

Kinetic Metallization

Application of Oxidation/Corrosion Resistant Coatings
to Rocket Engine Combustion Chamber Liners

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Overview

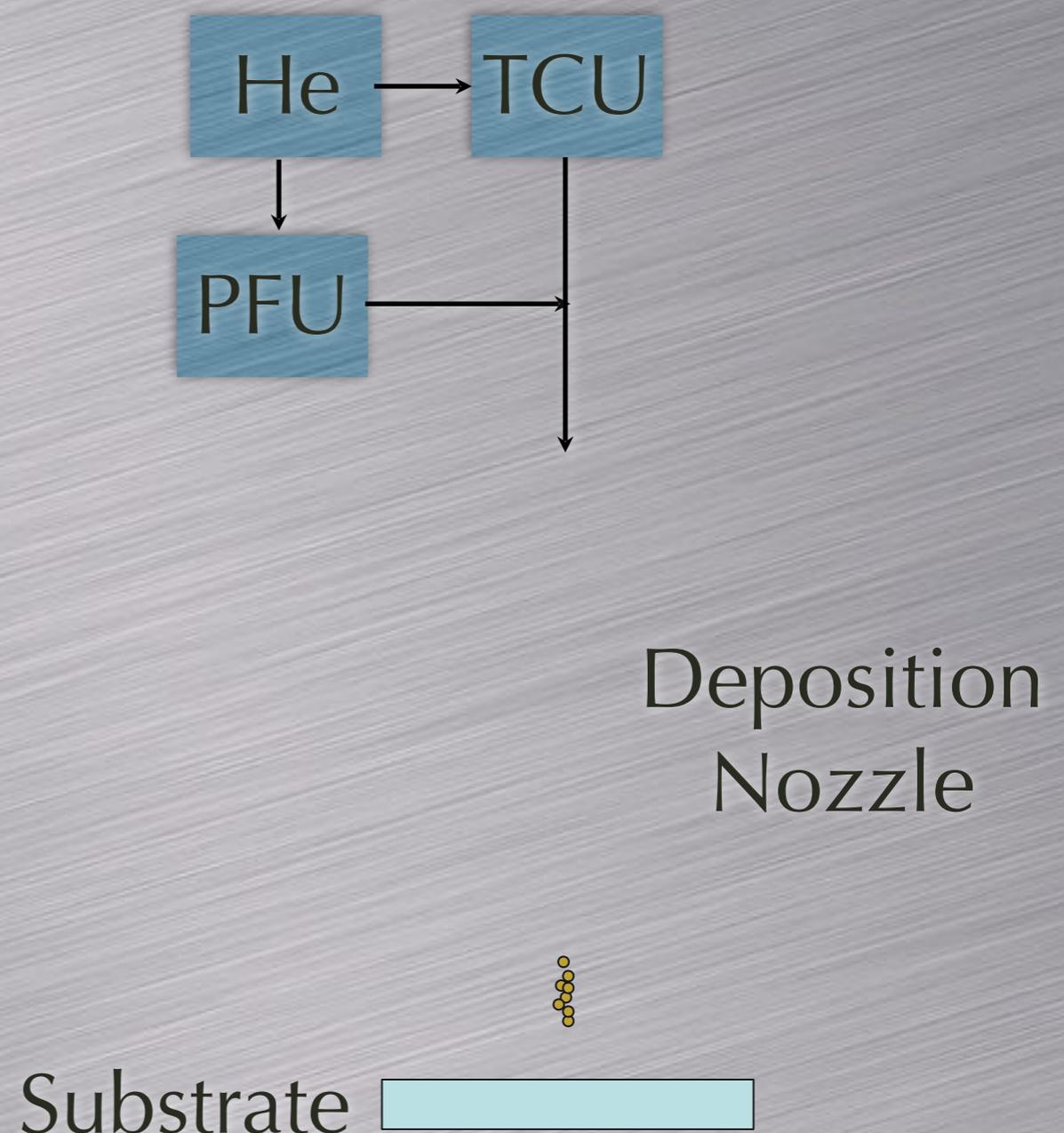
- Introduction to Kinetic Metallization
- Application
 - Oxidation/Blanching Resistant Coatings for Combustion Chamber Liners
- Coating Properties
 - Tensile Properties
 - Thermal Conductivity
- Oxidation Test Results
 - TGA
 - Cyclic Oxidation
- Summary/Future Work

Kinetic Metallization

- Impact Consolidation Process
 - Feed-stock: fine powder
 - Accelerant: inert light gas
- Solid-state Consolidation
 - No Bulk Melting
 - No Liquid Chemicals
- Environmentally Innocuous
 - No Particle or Hazardous Gas Emission

Process Flow

- Powder fluidized using pressurized He gas (PFU)
- Powder/gas mix thermally conditioned to improve deposition efficiency (TCU)
- Deposition nozzle produces highly collimated spray pattern
- Area coverage using X-Y rastering of nozzle and/or rotation of substrate



KM-CDS

First KM-CDS Shipped!!

