Tantalum Oxide-Based Environmental Barrier Coatings

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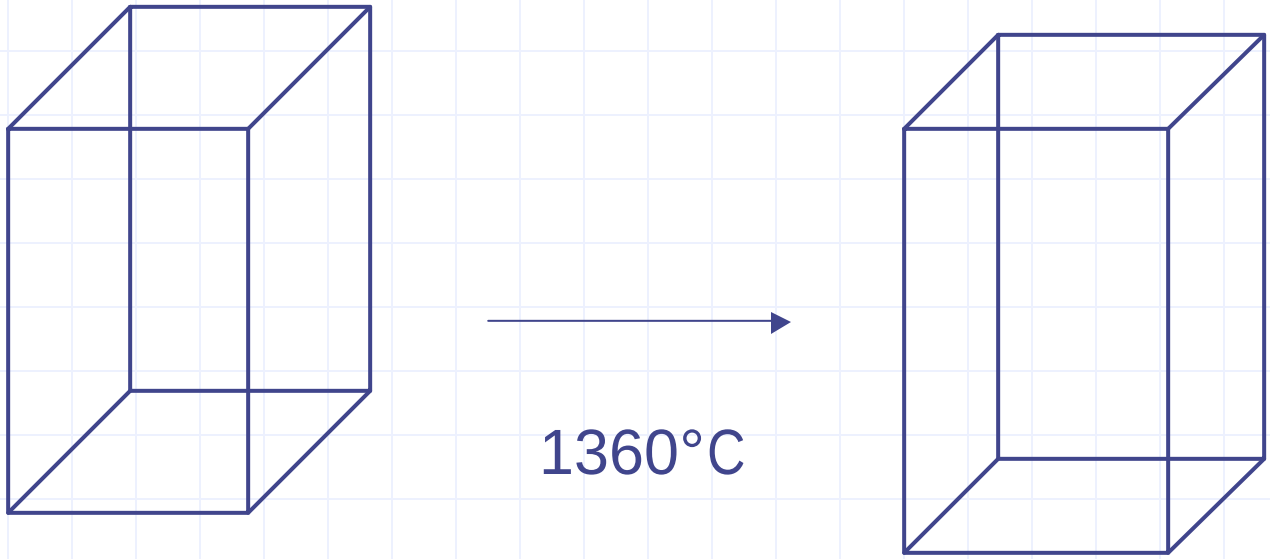
Requirements for Environmental Barriers

- Thermal match with the substrate (AS800)
- Corrosion resistance
- Microstructural stability
- Phase stability
- Chemical compatibility with the substrate

