High Temperature Bond and Thermal Barrier Coatings

Kyle Murphree, Anatoliy Shchetkovskiy, and Timothy McKechnie

Plasma Processes, Inc.

Introduction

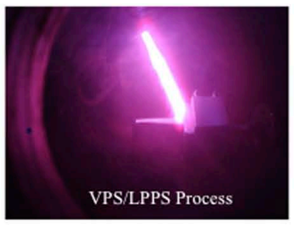
- To increase turbine temperatures, materials/coatings new to turbines required
- Rocket nozzles operate at higher temperatures: 1600 – 3000+°C
- Can high temperature thermal and oxidation systems increase turbine temperatures?

1

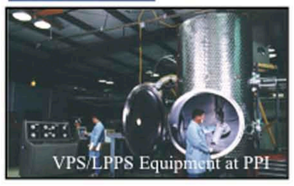
Conventional TBCs

- MCrAlY by VPS/LPPS or PtAl by plating & diffusion
- Zirconia partially stabilized with 8% yttria (YSZ) by EB-PVD or plasma spray

Large gas turbine blade with LPPS MCrAlY bond and plasma sprayed YSZ thermal barrier coating



VPS/LPPS Process



VPS/LPPS Equipment at PPI

2

New Coating System

Table 1. Thermal protection system description

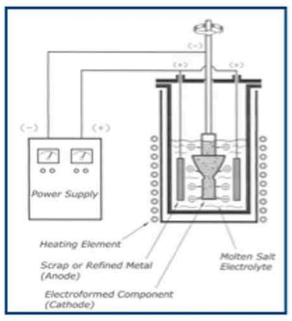
Component	Material	Melting Point (°C)	Manufacturing Process
Thermal Barrier	YSZ or $La_2Zr_2O_7$	2715	Very Low Pressure Plasma Spray[1]
Thermally Grown Oxide	Hafnium Oxide	2758	Electrodeposition[2] of Hf and oxidation
Oxidation and Corrosion Barrier	Iridium	2410	Electrodeposition[2]
Diffusion Barrier	Rhenium	3180	Electrodeposition[2]
Superalloy	Inconel 738	1400	Casting

1. Very Low Pressure Plasma Spray also known as LPPS-TF is new technology to apply coatings with PVD type properties using large footprint vacuum plasmas
2. Electrodepositon by EL-Form™ molten salt electrodeposition which deposits thick, dense, ductile, and crack free metal coatings.

3

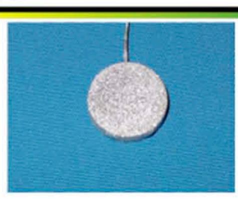
EL-Form™ Deposition

- EL-Form™ is electrodeposition in a molten salt solution
- Inert atmosphere enables the processing of oxygen sensitive materials such as refractory metals
  - Re, Nb, Nb-Zr, W, W-Re, etc.
  - Ir, Rh, Pt (corrosion resistance)
- Low cost due to reduced material and labor requirements
- Ability to produce high purity components utilizing scrap/refined material as the precursor due to electrochemical refining
- Non-toxic molten salt processing (electrolyte)
- Deposition rates of 10-50 μm/hour
- Thickness: microns to 5 mm
- Pulse-current processing enables the ability to tailor the microstructure of the deposit

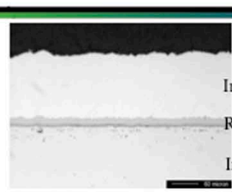


4

High Temperature Bond Coat



- Coated Inconel 625 sample after ten cycles of 1200°C air to water quench



Iridium
Rhenium
Inconel 625

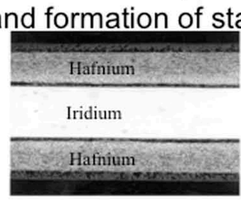
- Inconel 625 coated with rhenium diffusion barrier and iridium oxidation barrier