Buyer: US Naval Academy

Located: NAVSEA-Carderock

- Coating Development System
- Desk sized
- Production unit
 - Same footprint
 - Remove spray enclosure



Application

SSME Main Combustion Chamber (MCC)

- MCC liner life in LOX/H₂ engine limited by thermal ratcheting failure initiated by cyclic oxidation/reduction (“blanching”) of copper alloy liner
 - Desire high conductivity coating that forms adherent, self healing oxide that is stable in H₂
- Candidate coatings include Cu-xCr, where x = 20 to 30 vol.%
 - Study initiated to select optimum composition of Cu-XCr based on mechanical properties and oxidation resistance

Advantages

● KM vs. Thermal Spray

● Eliminates:

- Porosity
- Oxygen pickup
- Interlayer bond coats
- Vacuum chamber

Coating Properties

KM Cu-Cr
Deposit

- Bulk Cu-Cr specimens machined from 10-mm thick KM deposits
- Tensile
- Thermal Conductivity
- Three Cu-Cr compositions evaluated:
 - Cu-20vol.%Cr
 - Cu-25vol.%Cr
 - Cu-30vol.%Cr



Copper
Substrate

Tensile
Specimens



Thermal
Expansion
Specimens

Thermal
Conductivity
Specimens

Tensile Properties

- KM Cu-Cr tensile properties equivalent to wrought
- Strength increases (ductility decreases) with increasing Cr content



Fractography

- Ductile, microvoid coalescence observed at room temperature

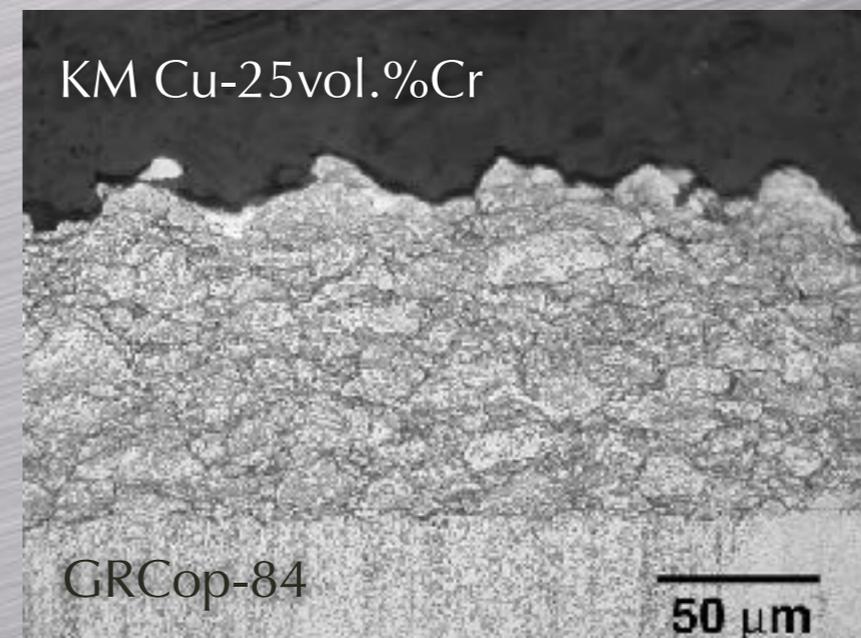
Thermal Conductivity

- KM Cu-Cr thermal conductivity equivalent to wrought
- Conductivity decreases with increasing Cr content

Oxidation Behavior

- Evaluation of KM Cu-Cr coated GRCop-84 TGA coupons included:
 - Coating Adhesion
 - Static Oxidation
 - Cyclic Oxidation
- Three Cu-Cr compositions evaluated:
 - Cu-20vol.%Cr
 - Cu-25vol.%Cr
 - Cu-30vol.%Cr

KM Cu-Cr Coated GRCop-84
TGA Coupons



Coating Adhesion

- Coating adhesion improved by post-deposition heat treatment



Note: Arrows indicate failure in epoxy

Static Oxidation

- Formation of continuous Cr_2O_3 layer underneath external CuO slows oxidation rate
- Oxidation rate decreases with increasing Cr content

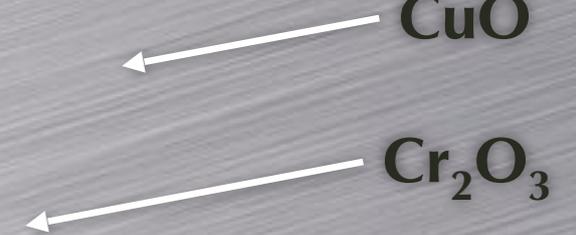
20Cr

25Cr

Cu-Cr coating

CuO

Cr_2O_3



Cyclic Oxidation

● Cyclic Temperature 77 °K to 1023 °K

- Best oxidation resistance Cu-Cr Coating with 25vol% Cr
- Spalling observed

25.0 Cr

20.0 Cr

Cu-25vol.%Cr

Cu-20vol.%Cr

650°C

750°C

Summary

- Kinetic Metallization achieves high density, adherent Cu-Cr coatings
 - Eliminates need for interlayer bond coat
 - Eliminates oxygen pickup during spray process
- Best balance of oxidation protection and mechanical properties offered by Cu-25vol. %Cr

Future Work

KM NiCrAlY

- NASA initiated new program to evaluate KM NiCrAlY coatings for next-generation LOX/kerosene engines
- Preliminary work has shown that low porosity, well-adherent KM NiCrAlY coatings can be applied to GRCop-84
 - No grit blasting surface preparation required
 - No interlayer bond coat required