understanding of the mechanisms of the planar He plasma jet development, propagation and interaction with a surface. Data on the jet uniformity and plasma chemistry in gas and liquid phase as a function of time (jet propagation), as well as electric field dynamics will be provided at the end of the project.

Title: Adaptive Plasmas

Project #4

PI: Michael Keidar, Taeyoung Lee

Budget: $45k/year

Duration: 3 years

NEED AND RELEVANCE

Medical applications of plasmas require understanding mechanism of plasma action and higher control over plasma application

GOALS

To develop novel adaptive plasma devices and to understand the mechanism of plasma interaction with cells and tissue

APPROACH

Develop new in situ diagnostics, model predictive control, feedback mechanisms

OUTCOMES AND DELIVERABLES

New adaptive plasma devices

Title: Plasma Simulation Validation

Project #5

PI: Carles Corbella, Michael Keidar

Budget: $45k/year

Duration: 2 years

NEED AND RELEVANCE

validation of new codes for high-pressure plasma processing, nanoparticle synthesis

GOALS

Development of plasma diagnostics for code validation

APPROACH

Develop new diagnostics, validation

OUTCOMES AND DELIVERABLES

Diagnostics for relevant plasma system, code validation

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Title: Discharge Initiation

Project #6

PI: Michael Keidar, Irina Schweigert

Budget: $45k/year

Duration: 2 years

NEED AND RELEVANCE

Simulation of discharge initiation is needed to understand the mechanism and to develop approaches to control the process

GOALS

To develop understanding of the mechanism of discharge initiation and approaches to control it

APPROACH

Develop new kinetic code, hypothesis and validation

OUTCOMES AND DELIVERABLES

Code validation, mechanisms and control approaches

Title: Adjustable pH plasma based water purification system

Project #7

PI: John Foster

Budget: $100k

Duration: 1yr

NEED AND RELEVANCE

There is a general need for a water purification technology that can also provide water conditioning such as pH adjustment. It has been shown that the pH of the water can greatly affect the biological response in agriculture applications as well as for drinking water. Anecdotally high pH waters have been touted as a means to boost the human immune system. Plasmas offer the prospect of not only removing contaminants of emerging concern but also adjusting the pH.

GOALS

Based of prior Suprawater research we will study a plasma reactor geometry that has shown promise for not only cleaning the water but also adjusting its pH. We will study the operating mechanisms of the device to better understand the underlying plasma induced chemistry and then use this knowledge to optimize the system.

APPROACH

Our starting point is the Suprawater device. We will fabricate the device in stages to understand underlying operating principles and then study its operating characteristics of the complete system using fast scopes and chemical probes.

OUTCOMES AND DELIVERABLES

Chief deliverable of this task is an operating reactor along with test data and documentation describing operation based on experimental investigations.

Title: Efficacy of Plasma Removal of Oil Molecules in Water

Project #8

PI: John Foster / Mark J. Kushner

Budget: $100k

Duration: 1 year

NEED AND RELEVANCE

In many chemical processing plants, there is a need to recycle water owing to the overall expense of delivery and pretreatment of new freshwater. Additionally, recycling also reduces the disposal cost of processed water (post treatment and ultimate sewer delivery). Plasma based water treatment technology features advanced oxidation of organics in solution without the need for consumables. It is possible that plasma treatment can address suspended oils and fats in water. Testing of water that has been collected and shipped can change properties from the original collected source. Actual testing at the water source will provide a more accurate determination of the treatment required at that source.

GOALS

The goal of this effort is to investigate the efficacy of plasma water purification systems for the removal of oils and fatty molecules in process water in batch and once through configurations. Two sources of water will be evaluated. First will be process cleaning water which will also contain microbials in addition to other hydrocarbons, the need to be eliminated and the second will be in process generated water that contains mostly oils and fatty molecules. Additional effort will be to evaluate a design for a road mobile testing unit capable of 10,000 gallons per day that can be used to gather real time data at water sources.

