

An overview of the Electrosark deposition process for aluminization of MCFC bipolar plates

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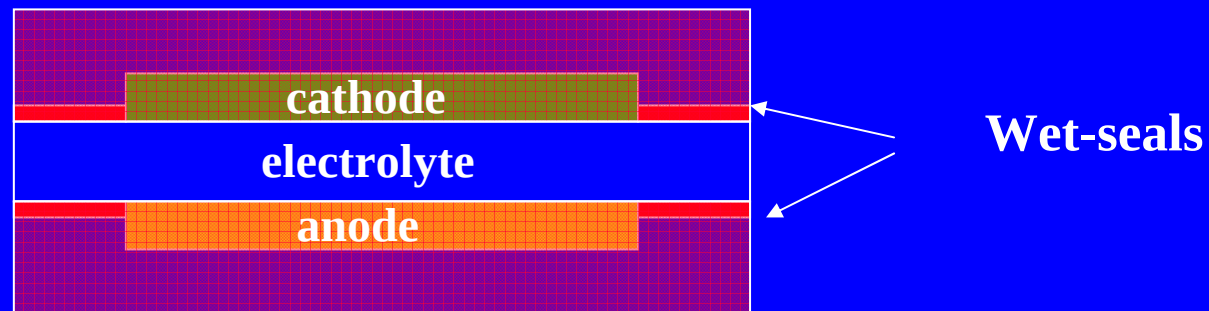
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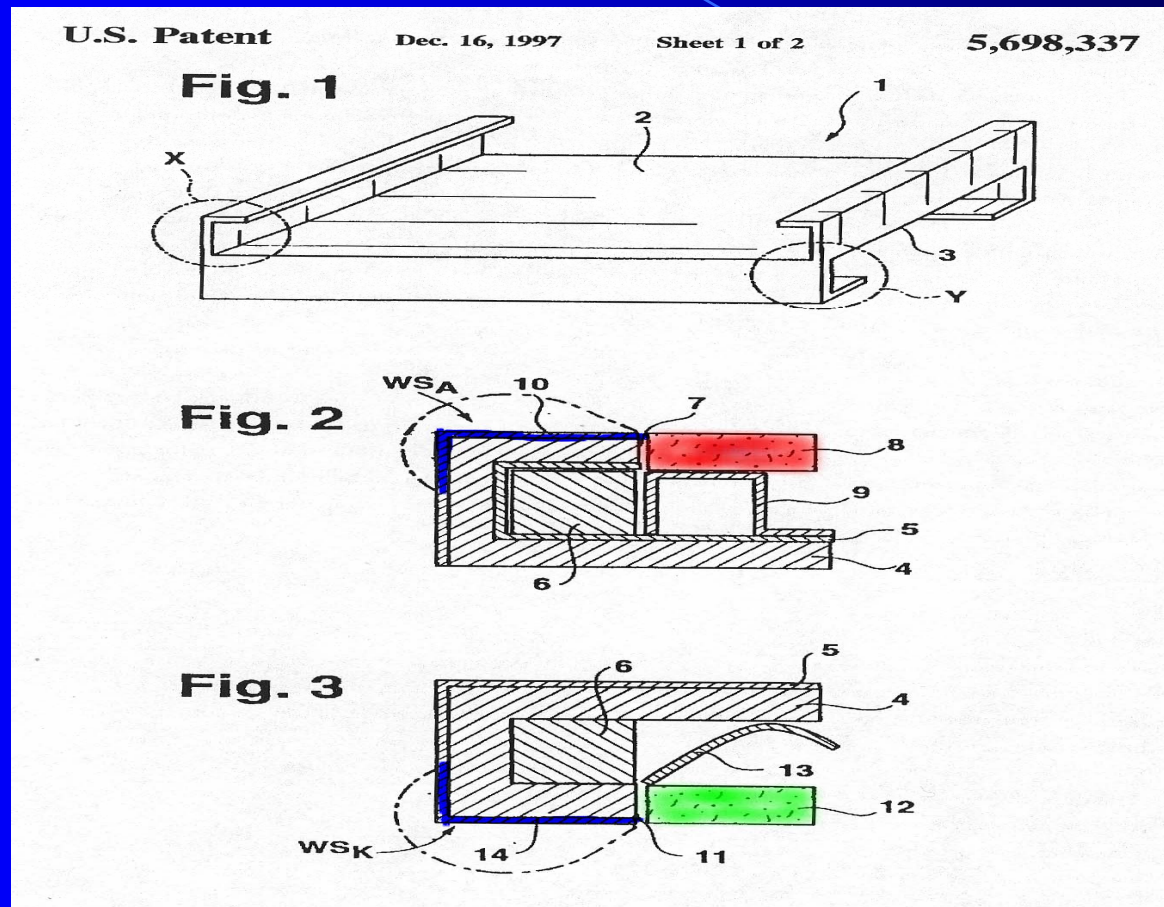
Problem statement