$\Rightarrow Ta_2O_5$ is a possible candidate

Phase Stability of Ta_2O_3

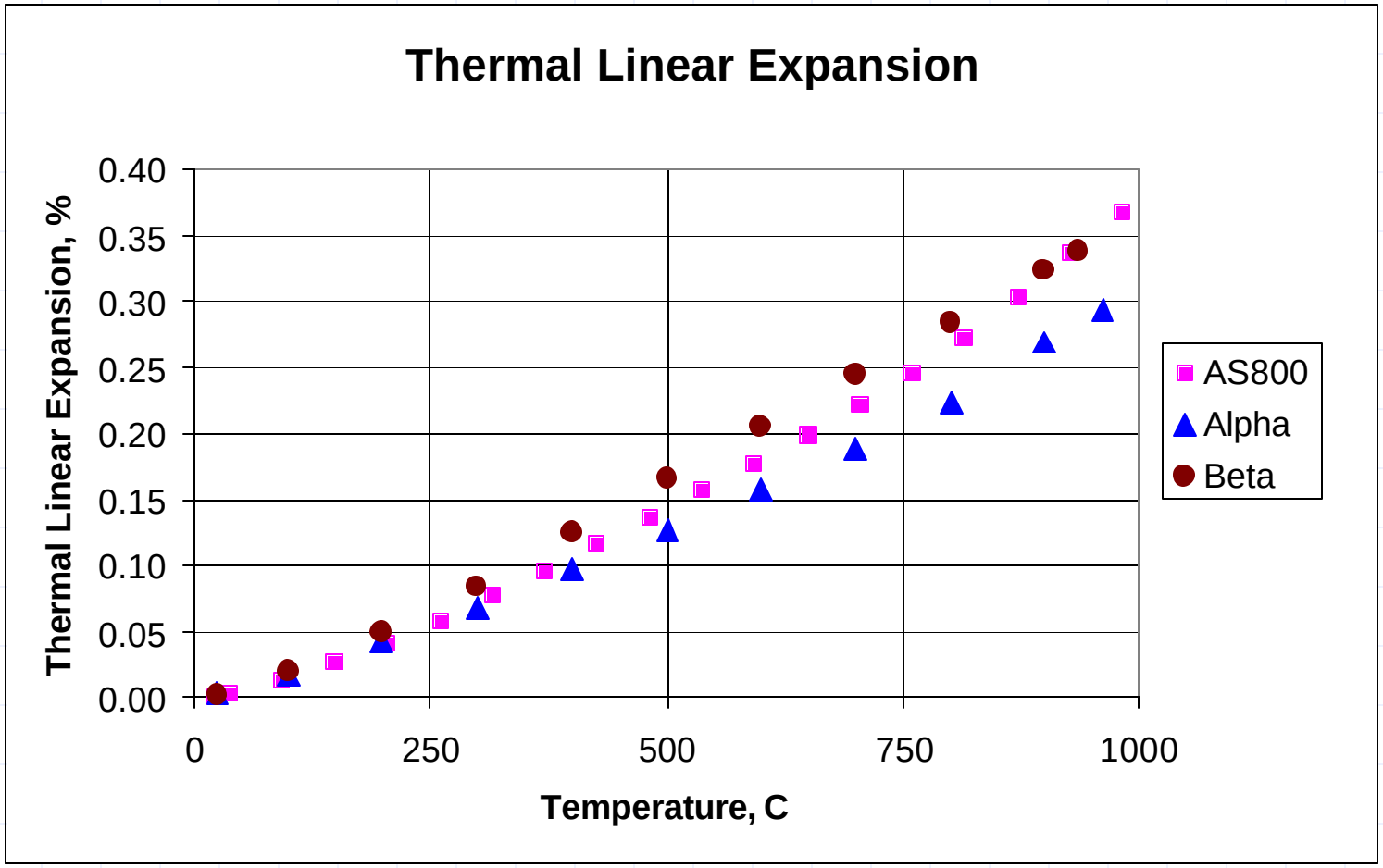


ß-Ta_2O_5
(orthorhombic)

α-Ta_2O_5
(tetragonal)

