

Atmospheric-Pressure Plasma Cleaning of Contaminated Surfaces

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Outline

- Summary of Progress
- Jet Design
- Physics and Chemistry of the Jet
- Tantalum Etching Results
- Conclusions
- Future Work

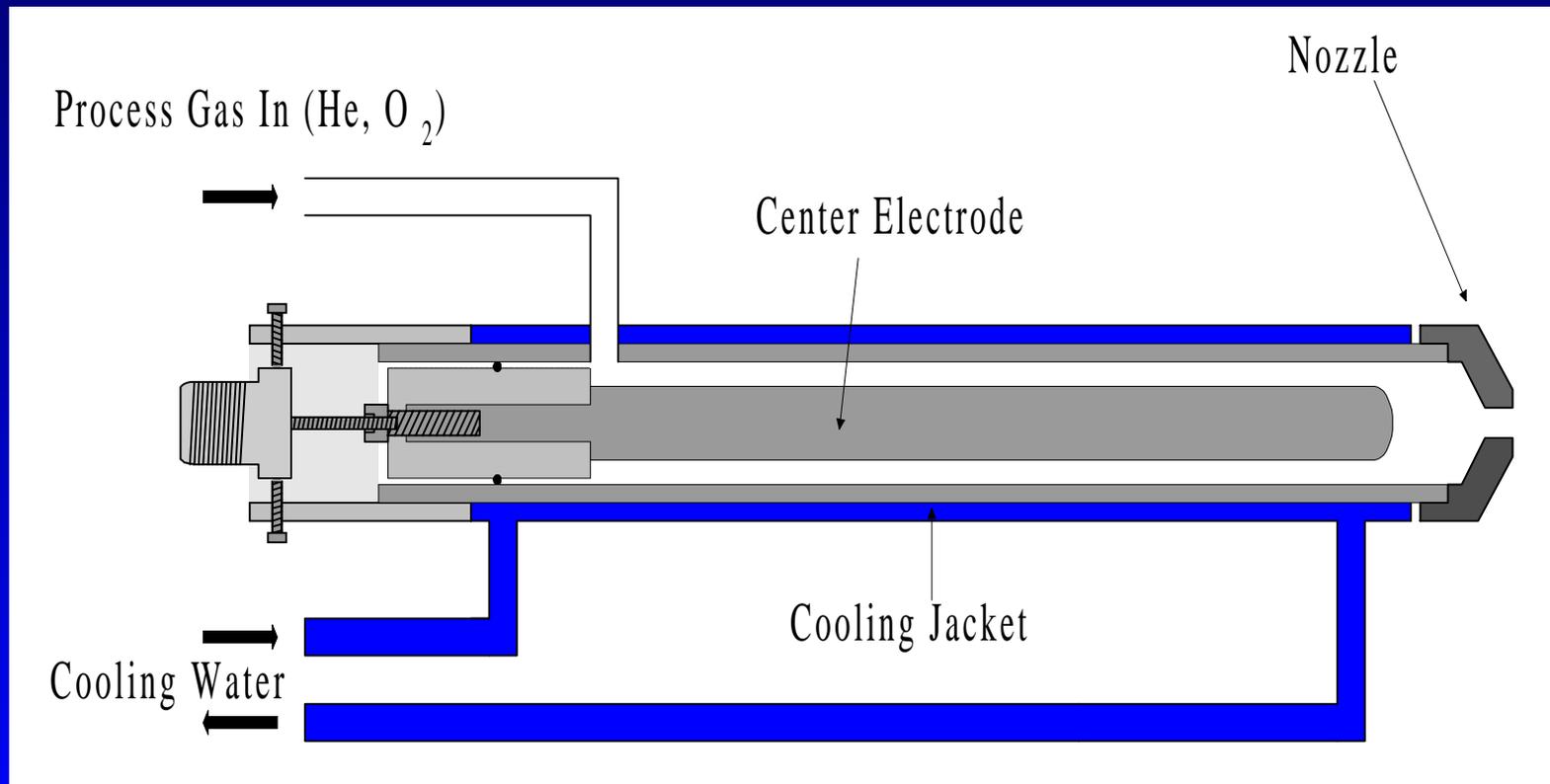


Summary of Progress

- Optimized electrode design.
- Scaled-up plasma jet to 4 inches.
- Characterized physics and chemistry of O_2/He plasma.
- Established process conditions for tantalum etching (plutonium surrogate).

