NTP CERMET Fuel Development Status

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Nuclear and Emerging Technologies for Space (NETS) 2017 Orlando, FL
NTP CERMET FUEL DEVELOPMENT
• GE710 Program
• NTP CERMET Fuel Development

CERMET FABRICATION USING TUNGSTEN POWDER COATING AND SPARK PLASMA SINTERING
• Background
• Tungsten Powder Coating
• Spark Plasma Sintering
• Experimental Approach
• Results
• Conclusions
GE710 Program

• Extensive CERMET fuel development program
  – Over 15 million invested from May 1962 to Sept 1968
  – Operated fuel element fabrication line for reactor-sized fuel elements
  – Successfully fabricated 40+ W-60vol%UO₂ fuel elements for qual testing
    • Conducted over 300,000 hours of qualification testing

• 710 fabrication approach
  – Press and sinter W-UO₂ compacts
  – Machine cooling channels
  – Stack compacts
  – Weld tubes for cooling
  – Weld external cladding
NTP CERMET Fuel Development

- Hybrid GE710 Approach
  - GE710 approach with modern fabrication processes
    - Spark Plasma Sintering
    - Tungsten Powder Coating

- FY16 Development Efforts
  - Fabricated W-dUO₂ compacts using Spark Plasma Sintering and Tungsten Powder Coating
  - Phase I SBIR – Bonding tungsten CERMET compacts
  - Phase I SBIR - Electrolytic method for tungsten coating

NTP CERMET Fuel Development

- **FY17 Development Efforts**
  - Developing process to fabricate subscale surrogate elements from compacts
  - Optimizing compact fuel element environmental testing (CFEET) apparatus
  - Initiating multiscale modeling task
  - Tungsten electron beam welding study

- **FY18 Planning**
  - SPS fabricate compacts with particles provided by BWXT
  - Hot hydrogen screening of W-dUO$_2$ compacts and subscale fuel segments
CERMET Fabrication using Tungsten Powder Coating and Spark Plasma Sintering

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Background

- Past efforts focused on consolidating blended tungsten powder and uncoated dUO$_2$ particles
  - Poor quality feedstock
    - Large particle size distribution
    - Non-spherical particles - agglomeration
    - Need for coated particles
  - Particle segregation/non-uniform distribution of UO$_2$ within W matrix
  - Low density/ partial consolidation
  - Fuel element distortion
  - Explored CVD coating
    - Complex process due to the need to fluidize particles

- Developed W powder coating
  - Non compatible with past consolidation methods
  - Led to SPS

- Small amount of CIF funding augmented by NTP Project
Tungsten Powder Coating

- Straightforward approach to particle coating
- Conducted experiments with 6 different organic binders
- Coating Process
  - Blend W powder, dUO$_2$ particles, and binder
  - Stir mixture above binder drop point on hot plate for 5 min
- Not as uniformly coated as CVD coated particles

Spark Plasma Sintering

- Rapid Consolidation/Sintering
- Net-shape/Near Net-Shape Parts
- High Density Parts
- Simple Process

1. Pictures courtesy of UC Davis and Substech
Experimental Approach

• Utilized SPS system at CSNR to sinter W/\( \text{UO}_2 \) samples
  – Used W powder coated particles
• Sintered 24 samples at 1600\(^\circ\)C, 1700\(^\circ\)C, 1750\(^\circ\)C, 1800\(^\circ\)C, and 1850\(^\circ\)C peak temperatures
• 20-minute dwell time at peak temperatures; Pressure of 50 MPa
• Measured density and SEM
• TEM, hardness, and further SEM planned
• CFEET testing planned
## Results

- **Density**
  - Increased with peak sintering temperature
  - Near theoretical density

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Results

- Density

**Max Temp vs % Theoretical Density**

- A graph showing the relationship between Max Temp (°C) and % of Theoretical Density.
- The data points indicate an increasing trend as Max Temp increases.
Results

• SEM
  – Improved microstructure
  – UO₂ particles more uniformly dispersed
  – Cross-section depicts some particle elongation

Results

- Energy-dispersive X-ray spectroscopy (EDS)
  - No unexpected phases
Conclusions

• Improved mechanical properties and microstructure
• Further characterization needed and planned
  – Mechanical Properties
  – Thermal Properties
  – Chemistry
• Develop process to form elements from compacts
  – Stacking
  – Bonding
  – Cooling channel formation
  – Cladding