5

Thermally Grown Oxide

- PtAl and NiAl oxidize to form α Al_2O_3
- Long term thermal exposure depletes Al via diffusion into superalloy and Al_2O_3
- Ir-Hf alloys have shown high oxidation resistance and formation of stable oxide

Hf/Ir sample after exposure to 1300°C for 3 hours



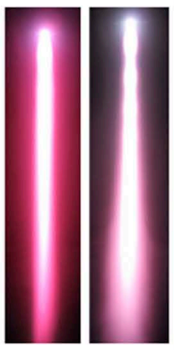
HfO_2

HfO_2

6

TBC by Very Low Pressure Plasma Spray

- Conventional TBCs use Zirconia stabilized with Yttria
  - EB-PVD => Columnar structure, better thermal fatigue
  - Plasma Spray => Splat structure, lower thermal conductivity
- Very Low Pressure Plasma Spray can produce ceramic layers:
  - Columnar
  - Splat structure
  - Mixed mode
- Use VLPPS to make lower conductivity columnar zirconia or pyrochlore



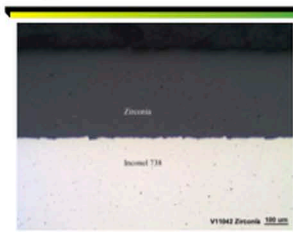
VLPPS 1.5 m length

7

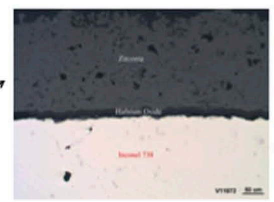
El-Form Deposition

8

TBC via Plasma Spray



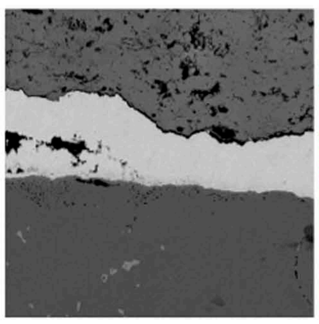
VLPPS produced very dense coating with little strain tolerance due to difficulty reaching extremely low pressures

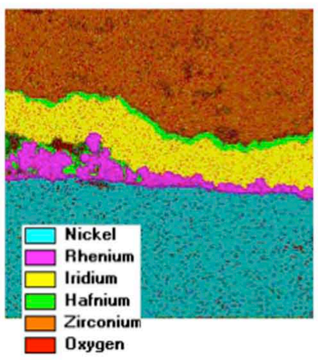


So APS YSZ was deposited as a TBC instead

9

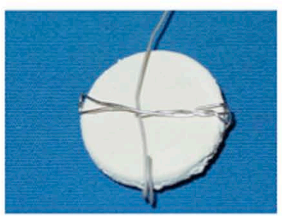
SEM and EDS of a sample before thermal cycling





10

Mass loss of samples



Sample with YSZ, HfO_2, Ir, Re, and Ni layer on Inconel 738 substrate

Sample	Average rate of mass loss (g/hour)
Iridium	0.045
Hafnia coated sample	0.011
1	0.011
3	0.0008
4	0.0007
5	0.001
6	0.003
7	0.001

Separation was observed in all samples. Sample 4 showed the least separation thus has the smallest mass loss.

11

Conclusions/Observations

- A complex new EBC/TBC system has been formed on superalloys. The coating system is comprised of four layers:
  - Rhenium (a diffusion barrier between superalloy and EBC)
  - Iridium (EBC)
  - HfO_2 TGO (formed from HF layer)
  - ZrO_2-$8Y_2O_3$ (TBC)
- Due to electrochemical reaction with rhenium electrolyte, Inconel 738 LC also required a nickel barrier coating
- In thermal exposure and cycle testing, the following were observed:
  - Bare iridium volatilized
  - Hf/ HfO_2 TGO slowed iridium volatilization to a minimum
  - HfO_2 TGO separated with zirconia TBC from Iridium (or the remaining Ir-Hf compound)

12

University Turbine Systems Research Workshop - State College, PA - October 19-21, 2010