Corrosion of stainless steel sheets in the wet-seal area of MCFC bipolar plates



- ✓ corrosion restricts performance and endurance of MCFC
- ✓ stainless steels must be protected by Al-diffusion coatings

Problem statement



Problem statement

Current aluminization technologies for MCFC wet-seals

- ✓ Ion Vapor Deposition (IVD)
- ✓ Slurry Painting
- ✓ Thermal Spraying

All these methods require a post-deposition treatment at 800-1000°C to diffuse Al into steel and form a corrosion-resistant and stable (Fe,Ni)Al aluminide surface layer

Problem statement

- **Ion Vapor Deposition (IVD):** excellent adherence to substrate, dense microstructure; uniform film properties; **costly and not easily available process;**
- **Thermal Spraying:** low adherent deposits; porous microstructure; non-uniform film properties; substrate deformation; **low cost;**
- **Slurry Painting:** easy to apply; non-uniform coatings; adherence problems?; impurities entrapped in the deposit layer?; **lowest cost;**

Possible alternative

- **ElectroSpark Deposition (ESD)**

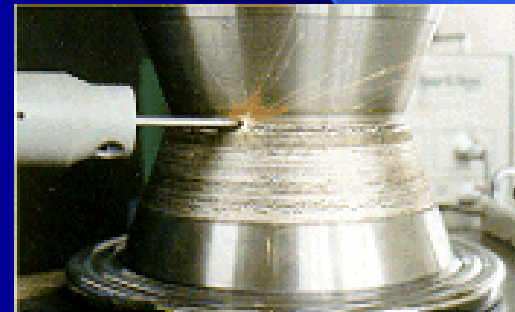
Electrospark Deposition process

Overview

ESD process produces superior diffusion-type coatings for corrosion, wear-resistant or dimensional restoration applications resulting in metal bonding with little thermal effects on the substrate (risks of distortion, discoloration or burn-through of thin components are minimal).

Definition

The ESD process is a form of capacitor discharge micro welding that uses a moving electrode to create short, high-current electrical pulses with discharge frequencies in the range 50-4KHz.



Electrospark Deposition process

Summary of ESD benefits

- ✓ minimal substrate heating and HAZ;
- ✓ rapid coating solidification (nano-structured, amorphous structures);
- ✓ no or little pre- or post-ESD processing required;
- ✓ no hazardous wastes, fumes or smokes generated;
- ✓ easily automated;
- ✓ simple process, low capital cost;
- ✓ applicable to most metals and cermets;
- ✓ applicable to complex shapes;

ESD process parameters

Electrode & Motion

- Material (composition, density, microstructure)
- Geometry
- Speed
- Contact force
- Number of passes

Environment

- Gas composition
- Flow rate and pattern
- Temperature

Substrate

- Material (composition, density, microstructure)
- Surface finish
- Temperature
- Geometry

Electrical

- Spark energy
- Spark frequency
- Voltage
- Capacitance
- Spark duration

ESD process for MCFC aluminization

Expected advantages of ESD vs IVD:

