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Nanomaterial Synthesis in Microplasmas

Kunning G. Xu
University of Alabama in Huntsville

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Faculty Mentor

Dr. Kunning G. Xu, Assistant Professor, Mechanical and Aerospace Engineering
E-mail: Gabe.xu@uah.edu *Phone*: (256) 824-5083
Office: Technology Hall, Rm S234, UAH

Project Summary

The overall goal of this research is to understand the physics of nanoparticle formation in an atmospheric-pressure microplasma. A microplasma is a plasma where at least one dimension is in the millimeter of smaller scale, or example inside a capillary tube. The small physical size allows the plasma to exist at non-vacuum pressures. In our work we utilize an argon or helium microplasma generated inside a 2 mm ID quartz tube. To generate nanoparticles, a small amount of methane (CH_4) gas is introduced into the plasma. The plasma breaks apart the methane molecule leaving C and H_2. The carbon atoms collect together and grow into larger particles. The particles are then collected and analyzed using electron microscopes to determine their size and shape. By varying the power, flow rate, and concentration of methane we can control the plasma parameters which affect the formation of the nanocarbon particles. Thus we can experimentally determine the relation between the plasma and nanoparticles.

Ultimately we wish to gain a fundamental understanding of the physics of the nanocarbon synthesis. However it is a very difficult and complex set of steps which we do not understand at this point. Thus this project will conduct experimental measurements of the plasma and the resulting nanoparticles to build an empirical understanding. The plasma properties of electron temperature and density are measured using Langmuir probes as well as optical emissions spectroscopy. The nanoparticle shape and size are measured with scanning electron microscopy. By changing the variables of gas flow rate, CH_4 concentration, and plasma power produces different sizes and shapes. For example an increase in gas flow rate decreases the deposited particle size, for a fixed separation distance between the plasma and collector. This is due to a fixed rate of formation, thus a faster flow rate means a shorter formation time before the particles are deposited on the collector.

The project may require the student make modifications to an existing experiment and take plasma measurements as well as nanoparticle images. Possible diagnostics include thermocouples, Langmuir probes, emissions spectrometer, and a scanning electron microscope. Assistance from graduate students and the professor will be available.

The RCEU student's tasks in the project include:

1) Independently operate the experiment according to procedures.
2) Use probes and emission spectrometer to obtain plasma measurements.
3) Take the nanoparticle images and determine the size and shape distribution using the program ImageJ.

Student Prerequisites

A successful student should be familiar with computer programs such as Excel, and Matlab. Some experience with ImageJ would also be helpful but not necessary.

Student Duties

The student will be responsible for running the experiment independently, collecting plasma data, and analyzing the plasma and nanoparticle results. The nanoparticle image will be obtained by the graduate student. Any necessary materials and parts will be provided. Graduate student support as well as my support will be available for the project. The last step, analyzing the data, will be a joint effort between the student, graduate student, and me. A tentative timeline for 12 weeks is as follows:

Weeks 1-3: Introduction to the lab, equipment, background of the project, first aid training, diagnostics training, and instruction in ImageJ.

Weeks 4-10: Conduct experiments, collecting measurements, analyze and discuss results.

Weeks 11-12: Documentation of the results including a poster.

The RCEU student is expected to be a self-motivated and diligent professional. He or she will have significant independence on the project, though assistance and direction is always available. The student is expected to contribute to group meetings, read necessary background material, and conduct any independent learning necessary to do the research. A journal club meeting occurs each week in the lab where one person is asked to prepare and present and discuss an article they have read. The RCEU student is expected to participate in the journal club and prepare at least one article presentation during the summer.

This project will provide the student a chance to conduct hands-on research in the interdisciplinary field of combustion and electromagnetics. The student will have the opportunity to see the project from beginning to end, from experimental design to documentation of the results. The work will build on topics in thermodynamics and electromagnetics learned in the classroom to provide new experiences that cannot be gained as part of a regular undergraduate curriculum or through internships and co-ops. This project is a great way to experience experimental research for future graduate pursuits.

The main expected deliverable is a poster and a detailed report of his or her work. I encourage submission of quality work to society or national conferences and journals.

Mentor Supervision and Interaction

During the summer semester, I spend 3-4 days a week personally working at the lab alongside my students. I may assist with their projects or do work on my own. Thus I will have regular interactions with the RCEU student. The student will also have daily interactions with the graduate students who work with me and conduct research in the lab. Direct supervision, mentoring, and evaluation of the project by me will occur once a week at the regularly scheduled project meetings. In the meetings we will discuss the current status of the project, recent results, difficulties encountered, what to do next, and address any other issues that may come up. Indirect interactions and mentoring by graduate students and I will occur throughout the semester as part of the day to day activities. The student will either report to me, the graduate student working on the larger research in plasma-assisted combustion of which this project is part of.