Detection of Iridium Using Laser-Induced Breakdown Spectroscopy

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Introduction

There are two common types of space-flight thrusters: Monopropellant and Bipropellant. Bipropellant thrusters require the use of both a fuel and oxidizer line, where as monopropellant thrusters need just a fuel line. This is because monopropellant thrusters release energy through catalytic decomposition of the fuel inside the rocket chamber.

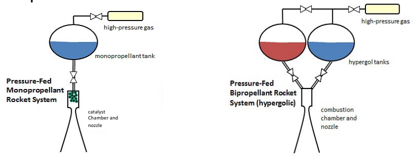


Figure 1. Diagram of a monopropellant thruster and a bipropellant thruster.

The development of new monopropellant hydrazine replacements, such as AF-M315E, requires new and greater capabilities in the state-of-health diagnostics such as detecting and quantifying catalyst degradation and active material migration. One of these active materials is iridium.

Laser-Induced Breakdown Spectroscopy

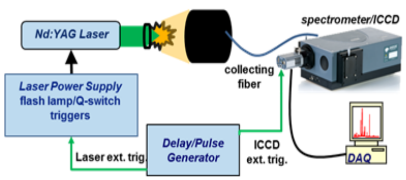


Figure 2. Basic set up of Laser-induced breakdown spectroscopy apparatus.

Plasma Spark

The sample to be interrogated is rapidly heated using a high intensity laser, which dissociates the sample into its constituent atoms. The high electric field of the laser also induces ionization; the atoms are stripped of their electrons, to form corresponding ions. The ionized gas (plasma) subsequently cools, whereupon the electrons and ions recombine to form exited species, which is accompanied by the emission of light as the exited species relax to lower electronic states.

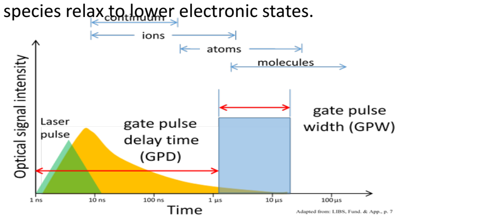


Figure 3. The optical intensity of the plasma spark versus time, and possible positions for gating (GPD) and width (GPW) to detect emission from various excited species (logarithmic x-axis).

Previous Work

Detection of iridium using LIBS and the identification of specific iridium lines that would be suitable for the monitoring of iridium in a rocket thruster plume.

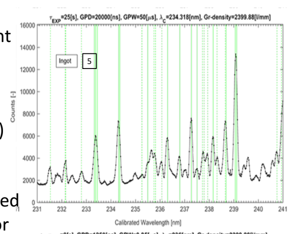
LIBS was conducted on four different samples containing iridium:

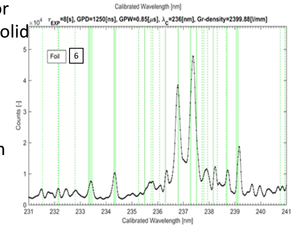
- Solid iridium ingot (99.95%)
- Iridium wire
- Iridium foil (comparable to ingot)
- Supported catalyst

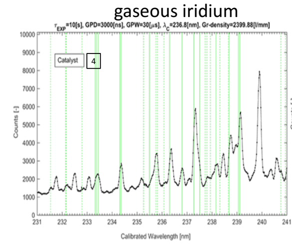
Initial summary and conclusion stated that these findings could be used for the analysis of both solid and non-solid phase iridium in thruster plumes.

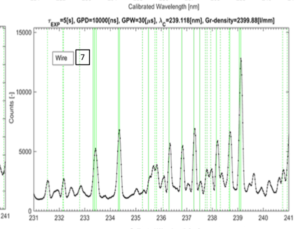
Furthermore, analysis revealed:

- Gaps in the LIBS spectra
- Solid and non-solid phase iridium plasma behave differently
  - Replicate study for gaseous iridium









Figures[1] 4-7. LIBS data for iridium ingot, wire, foil, and catalyst. Solid and dotted green lines represent, respectively, strong and weak iridium emission wavelength values in the NIST database.[2]

Current Method[3]

A beam from a 10-ns pulsed-Nd:YAG laser operating at 532 nm was focused to deliver about 80 mJ of energy into the center of a Pyrex cell containing the sample to be interrogated.

Figure 8. LIBS setup showing the laser, focusing lens, Pyrex cell, and the emission collection box.

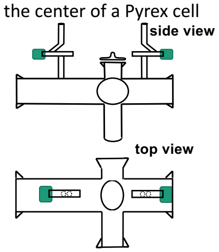
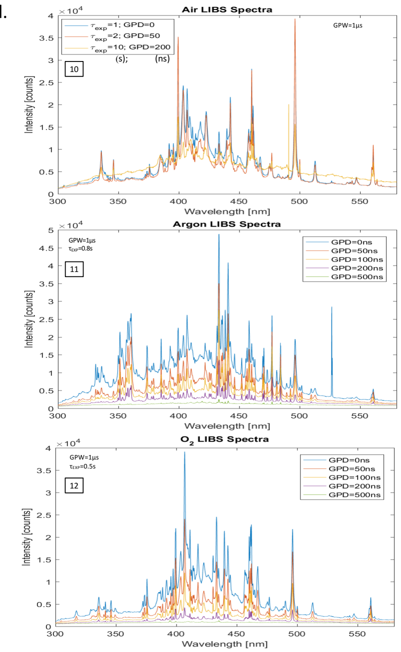


Figure 9. Schematic of the Pyrex cell used to analyze the iridium samples.

Results

LIBS data collected in different background gases indicated that the intensity of the spectrum decreases as the gate pulse delay (GPD) increased.



Figures 10-12. LIBS data in air, argon, and oxygen with various GPDs.

Discussion and Future Work

Solid iridium has been successfully analyzed using laser-induced breakdown spectroscopy (LIBS). The results indicate that as the GPD increases, the relative spectral intensities of the atomic species decrease. Moving forward, more labile samples of iridium are being tested in the hopes of acquiring a LIBS signature from gas-phase iridium. This method will be used *in-situ* to quantify the rate of active catalyst material loss in conjunction with *real-time* thruster performance measurement.

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