WP-2608 - Novel Atmospheric Pressure High Power Impulse Plasma Source for Durable, Field Applicable Coatings

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Summary

PROBLEM STATEMENT

- Cost-effective, deployable coating alternatives to electrolytic hard chrome (EHC) plating are needed.
  - EHC uses chromium in the hexavalent state (hex-Cr, Cr^{6+}).
  - Hex-Cr is a known carcinogen.
  - Significant hazardous waste generation & pollution control costs.
  - Increasingly stringent U.S. OSHA and EPA regulations will continue to drive up costs in the use of hex-Cr processes. (Current PEL is 5 µg/m3)
- There is an expanding need for the ability to execute metallic coating repair operations on low-risk military items and components to minimize transportation and regulatory costs and maintain combat readiness levels.

BACKGROUND

SwRI® has developed through Defense Advanced Research Projects Agency (DARPA) funding a promising High Power Impulse Plasma Source (HiPIPS).

HiPIPS outperforms state-of-the-art (SOA) ambient pressure plasmas in areas such as power, current, precursor dissociation and flux, ion energy and precursor diversity, and rivals SOA vacuum plasma systems in many of these same categories.

HiPIPS process advantages for SERDP SON include:

Environmentally Friendly:

- Operates solely with an inert carrier gas and solid metallic wire/rod.
- No hexavalent chromium in HiPIPS Cr plasma.
- Wire-fed; no powder source materials.

Field Deployable:

- Could allow for coating removal, pre-cleaning, and coating using same equipment and varying process parameters
- Does not require any substrate heating or biasing.
- Can be portable and used in field or at depots and the OEM

Objective

OVERALL OBJECTIVE

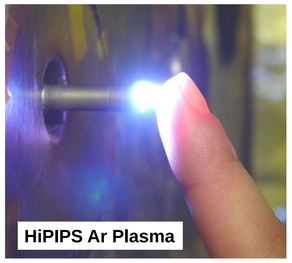
Investigate a novel atmospheric pressure, non-thermal HiPIPS for deposition of field applicable protective coatings that meet weapon systems' technical requirements while reducing DoD's current weapon systems' environmental and logistical footprints.

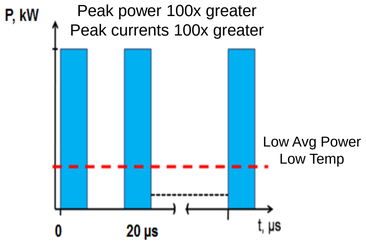
SPECIFIC AIMS

1. Investigate atmospheric pressure HiPIPS for deposition of durable protective (Cr, CrN, and TiN) coatings.

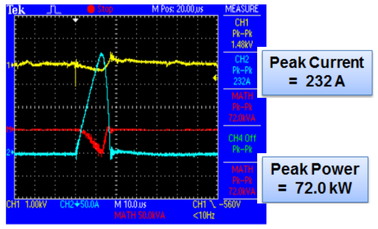
2. Characterize the structural, mechanical and corrosion performance of the resultant coatings.

Atmospheric Pressure HiPIPS





Atmospheric Pressure Plasma Jets + High Power Pulsed DC Generators



Oscilloscope traces of current, voltage & power

Increased Ionization
Increased ion current density

↓

Increased ion flux at
low temperature

↓

Increased ion bombardment of
the growing film

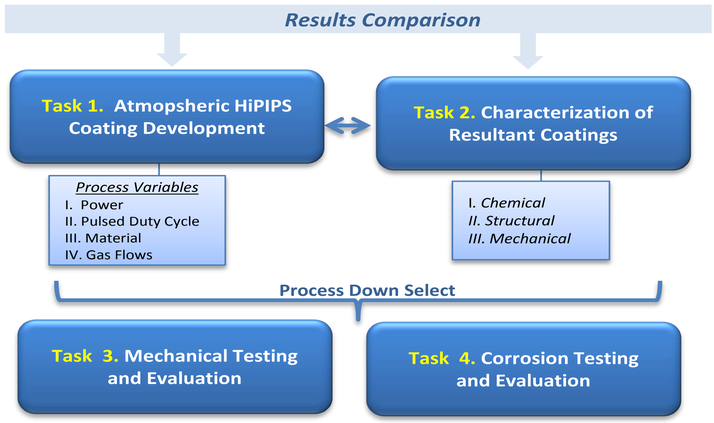
Increased ion density and flux at low temperature

Power, current, ion energy, and precursor dissociation properties that are comparable with vacuum plasma systems

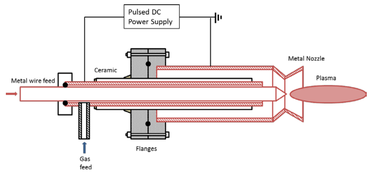
Technical Approach

We plan to conduct a comparative experimental study towards the development of atmospheric HiPIPS process for the deposition of field applicable and durable protective coatings.

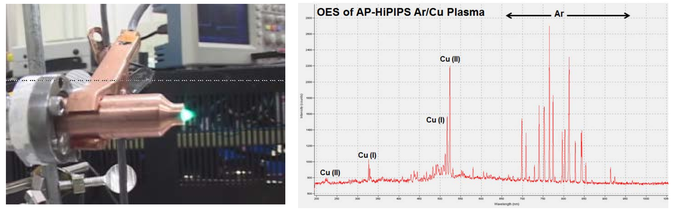
The overall approach consists of 4 main technical tasks illustrated below.



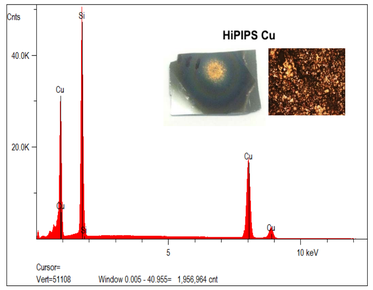
HiPIPS Metal Coatings



Schematic drawing (left) of a variation of HiPIPS that involves physical vapor deposition of a metal wire feed stock for metallic or ceramic coatings.



Photograph (left) and optical emission spectrum (OES) of HiPIPS Cu plasma. Power supply settings: V= 1.2 kV, pulse frequency = 500 Hz, pulse width = 20 µsec



Energy dispersive spectroscopy (EDS) data, inset photograph and optical microscope image of resultant HiPIPS Cu coating on Si wafer.

The process is applicable to other metal and metal alloys by changing the wire source material. Metal oxide and metal nitride compositions are also accessible. For example, metal nitride coatings can be deposited by using nitrogen gas.

Photograph of HiPIPS plasma deposition process on a plastic substrate. Inset photograph showing resultant conductive HiPIPS Cu coating on plastic substrate.

Unlike thermal plasma spray, HiPIPS produces a non-thermal plasma with processing temperatures ≤ 100 °C.

Acknowledgment

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Views, opinions, and/or findings contained in this report are those of the authors and should not be construed as an official DoD position or decision unless so designated by other official documentation.

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