U.S. DEPARTMENT OF
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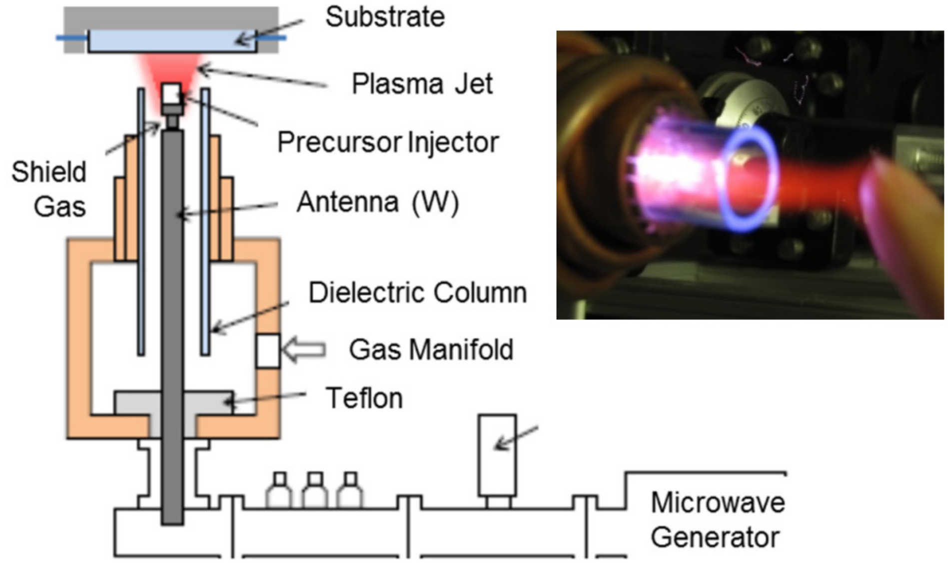
Atmospheric Cold Plasma Jet Coating and Surface Treatment for Improved Adhesive Bonding Performance of Dissimilar Material Joints Subject to Harsh Environmental Exposure



Atmospheric-Pressure Microwave Plasma Generator @ CPMI Bulky Microwave Waveguide, Power System and Plasma Generator To Be Replaced With Miniature Plasma Head Using Flexible Coaxial Lines, Gas Feeds And Solid State Electronics

Proof of concept demonstrated with laminar flow channel for shield gas with precursor injection at coaxial conductor terminus. Generation of >5cm long plasma jets extend towards the substrate that is safe to touch.

Graphic image courtesy of Starfire Industries, LLC

Multi-material joints are crucial elements to be addressed in vehicle light-weighting strategies. These joints are exposed to harsh environments, so weakened durability can lead to cohesive failure. Present-day wet-chemical treatments, such as Alodine, are applied to the entire part for corrosion protection at remote facilities, leading to significant transport, energy, masking, and waste disposal cost. Improving or replacing these wet-chemical treatments will help eliminate transportation, waste disposal, and energy usage.

This project is developing a novel plasma jet coating to replace wet-chemistry corrosion protection methods. This low-cost material coating system consists of an innovative atmospheric cold microwave plasma jet. The project will begin with demonstrating a smaller plasma launcher attached to a coaxial power feed that can be easily mounted onto a robotic arm for in-line surface treatment and localized plasma cleaning, coating and activation. The plasma source and coating will be tested and optimized for corrosion and adhesion targets.

Benefits for Our Industry and Our Nation

The use of the atmospheric cold plasma jet coating under development can improve corrosion protection, wear resistance and bonding strength in multi-material automotive body applications in harsh environmental exposures. Conventional bath-type corrosion pretreatments are energy intensive, environmentally wasteful, and costly. Using state-of-the-art cold plasma coating technology is expected to have various benefits for dissimilar material joints, including:

- Reduced energy consumption, wastewater effluent disposal, and off-site transportation costs by an estimated $100-$300 per vehicle by eliminating wet chemistry steps
- Greater dissimilar material utilization across the vehicle as result of creating a single coating substrate as well as a single adhesive, which can enable vehicle weight reduction

Applications in Our Nation's Industry

This cold plasma coating technology will provide extensive benefits for in-line automotive manufacturers. The initial application is in-line automotive anti-corrosion coatings for adhesive bonding of dissimilar materials. This technology is expected to replace traditional wet chemistry processes.

Project Description

The project objective is to develop a novel material coating system using an innovative atmospheric cold microwave plasma jet to enable surface functionalization for harsh environments. The atmospheric cold microwave plasma jet method provides a single, cost-effective, high-volume production process that meets the requirements of multi-material combinations relevant to the energy-intensive transportation industry while eliminating off-line material pretreatment.

The project outcomes address the following steps: (a) develop the compact plasma microwave source with sufficient size, weight and power to meet the requirements and technical specifications for an in-line process in a manufacturing environment; and (b) process development to demonstrate corrosion resistance and improved adhesion and bonding performance suitable for difficult-to-join or dissimilar materials.

The full-scale coating should validate dissimilar material adhesive joint strength following environmental exposure specified as a minimum of 80% of the ambient adhesive bond strength coupled with a cohesive bond fracture mode.

Barriers

- Miniaturization and integration of microwave delivery system for size, weight and power specifications for in-line robotic manufacturing
- Wide parameter space for harsh-environment coatings with hybrid sputtering and chemical vapor deposition

Pathways

The project is structured to address the key barriers and minimize risk. The ultimate goal is to apply a novel corrosion-resistant material coating using the microwave cold plasma jet for multi-material structures in harsh environments.

The first project pathway will identify and resolve roadblocks for microwave plasma jet applicator development. These roadblocks (e.g. mechanical tuning elements, bulky waveguides, etc.) will be addressed by demonstrating a compact microwave plasma generator, as well as streamline flow for the extended plasma jet. Laboratory-scale demonstrations will be completed at a third-party test site to validate sufficient size, weight, and power requirements for in-line manufacturing environments.

The second pathway will conduct design of experiments on material coatings. These experiments include surface analysis screening tests for initial material coating designs, tactical wet exposure lap-shear strength evaluations, and corrosion testing analyses on ideal material coatings. These tests will be accomplished using baseline silicon dioxide coatings, as well as silane, alumina or zirconia precursors.

The third pathway will validate plasma jet and coating implementation readiness. This will include the plasma source design for operation in a relevant field test environment and the surface coatings for corrosion resistance under harsh service conditions. The final coatings will then undergo strategic corrosion analyses to verify target performance factors.

Milestones

This two-year project began in July 2018.

- Confirm verifiable pathway for plasma source to meet minimum system requirements (2019)
- Validate plasma surface coatings provide minimum 80% adhesion strength subject to baseline harsh corrosion environment (2019)
- Complete down-selected matrix of approximately 20 plasma coating exposures per material set under selected recipe conditions; and perform corrosion analysis with basic lap shear and environmental exposure analysis plus full-range strategic corrosion testing (2020)

Technology Transition

Starfire Industries, LLC is partnering with the University of Illinois and General Motors, LLC for the design, fabrication and testing of the novel material coating system using an innovative atmospheric cold microwave plasma jet. Following successful development, the team plans to retain intellectual property rights developed under this program. In addition, Starfire will insert the microwave cold plasma jet coating system into their internal product development process, use internal resources for product beta testing and deployment, and manufacture domestically. The team plans to transition the plasma coating system to an available technology for multi-material automotive joints.

Project Partners

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