?V= 8.6%

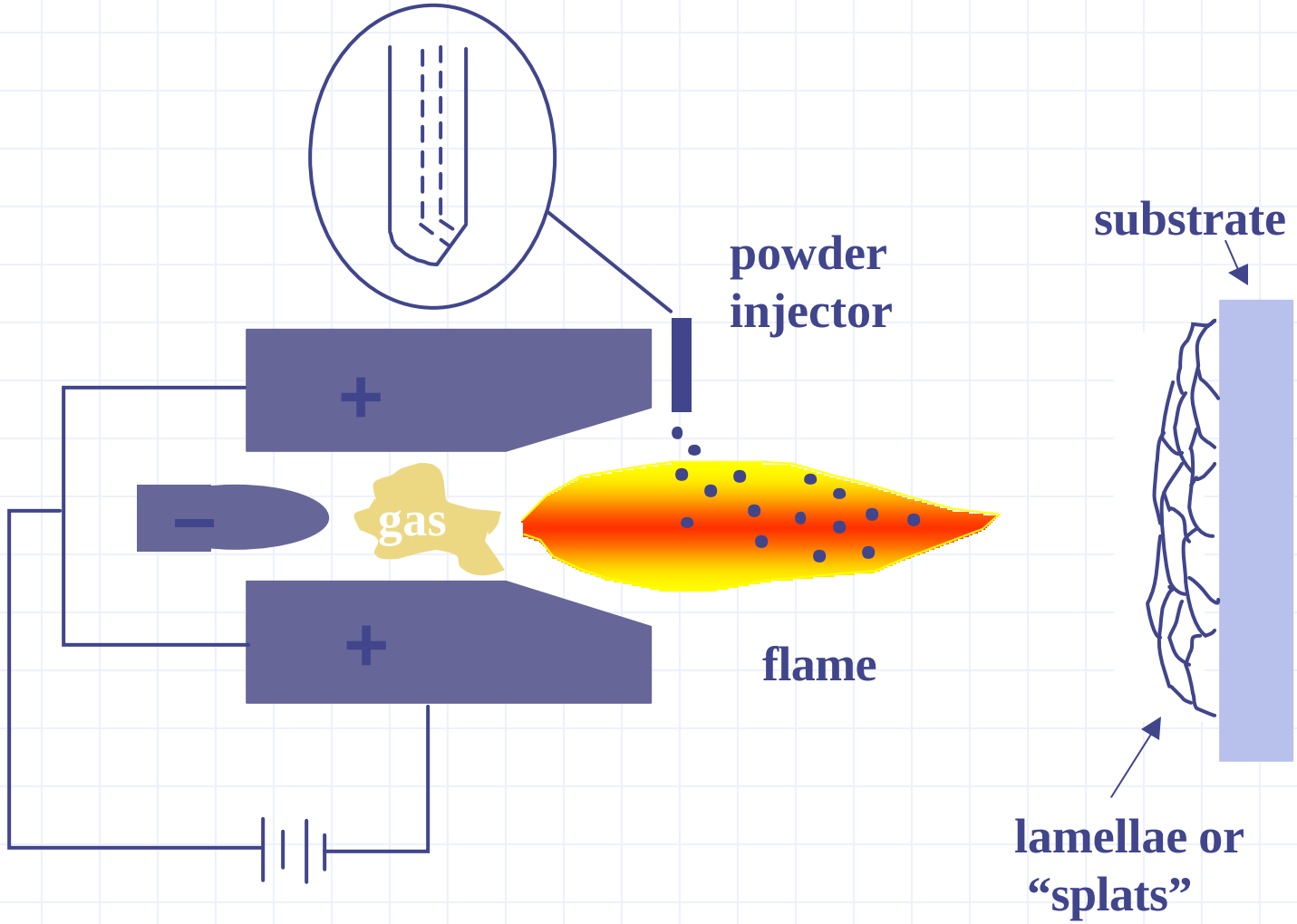
Thermal Expansion of Ta_2O_5 and AS800



Honeywell/NU/Lehigh/ORNL Program on EBC's

- Processing Methods for Ta_2O_5 and Ta_2O_5 Alloy Coatings/Plasma Spray Optimization
- Compositional Tailoring of a Family of Ta_2O_5 Coatings
- Life Limiting Phenomena:
  - Oxidation/Recession
  - Residual Stress
  - Thermal Cycling

Air Plasma Spraying

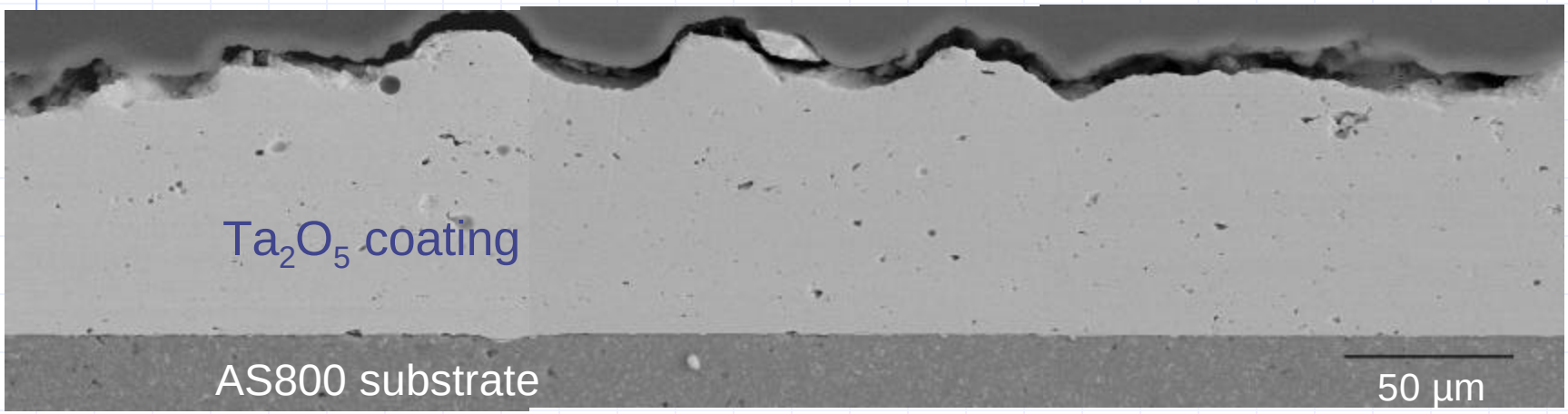


Optimized Coating

Used Design of Experiments methodology to optimize coating.

