White Paper for *Frontiers of Plasma Science Panel*

Date of Submission:	***June 19, 15***

Indicate the primary area this white paper addresses by placing "P" in right column.
Indicate secondary area or areas by placing "S" in right column

	"P", "S"
• Plasma Atomic physics and the interface with chemistry and biology	S
• Turbulence and transport	
• Interactions of plasmas and waves	
• Plasma self-organization	P
• Statistical mechanics of plasmas	

Indicate type of presentation desired at Town Hall Meeting.

	"X"
Oral	
Poster	
Either Oral or Poster	X
Will not attend	

Title:	Plasmas, particulates, and plasma-facing surfaces at high magnetic fields
Corresponding Author:	C. A. Romero-Talamás
• Institution:	University of Maryland – Baltimore County
• email:	romero@umbc.edu
Co-Authors:	Z. Wang and G.-L. Delzanno (Los Alamos National Laboratory), E. Thomas, Jr. (Auburn University), R. Kaita and M.A. Jaworski (PPPL).

(Limit text to 3-pages including this form. Font Times Roman size 11.
1 page of references and 1 page of figures may also be included. *Submit in PDF format.*)

- ***Describe the research frontier* and importance of the scientific challenge.**

The interplay between magnetic fields and plasmas is an important aspect of plasma physics. From astrophysical plasmas to magnetic fusion plasmas, the coupling of the magnetic field to the plasma environment drives many interesting dynamics of the plasma and give rise to important phenomena such as dynamos, magneto-rotational instabilities, a zoo of waves and sometimes turbulence. With the technological advances and cost reductions in the design and construction of both conventional and superconducting magnet systems, it is now possible to consider the operation of laboratory scale devices in which the electron/ion Hall parameter (i.e., ratio of the gyrofrequency of the electrons/ions to collision frequency) is much greater than one. This is coupled with the research needs to benchmark diagnostic systems, computer codes, and gain a better understanding of long-duration plasma wall interactions in high temperature and density fusion plasmas.

Therefore, the research frontier is the development of fundamental experimental and numerical studies that couple strongly magnetized plasmas with processes that lead to the production and transport of particulate matter of different sizes and material compositions, in warm plasmas.

- ***Describe the approach to advancing the frontier and indicate if new research tools or capabilities are required.***

Approach: The US plasma research portfolio is currently lacking the tools to understand the interactions between plasmas, particulates, and plasma-facing surfaces under conditions that go beyond the regime of low temperature, laboratory plasmas. This lack of tools, and the associated gaps in knowledge, mean that there are important, new opportunities for innovative research that can address this research need. An important approach to address this research gap is to develop a dedicated research program that can focus on this area. These investigations can range from studying the transport and ablation of small particles in warm plasmas, the production and injection of small particulates from plasma facing surfaces into the surrounding plasma, and the behavior of chemically active particulate matter (e.g., lithium, sodium salts, etc.) into warm plasmas. These types of studies go beyond the "typical" laboratory dusty plasma research environment and will involve new physical processes that have not yet been studied extensively including: variable mass effect, secondary and thermionic electron emission, chemical processes at elevated surface temperatures.

In order to perform this research, it will be necessary to develop a new class of laboratory plasma sources that can deliver reasonably high density ($>10^{18}$ m^{-3}), warm ($T_e \geq 10$ eV, $T_i \geq 5$ eV) plasmas in reasonably strong magnetic fields ($B \geq 1$ T). There are new university-based high magnetic field (both steady-state and pulsed) facilities that can leverage the resources and experiences of the national lab program at designing and building new plasma sources. This provides an approach that can maximize the impact of this work.

Resources: At the present time, the US plasma research program has limited experience with long-duration, high magnetic field systems. However, within the current research portfolio, there are new opportunities that – if properly leveraged – can make a substantial impact in our field.

The Magnetized Dusty Plasma Experiment (MDPX) facility at Auburn University is uniquely suited to address this research area. As a 4-Tesla, split-bore, superconducting, variable magnetic field system with a 50-cm bore and excellent diagnostic access from both the top/bottom and sides – the MDPX device is a highly flexible research instrument that can serve a variety of missions from exploring the basic physics of dusty plasmas to providing a test-bed for high magnetic field diagnostics, long-duration plasma experiments, and superconducting technologies.

The Dusty Plasma Laboratory at University of Maryland – Baltimore County (UMBC) is presently developing a 10 T resistive magnet with a 15 cm bore capable of sustaining the field from 10 seconds to minutes (depending on the number of experimental events required per day). The design if of the Bitter-type magnet requires high cooling rates and high power to drive it, but allows high flexibility in the field strength, duration, and field gradients that can be achieved within the same day of experimental runs. Lower fields can be easily configured and will significantly extend run time. A 1 T, 2 cm bore magnet is being completed and will be used to refine operation and safety of cooling and electrical interlocks required for the 10 T version. Both magnets will be used in dusty plasma experiments, as well as in the development of diagnostics and detectors in collaboration with UMBC and external researchers.