APPROACH

The general approach is to use ECCL Aerospace Services test samples as the feed water for two water reactors: the dielectric barrier discharge (DBD) underwater plasma jet and the packed bed water reactor. We will analyze water before and after processing using liquid chromatography and chemical oxygen demand (COD) methods. We will determine the evolution of the concentration of oils in solution as a function of treatment time. The goal is to optimize the reactors in both batch and once-thru mode to determine which approach is most effective. .Modeling of both systems will be used to help determine reaction mechanisms and methods to optimize the reactors. We will also use global modeling to predict decomposition rates to investigate the decomposition mechanism. Multi-dimensional modeling will be used to determine the plasma dose delivered. We will also investigate plasma induced precipitation and subsequent filtering as an alternative pathway for cleaning the water for recycling.

OUTCOMES AND DELIVERABLES

The chief deliverables from this effort are test data and modeling results. We will document the decomposition efficiency of both reactors to assess power requirements. We will also provide data on reactor effectiveness as a function of organic load.

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Title: Addressing impedance matching and noise generation in pulsed power plasma reactors

Project #9

PI: John Foster/ Mark Kushner

Budget: $100k

Duration: 1yr

NEED AND RELEVANCE

The basis of many of the atmospheric pressure water treatment systems is the pulsed power modulator. The modulator delivers power to electrodes using fast rise time, high voltage pulse which are repetitively applied to the load at rates up to a few hundred kilohertz. These technologies enable 1 atm plasmas since the fast rise time circumvents the development of an arc discharge. While this technology is enabling for large scale water systems, there are two issues associated with its implementation that is problematic: 1) impedance matching to load and 2) noise. For any realistic system, the delivered power fraction to the load must be reasonable high and the associated noise must be manageable to the point that it does not interfere with other equipment operation.

GOALS

The goal of this effort is to 1) optimize EHT power delivery to the plasma load to improve overall system efficiency and 2) to develop a transmission line methodology and shielding that prevents electromagnetic pulse effects from adversely affecting nearby equipment. Additionally, the goal is to model the pulse shape and understand its effect on delivered power to the load.

APPROACH

The general approach is to utilize an EHT supplied power supply with two plasma water reactors and study the power delivered to the load. We will analyze the waveform and also assess using plasma diagnostics the actual power delivered to the plasma. Plasma modeling tools will be used to assess the nature of power delivery to the plasma for the two reactor geometries to complement the experiments as well as enable optimization. We will utilized EMI best practice approaches to reduce noise associated with the reactor to acceptable levels.

OUTCOMES AND DELIVERABLES

The chief deliverables from this effort is test data. We will show the sensitivity of delivered power for each reactor as a function of waveform. We will also correlate delivered power to decomposition efficiency of model compounds. We will also document the results of the EMI reduction tests and recommend best practices for the EHT system. These results should be useful to the greater community that utilizes this power supply system regardless of the environmental application.

Title: **Water Treatment and Waste-to-Energy Conversion by Plasma and Nanoparticles synergetic action on pollutant in water**

Project # 10

PI: Anatoly Maltsev

Budget: $100,000.00

Duration: 24 months

NEED AND RELEVANCE

Wastewater deep and cost-effective treatment from toxic inorganic pollutant (like heavy metal ions, arsenic, fluoride, etc.) and/or high concentrated organics (like landfill leachate), as well as waste-to-energy conversion by such a treatment process (for the process operation cost decreasing or even net energy production) need new approaches to solve existing technological problems (high cost and low effectiveness) in these niches of market with a huge volume.

GOALS

Development of effective and low-cost technologies for wastewater treatment and waste-to energy conversion to decrease operational cost of wastewater treatment or even to generate net energy by such a process.

APPROACH

Heavy hydrocarbons and other organics direct destruction by hard electrons using Atmospheric Discharge with Runaway Electrons (ADRE of corona, DB, or gliding types); Atmospheric plasma and nanoparticles (generated inside water) synergetic action on pollutant with plasma-chemical byproducts sorption on surface of nanoparticles and following coagulation of these nanoparticles for its removing by treated water ultra-filtration.

OUTCOMES AND DELIVERABLES

The results of study of atmospheric plasma (ADRE, and some other types) and nanoparticles (generated by plasma) synergetic action on toxic ions (heavy metal ions, arsenic, fluoride, etc.) in water with chelating agents or with high concentration of some of organics (like in landfill leachate).

New technologies description and evaluation for above mentioned toxic ions/organics deep and low-cost removing from wastewater, as well as for effective waste-to energy conversion by use of ADRE or other atmospheric plasma.