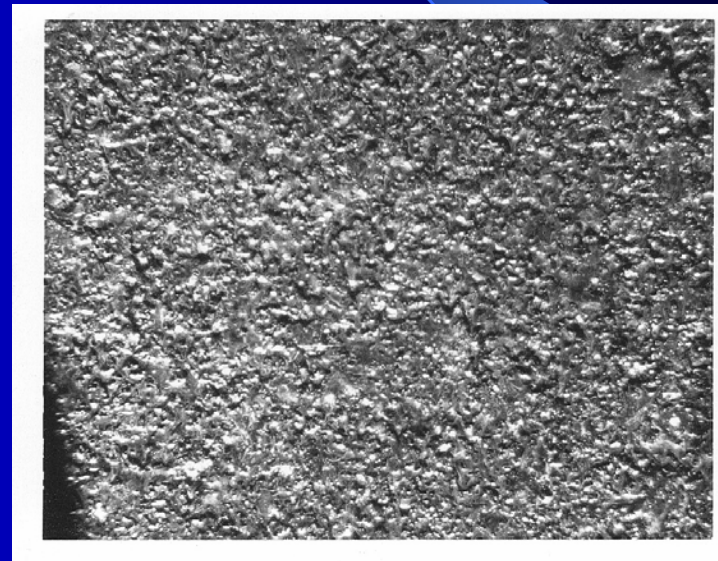
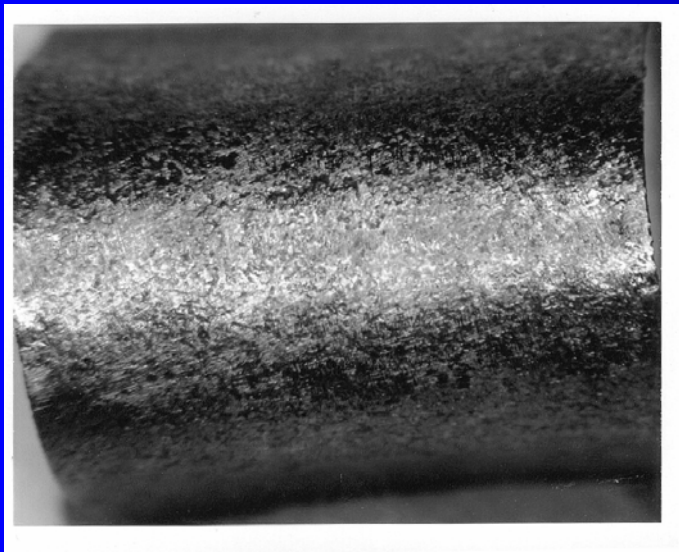
- ✓ Al deposition and diffusion in one single step;
- ✓ no vacuum systems and chambers required;
- ✓ lower capital and operating costs;
- ✓ no post-processing heat treatment required;

Manual application of ESD for aluminization of MCFC bipolar plates

ESD equipment: SparkDepo model 28-40 , manual deposition

Electrodes: Fe aluminide , metallic Al,

Gas shielding: air, argon



x15

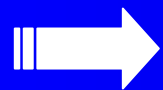
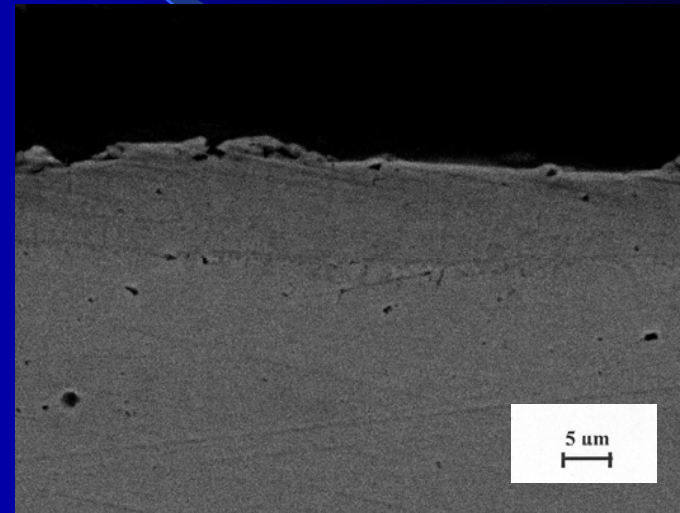
Manual application of ESD for aluminization of MCFC bipolar plates

Low-magnification



Poor thickness uniformity

High-magnification



Quality optimization is required

Manual application of ESD for aluminization of MCFC bipolar plates

Drawbacks:

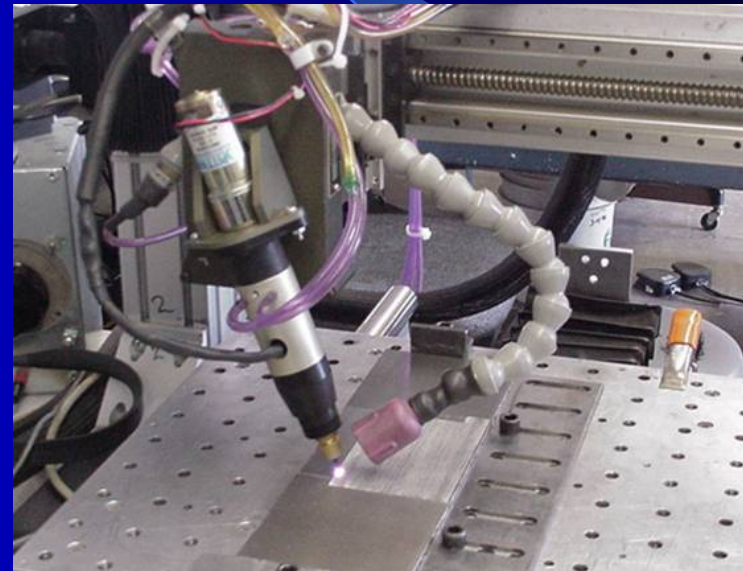
- ❖ low productivity rates (grams per hour, a few cm² per minute)
- ❖ difficulty in the control of the arc gap (i.e., contact force) between electrode tip and substrate (this affects coating properties).



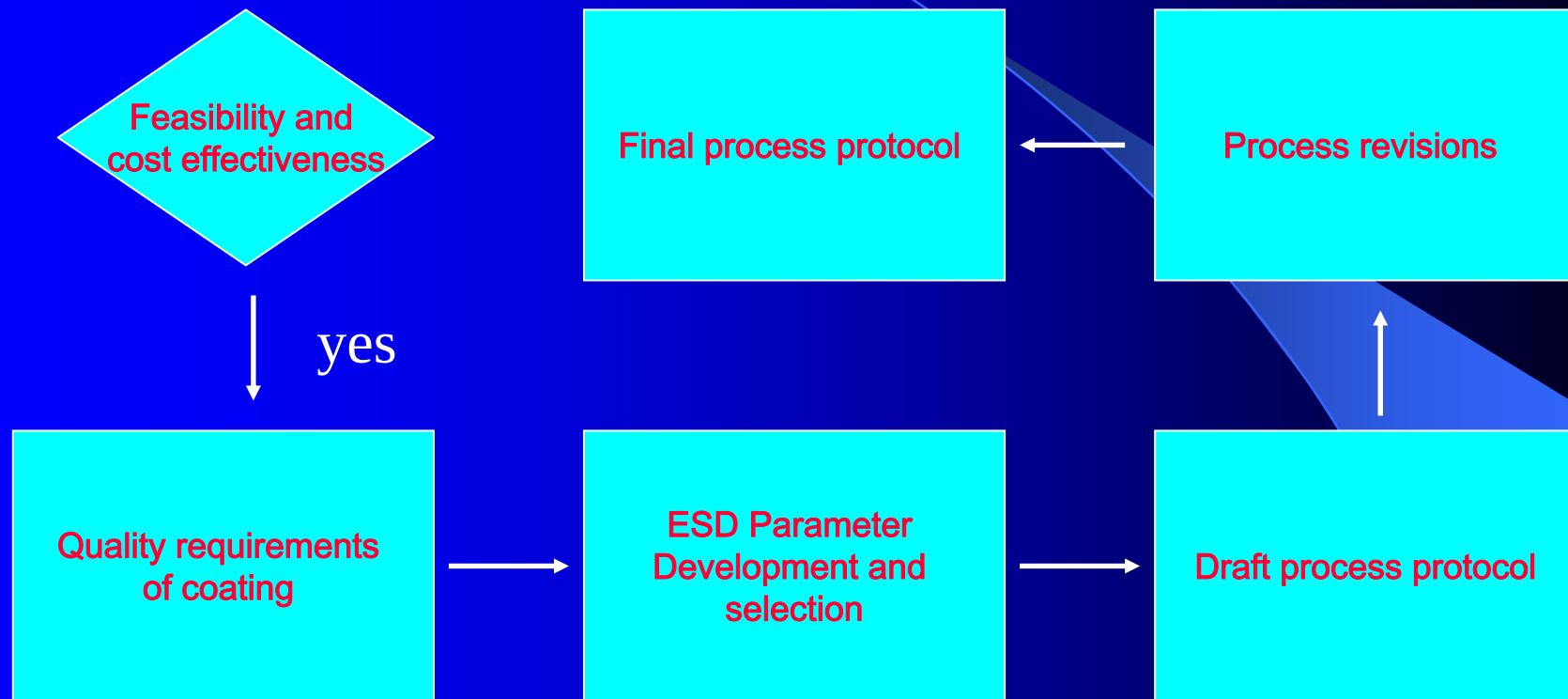
Process optimization is possible by integrating ESD equipments with automatic or semi-automatic devices, for example, 3-axis coordinate tables, for:

- ☐ **higher production rates**
- ☐ **precise control of the contact force**

Examples of automated ESD equipments



Decision flow chart for the development of ESD automated process



Quality coating requirements for MCFC wet seals

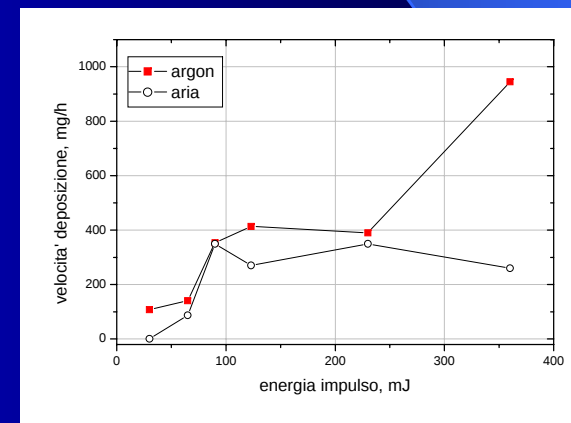
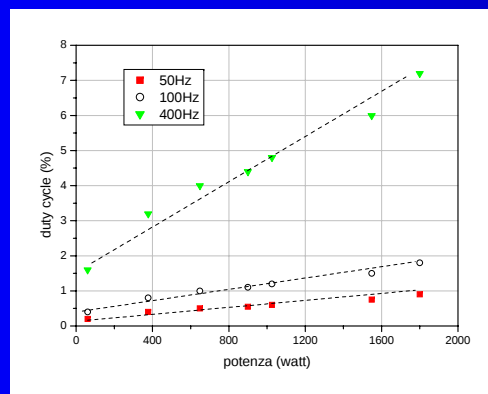
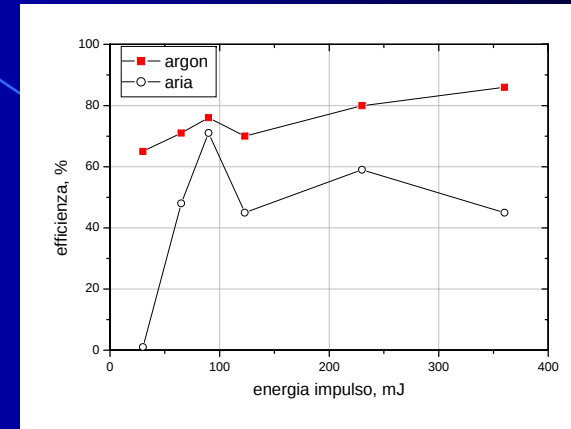
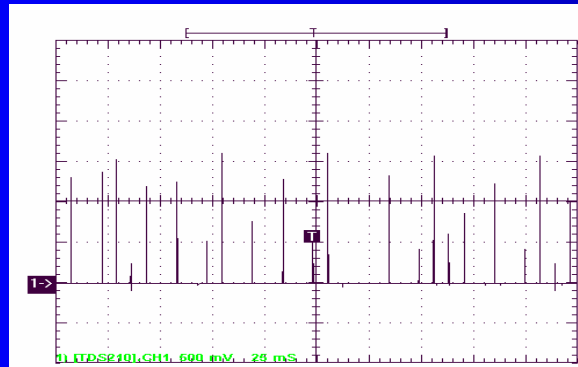
- coating thickness: 20-50 μm
- uniformity (thickness, chemical composition)
- corrosion resistance
- adherence (resistance to bending)
- low porosity
- low oxide inclusions
- workability (forging processes)

Development of parameter settings for automatic ESD

On-going activity

- electrical parameters (relationship between discharge rates, voltage, current, duty cycle)
- gas shielding (air, argon)
- electrode motion (90° rotation to fill in valleys)

Development of parameter settings for automatic ESD process



Conclusions

- ESD process has the potential to reduce the costs of MCFC bipolar plate aluminization
- Preliminary evaluation of ESD by manual equipment has demonstrated its suitability for aluminization of thin metallic sheets
- Development of an automatic ESD device is ongoing to increase productivity rates and coating properties uniformity