- ***Describe the impact of this research on plasma science and related disciplines and any potential for societal benefit.***

This area of research is multidisciplinary and will have an impact on many areas of plasma science. First, the ability to perform fundamental plasma science research in steady state plasmas at high magnetic field will extend plasma science to new experimental regimes that have not yet been explored. For research topics such as microplasmas, dusty/complex plasmas, and plasma processing, the addition of a magnetic field to these systems will provide additional degrees of freedom that may open new lines of basic research. This work will also support the advancement of magnet technologies, an important technological area for the US economy that impacts areas as diverse as material science (e.g., understanding the electronic structure of materials) to the medical industry (e.g., the development of Magnetic Resonance Imaging tools). The advancement of superconducting magnet technologies is critical for the commercialization of fusion.

Finally, experimental studies of plasma-materials interactions are lacking at realistic scenarios for high-temperature plasmas in which electron and ion temperatures are comparable, and plasmas are sufficiently dense and magnetic fields terminating at surfaces have sufficiently long conduction lines back to the hotter plasma to be representative of fusion-scale devices. Support of long pulse high magnetic field technology will help drive construction and maintenance costs down for experiments that aim at solving scientific and engineering challenges of materials at the extreme conditions expected in sustained fusion devices.

Figures (maximum 1 page)

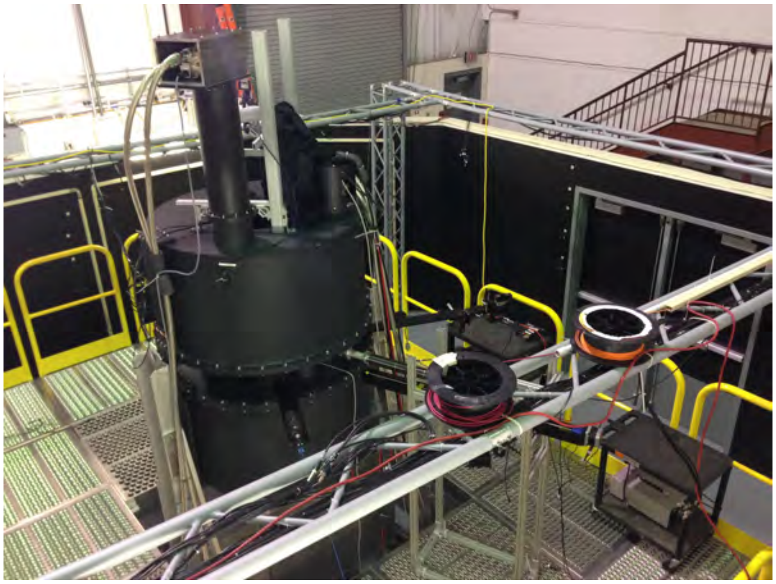

Fig. 1: Photograph of the assembled Magnetized Dusty Plasma Experiment (MDPX) device at Auburn University. The superconducting coils are inside of the black painted cryostat. The split-bore between the two halves of the cryostat can be seen.

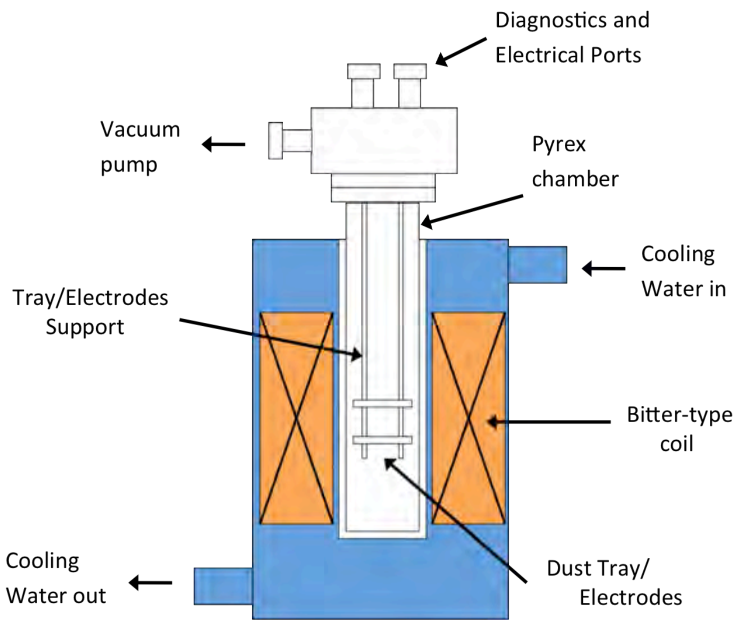

Fig. 2: Design of the pulsed 10 Tesla Bitter-magnet system, under development at the University of Maryland – Baltimore County (UMBC).