Fundamental Studies of transient, atmospheric-pressure, small-scale plasmas

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01/23/2017
Final Report

DISTRIBUTION A: Distribution approved for public release.
14. ABSTRACT
Fundamental studies of nanosecond pulsed atmospheric pressure plasmas including a millimeter He-O₂ plasma jet, generated with a concentric tubular electrode configuration, and micrometer He plasma jet, generated with a single electrode, were conducted. These studies include 1) temporally and spatially resolved measurements of atomic oxygen ground state (O(3P)) in the 2-cm long, 1-mm He-O₂ plasma jets using Two-Photon Absorption Laser Induced Fluorescence (TALIF); 2) plasma dynamics and emission spectroscopic comparisons of single-electrode helium microplasma jets that was excited with 5 ns or 164 ns, 8 kV pulses at 500 Hz. Applications of the atmospheric pressure plasma jets and jet arrays (e.g. plasma brush) were explored for surface decontamination against pathogenic bacteria and biofilms, as well as for treatment of cervical cancer, in vitro. Other studies involving portable nanosecond pulsed power generation based gas switches or photoconductive solid state switches, non-equilibrium surface plasma chemistry and applications were also conducted.
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Abstract:
Fundamental studies of nanosecond pulsed atmospheric pressure plasmas including a millimeter He-O₂ plasma jet, generated with a concentric tubular electrode configuration, and micrometer He plasma jet, generated with a single electrode, were conducted. 1) Temporal development and spatial distribution of atomic oxygen ground state (O⁢[^{3}P]) in the 2-cm long, 1-mm He-O₂ plasma jets were measured using Two-Photon Absorption Laser Induced Fluorescence (TALIF) in collaboration with Dr. Campbell Carter at Wright-Patterson AFRL. Oxygen number density on the order of 10^{13} cm^{-3} in a 150-ns, 6-kV plasma jet was obtained for an axial distance up to 5 mm above the device nozzle. Electrostatic modeling and energy-dependent studies showed that the direct and indirect electron-induced processes in the pulsed plasma jet are responsible for the O production. 2) A single-electrode helium microplasma jet was generated in ambient atmosphere when the electrode was excited with 5 ns or 164 ns, 8 kV pulses at 500 Hz. Spatially-resolved optical emission spectroscopy showed that the production of excited atomic oxygen increased by a factor of 2 for the 5 ns pulsed plasma jet when compared with that for a 164 ns pulsed plasma jet operating at the same voltage amplitude, pulse frequency, and flow conditions. This signifies an enhanced efficiency of atomic oxygen production by highly non-equilibrium plasmas excited with high voltage pulses with fast rising time and relatively short durations. Analysis of the rovibronic emission from N₂ (C-B) indicated a rotational and vibrational temperature of 300 K ± 50 K and 3000 ± 200 K, respectively, for both the 5 ns and 164 ns pulsed plasma jets. 3) Applications of the atmospheric pressure plasma jets and jet arrays (e.g. plasma brush) were explored for surface decontamination against pathogenic bacteria and biofilms, as well as for treatment of cervical cancer, in vitro. 4) Other studies involving portable nanosecond pulsed power generation based gas switches or photoconductive solid-state switches, non-equilibrium surface plasma chemistry and applications were also conducted.

Archival publications during reporting period:


Changes in research objectives, if any: None

Change in AFOSR program manager, if any:

Changed from Dr. John Luginsland to Dr. Jason Marshall

Extensions granted or milestones slipped, if any:

No cost extension was granted from the ending date of July 14, 2016 to the ending date of January 14, 2017

Include any new discoveries, inventions, or patent disclosures during this reporting period (if none, report none): None
1. Report Type
   Final Report

Primary Contact Email
Contact email if there is a problem with the report.
   cjiang@odu.edu

Primary Contact Phone Number
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   757-683-7061

Organization / Institution name
University of Southern California/ Old Dominion University

Grant/Contract Title
The full title of the funded effort.
   Fundamental Studies of Transient, Atmospheric-Pressure, Small-Scale Plasmas

Grant/Contract Number
AFOSR assigned control number. It must begin with "FA9550" or "F49620" or "FA2386".
   FA9550-11-1-0190

Principal Investigator Name
The full name of the principal investigator on the grant or contract.
   Andras Kuthi/Chunqi Jiang

Program Officer
The AFOSR Program Officer currently assigned to the award
   Jason Marshall

Reporting Period Start Date
   07/15/2011

Reporting Period End Date
   01/14/2017

Abstract
   Fundamental studies of nanosecond pulsed atmospheric pressure plasmas including a millimeter He-O2 plasma jet, generated with a concentric tubular electrode configuration, and micrometer He plasma jet, generated with a single electrode, were conducted. 1) Temporal development and spatial distribution of atomic oxygen ground state (O3P) in the 2-cm long, 1-mm He-O2 plasma jets were measured using Two-Photon Absorption Laser Induced Fluorescence (TALIF) in collaboration with Dr. Campbell Carter at Wright-Patterson AFRL. Oxygen number density on the order of 10^{13} cm^{-3} in a 150-ns, 6-kV plasma jet was obtained for an axial distance up to 5 mm above the device nozzle. Electrostatic modeling and energy-dependent studies showed that the direct and indirect electron-induced processes in the pulsed plasma jet are responsible for the O production. 2) A single-electrode helium microplasma jet was generated in ambient atmosphere when the electrode was excited with 5 ns or 164 ns, 8 kV pulses at 500 Hz. Spatially-resolved optical emission spectroscopy showed that the production of excited atomic oxygen increased by a factor of 2 for the 5 ns pulsed plasma jet when compared with that for a 164 ns pulsed plasma jet operating at the same voltage amplitude, pulse frequency, and flow conditions. This signifies an enhanced efficiency of atomic oxygen production by highly non-equilibrium plasmas excited with high voltage pulses.
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Changes in research objectives (if any):

None

Change in AFOSR Program Officer, if any:

Changed from Dr. John Luginsland to Dr. Jason Marshall

Extensions granted or milestones slipped, if any:

No cost extension was granted from July 14, 2016 to January 14, 2017.

AFOSR LRIR Number

LRIR Title

Reporting Period

Laboratory Task Manager

Program Officer

Research Objectives

Technical Summary

Funding Summary by Cost Category (by FY, $K)

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