Electrolytic Plasma Processing for Sequential Cleaning and Coating Deposition for Cd Plating Replacement

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New SERDP Project
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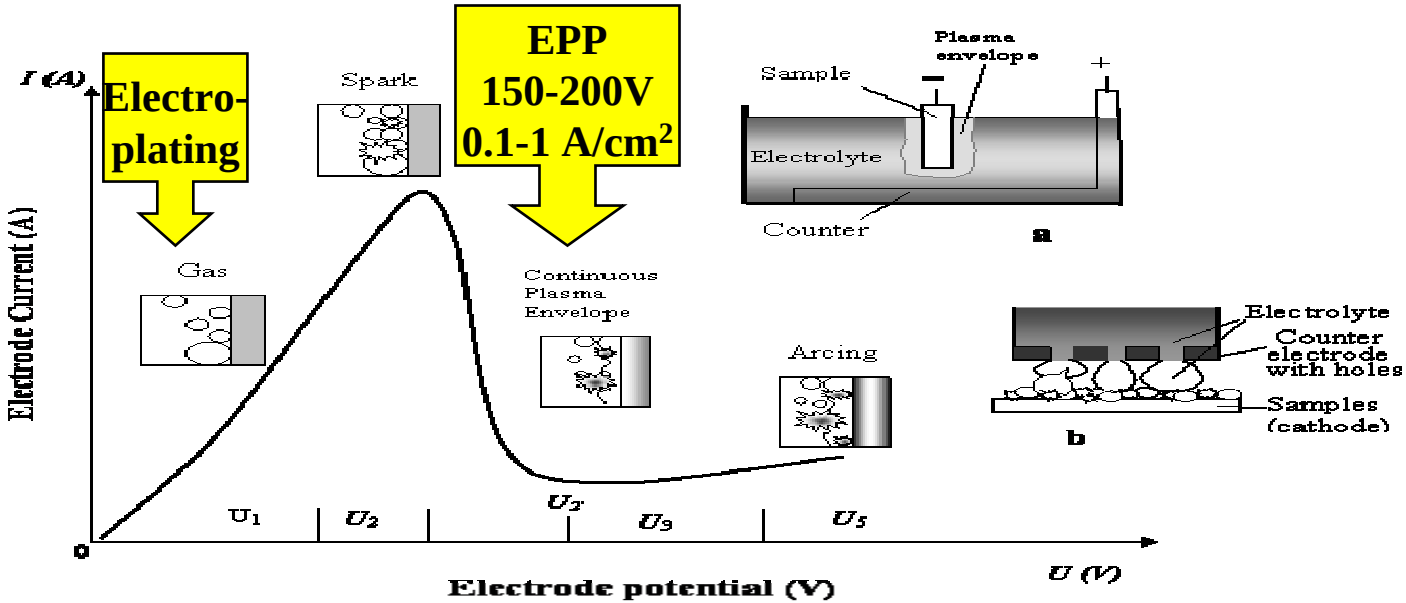
Technical Objective

Develop electrolytic plasma processing technology as an environmentally benign process for:

- **Surface cleaning of high-strength steels in preparation for coating application**
- **Application of coatings exhibiting properties equivalent or superior to cadmium plating on high-strength steels**
  - **Capable of uniform deposition on internal surfaces and complex geometries**
  - **Does not degrade performance characteristics (e.g., fatigue) of base steel**

Technical Background

- **EPP is an aqueous process involving two phenomena**
  - **electrolysis of liquid by high potential (200V vs a few V for plating)**
  - **production of a plasma at or in the vicinity of the cathode (workpiece)**
- **Figure shows typical current-voltage characteristic curve**
  - **most electroplating operates in U1 gas generation region**
  - **EPP operates around $U_{2'}$ where continuous plasma envelope forms on surface**
- **Near-surface heating due to plasma enhances cleaning but bulk temperature remains relatively low**



Technical Approach

Cleaning Studies:

- **Can HSS be cleaned effectively without substrate damage?**
  - extent of cleaning
  - hydrogen embrittlement
  - surface characteristics, microstructure
  - hardness and residual stress

Coating Studies:

- **Is Zn-Al & Zn-(Al-O/OH) coating quality adequate?**
  - hydrogen embrittlement
  - composition, thickness uniformity
  - microstructure
  - characteristics (porosity, hardness)

Selection of cleaned and coated material
Conduct fatigue, corrosion, torque/tension measurements

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Demonstrate cleaning and deposition of optimum coatings onto actual components provided by the military repair depots

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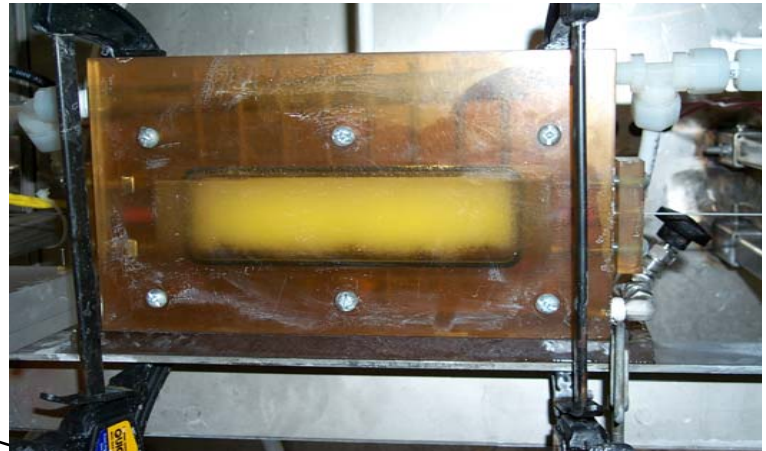
Conceptual design of EPP system for demonstration at one or more military repair depots

Technical Approach – Year 1 Cleaning

Study the characteristics of EPP-cleaned surfaces by varying process parameters to understand and optimize their effect

Motivation is not only the degree of surface cleanliness obtained but also the surface morphology and impact on properties of HSS

Property/Characteristic	Methodology
Oxide thickness, organic contamination	SEM/EDAX, AES, XPS
Surface morphology (roughness)	Optical profilometry, SEM
Heat-affected zone thickness/μstructure	Xsection TEM and microhardness
H content near surface	Nuclear reaction analysis
H embrittlement	ASTM F519 test
Residual stresses near surface	low-angle XRD



Reactor at CAP Technologies for studying cleaning and coating deposition

Technical Approach – Year 1 Coating

Study the deposition of Zn-Al alloy and Zn-(Al-O/OH) composite coatings by varying process parameters to determine effects on composition and required performance characteristics

Motivation is to determine ability of EPP to deposit different coating compositions such that performance characteristics can be modified depending on in-service applications

Property/Characteristic	Methodology
Thickness uniformity, morphology	SEM, optical profilometry
Composition, porosity	SEM/EDAX (plan-view or Xsection)
Microstructure	TEM
Residual stress	XRD
Adhesion	ASTM D4541
Microhardness	Vickers or Knoop indenter

Technical Approach – Year 2

Measure performance characteristics of coatings developed in first year in comparison to cadmium plating and determine effects on base HSS material

Property/Characteristic	Methodology
Hydrogen embrittlement	ASTM F-519 test
Electrochemical evaluation	Anodic polarization
Salt-fog corrosion behavior	ASTM B117 test
Fatigue	ASTM E466 axial test
Wear	Pin-on-disk test
Torque/tension test (fasteners)	ARL-developed test

Technical Approach – Year 3

If previous studies prove efficacy of process related to coating performance and impact on base material, then:

- **Demonstrate process for cleaning and coating of external and internal surfaces, and complex geometries**
- **Demonstrate process on selected components obtained from Naval Aviation Depot North Island, Ogden Air Logistics Center, and Anniston Army Depot**
- **Generate conceptual design of prototype EPP cleaning/coating system that could be utilized as a demonstration unit at a repair depot**