High-pressure, oxygen-rich environments increase risk of a metal-fire in the ox-rich turbopump of a staged combustion rocket engine. A triple-phase composite environmental barrier coating (EBC) has shown to provide resistance to particle-impact ignition, a dominant failure mode in the turbine of these turbopumps.

### II. Background

Thermal transients at engine start-up and shut-down can cause the coating to delaminate.

### III. EBC Deposition and Preferential Etching

#### A. EBC Deposition

- Add 1 part distilled water to a plastic bottle.
- Add 20 g of FeCl$_2$ powder in a separate dry container.
- Use a plastic spoon to add small portions of the powder into the water bottle.
- Stir to dissolve the solution as you add more FeCl$_2$ powder.
- Let the solution cool down and dip the EBC pellet for 96 hours after immersing it in the solution.

#### B. EBC Preferential Etching

- Step 1: Add 100 mL of distilled water to a plastic bottle.
- Step 2: Add 50 g of FeCl$_2$ powder in a separate dry container.
- Step 3: Use a plastic spoon to add small portions of the powder into the water bottle.
- Step 4: Stir to dissolve the solution as you add more FeCl$_2$ powder.
- Step 5: Let the solution cool down and dip the EBC pellet for 96 hours after immersing it in the solution.

### IV. EBC Thermal Cycling Rig Design

**Purpose:** Subject an EBC-coated disk specimen to the thermal cycling conditions of a reusable rocket engine.

- The sample, mounted at one end of a tubular steel arm, is rotated between a liquid nitrogen (LN) container and flame torch.
- Hot flame subjects the sample to a hot-shock that simulates the start-up of the engine.
- LN reproduces cold shock conditions at shut down.
- A step-servo motor and gear-box assembly is used to actuate the rig.
- A programming code specifies the motion profile that replicates rocket engine thermal transients.

### V. Conclusions

- Deposited protective EBC of thicknesses greater than 50 µm using multiple coating deposition cycles.
- Interpenetrating phase structure revealed by etching indicates presence of ductile-toughening effect in the EBC.
- Designed a rig to test EBC coated IN718 samples under thermal cycling conditions of a reusable rocket engine.

### VI. Future Work

- Conduct thermal shock experiments in the final setup until simulating 1000 flights.
- Install a gear box in the thermal shock rig system in order to fix the inertial mismatch between the motor and the load (rig and EBC specimen).
- Identify the optimal angle and speed to submit the EBC sample into thermal shock.
- Characterize the EBC sample to further assess its performance throughout thermal cycling.
- Identify a method that prevents oxidation between the metal-ceramic-glass composite coating, Ni bond-coat, and IN718 sample.

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### VIII. References