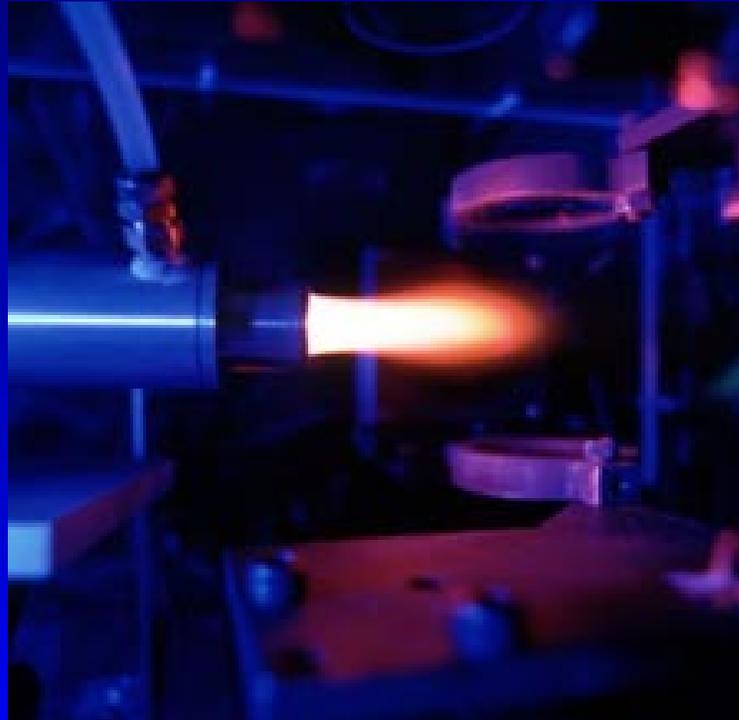


Schematic of the Plasma Jet





Current Jet Design

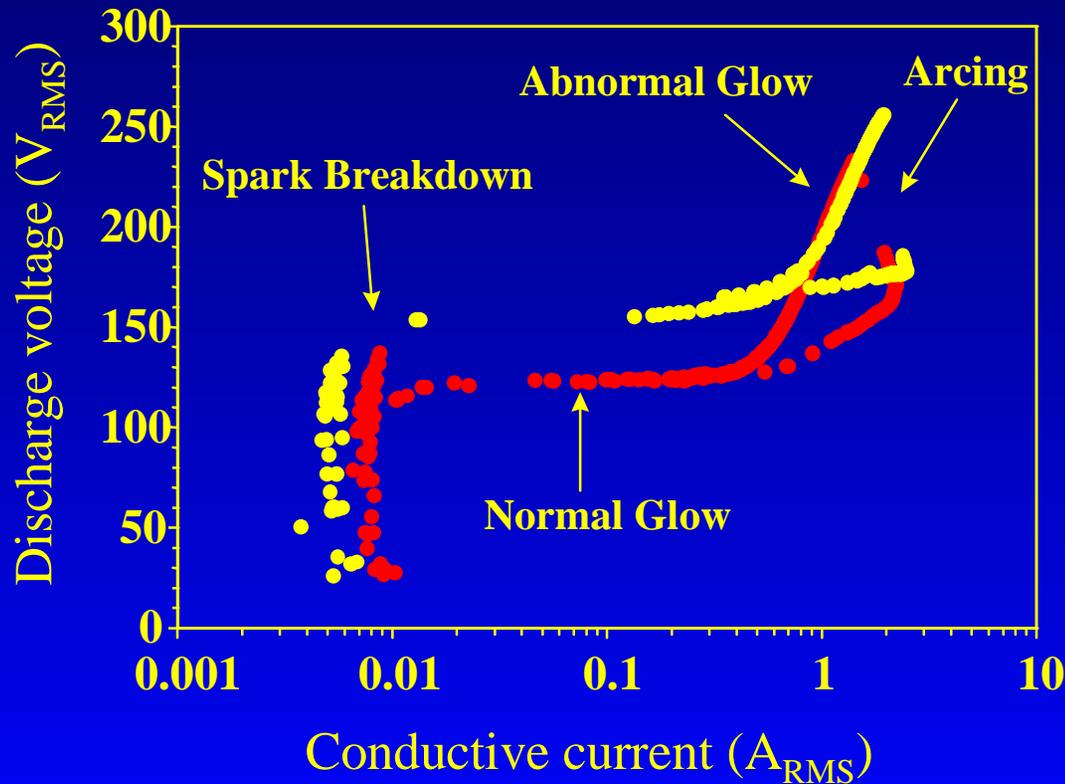


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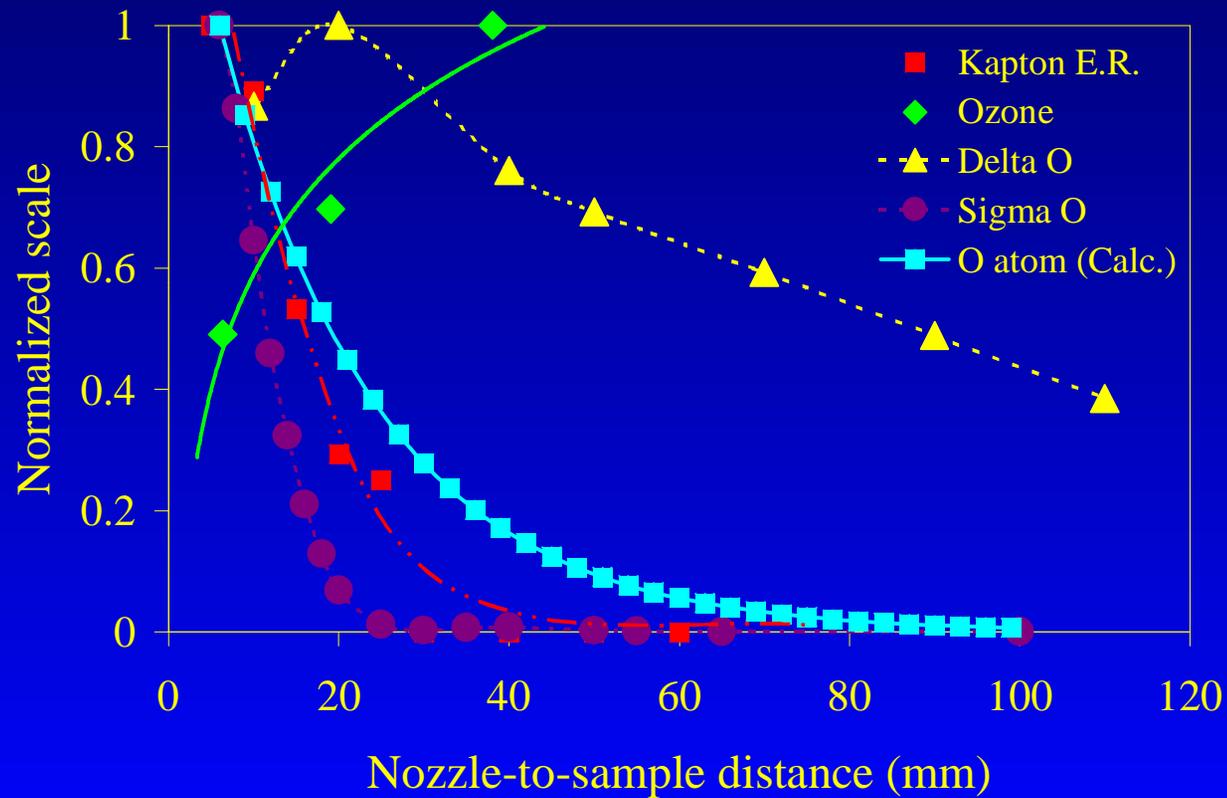
Voltage-Current Characteristics of the Plasma Jet



- Similar trend to DC discharge.
- Helium provides normal glow region.



Effect of Distance on Etch Rate and Signals for Reactive Species





Comparison of Species in Low- and Atmospheric-Pressure Plasmas

Source	Density (cm ⁻³)		
	O ⁺ , O ₂ ⁺ , O ⁻	O	O ₃
Low-pressure discharge	10 ¹⁰	10 ¹⁴	<10 ¹⁰
Arc and plasma torch	10 ¹⁵	10 ¹⁸	<10 ¹⁰
Corona	10 ¹⁰	10 ¹²	10 ¹⁸
Dielectric barrier	10 ¹⁰	10 ¹²	10 ¹⁸
Plasma jet	10 ¹²	10 ¹⁶	10 ¹⁶



