Environmental Management Science Program

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Atmospheric-Pressure Plasma Cleaning of Contaminated Surfaces

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Research Objective

The object of this research program is to develop an atmospheric-pressure plasma jet for converting transuranic wastes (TRUs) into low-level radioactive wastes (LLWs). This plasma process will be used to efficiently decontaminate a wide range of structures and equipment.

Research Progress and Implications

This report summarizes work after 1 year and 9 months of a 3-year project.

A picture of the atmospheric-pressure plasma jet is shown in Fig. 1. This new plasma source consists of two concentric electrodes through which a mixture of helium and reactive gases flow. The plasma is ignited by applying 13.56 MHz RF power to the inner electrode. The characteristics of this discharge are different from other atmospheric-pressure plasmas, such as transferred arcs, torches, coronas and silent discharges. Shown in Fig. 2 is the current-voltage curve for the plasma jet. Spark breakdown occurs at 0.01 A, and is proceeded by a “normal glow” region, in which the voltage remains constant with increasing current, and an “abnormal glow” region, in which the voltage increases rapidly with current. At about 1.0 A and 225 V, the plasma begins to arc. The normal glow region is rarely observed in atmospheric pressure plasmas. They usually proceed directly from spark breakdown to arcing. The trend shown in the figure indicates that the plasma jet is stable over a wide range of operating conditions.

The distribution of reactive species in a plasma jet, containing oxygen and helium, has been characterized by Langmuir probe measurements, optical emission spectroscopy, and ultraviolet absorption spectroscopy. The charged particle density ranges from about $5x10^{11}$ cm^{-3} inside the plasma to $1x10^{10}$ cm^{-3} in the jet exit. The concentration of metastable oxygen molecules ($a^1\Delta_g$ and $b^1\Sigma_g^+$) is estimated to be between 10^{12} to 10^{13} cm^{-3}. By contrast, the ozone concentration increases from about $5x10^{14}$ cm^{-3} inside the plasma to $1x10^{16}$ cm^{-3} in the effluent. The ozone molecules are produced by the reaction of O atoms with O_2 molecules: $O + O_2 + M \rightarrow O_3 + M$. To generate the amount of ozone observed, the O atom concentration in the plasma must be near $1x10^{16}$ cm^{-3}, or about 10% of the oxygen fed. These results are quite unexpected, because most non-equilibrium, low-temperature plasmas achieve a much lower degree of dissociation.

The etching of actinide metals has been simulated by using tantalum as a surrogate material. Tantalum etching rates of up to 1.2 μm/min are achieved with the plasma jet using a CF_4/O_2/He gas feed. This is 10 times faster than conventional plasma systems, and indicates that our atmospheric-pressure plasma is a promising technology for decontamination of DOE sites.

Finally, the plasma jet has been successfully modified to process larger areas, up to about 1.0 ft^2. Work is underway to increase the process scale further. We are confident that this technology is capable of being adapted for decontamination operations in the field.

Planned Activities

Our research in the third year will include etching of actinide metals (Ur and Pu), further studies of tantalum etching, jet scale-up, and characterization of the chemical constituents in plasmas containing CF_4, O_2, and He gases. A collaboration with the actinide research group at Los Alamos National

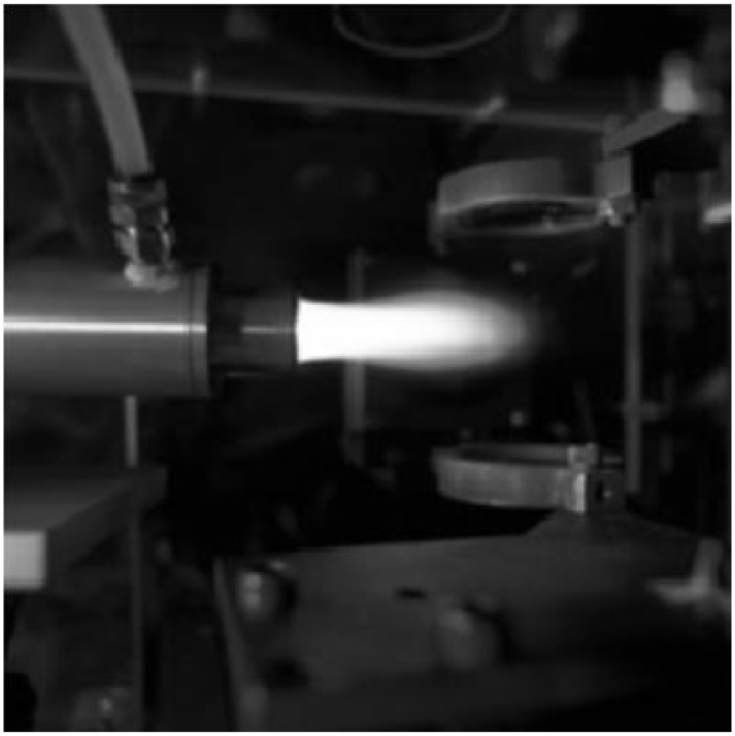

Fig. 1. The atmospheric-pressure plasma jet.

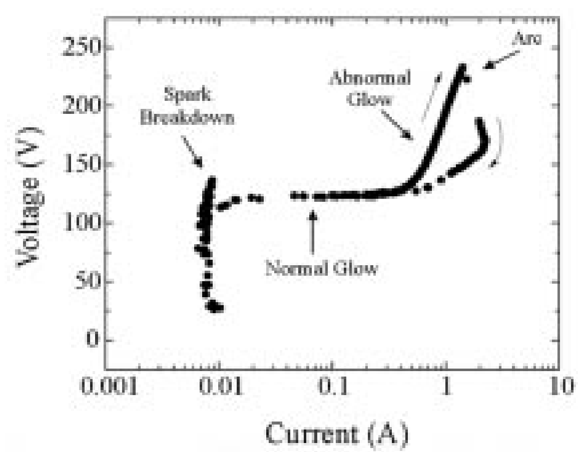

Fig.2. Current-voltage characteristics of the atmospheric pressure plasma jet.

Laboratory has been established, and a plasma jet will soon be installed in the radioactive material research facility. The other projects are well underway.

Other Access To Information

J.Y. Jeong, S.E. Babayan, V.J. Tu, J. Park, R.F. Hicks, and G.S. Selwyn, Plasma Source Sci. Tech., accepted for publication.
S.E. Babayan, J.Y. Jeong, V.J. Tu, J. Park, G.S. Selwyn, and R.F. Hicks, Plasma Source Sci. Tech., accepted for publication.
Schütze, J.Y. Jeong, S.E. Babayan, J. Park, G.S. Selwyn, and R.F. Hicks, IEEE Transaction in Plasma Sci., accepted for publication.

For more information, visit our web site at: **prosurf.seas.ucla.edu/memc/plasma.html**