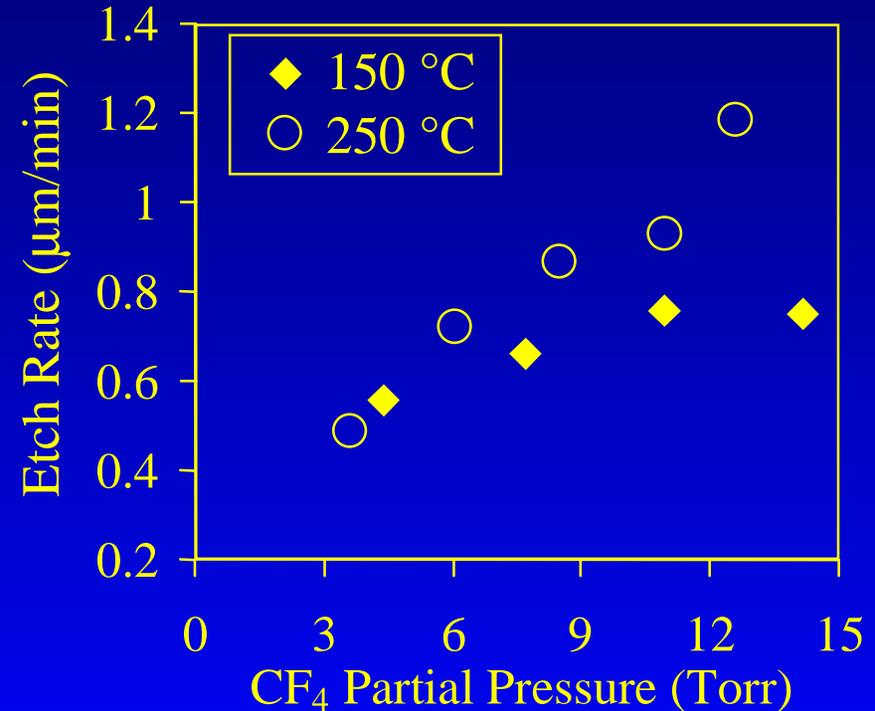
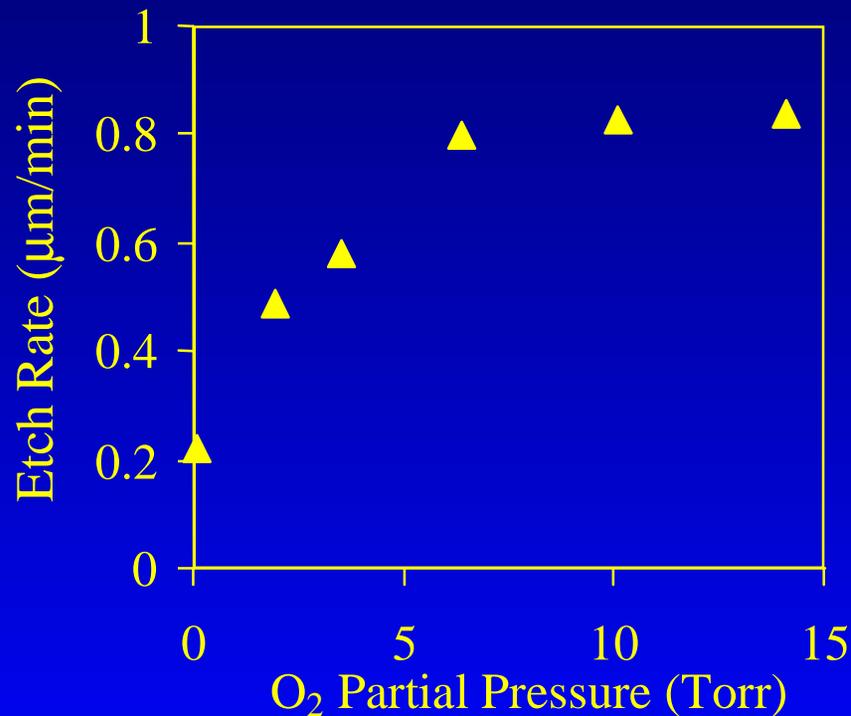
Plasma Etching of Tantalum

Process conditions:

- Total Flow: 51 L/min, He/O₂/CF₄
- O₂: 6 ~ 12 Torr
- CF₄: 6 ~ 24 Torr
- Power: 200 ~ 550 W
- Temperature: 100 ~ 300 °C
- Nozzle-to-sample distance: 2 ~ 5 mm



Effect of Process Conditions on Tantalum Etching Rate





Conclusions

- Fast etching rates of tantalum: up to 2 $\mu\text{m}/\text{min}$.
- The plasma jet performs the same as low-pressure plasmas, but without requiring a vacuum chamber.
- The jet may be scaled up to decontaminate buildings and structures.
- Technology will soon be ready for field testing.



Future Work

- Determine uranium etching rates.
- Identify surface reaction mechanism for plasma-jet etching of tantalum.
- Identify reactive species in CF_4/He plasma.
- Field test plasma jet for decontamination of DOE sites.