Round 1: Seven factors; two levels

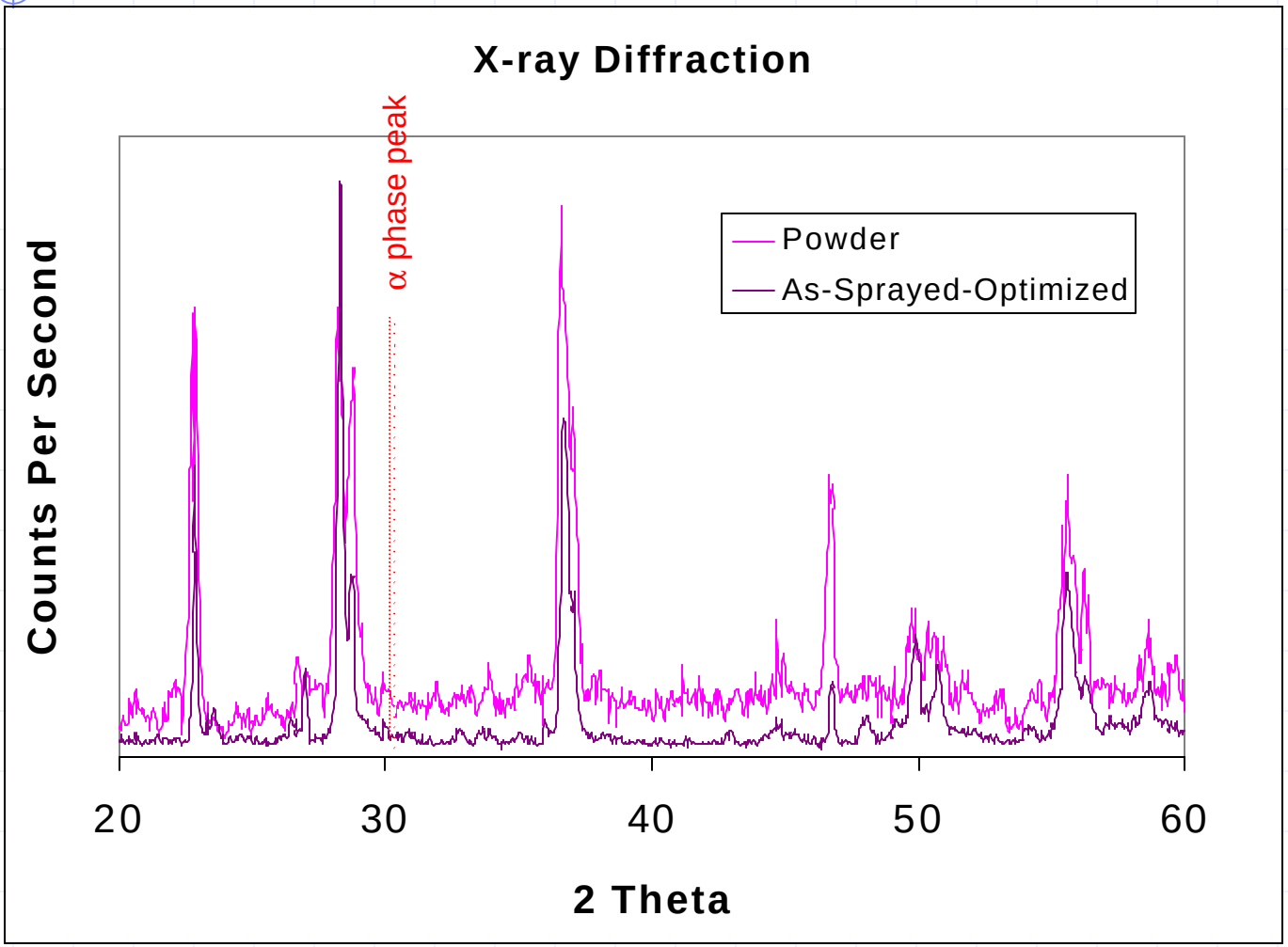
Round 2: Five factors; two levels and one factor; three levels



Minimize offset, injector angle, distance, carrier gas flow.

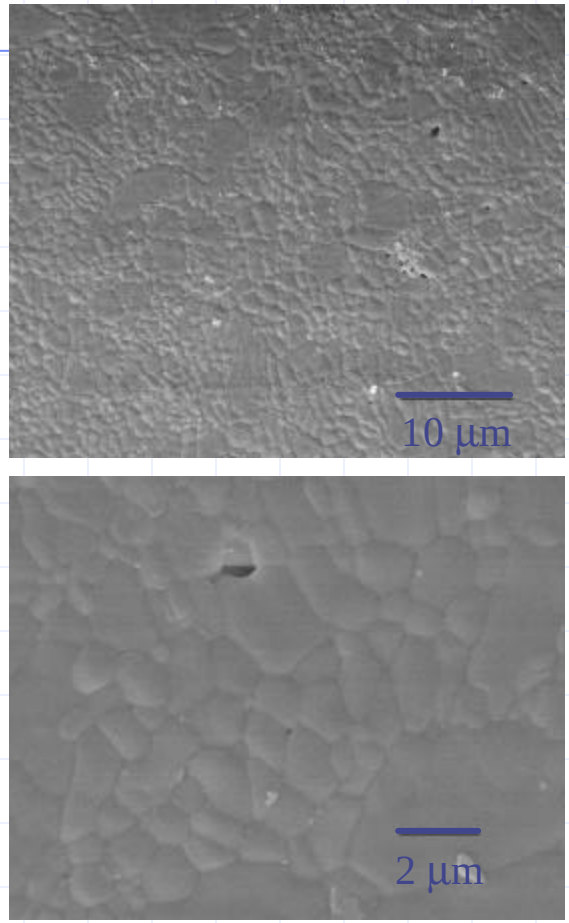
Maximize power, total gas flow and % hydrogen.

Phase Stability of Ta_2O_5

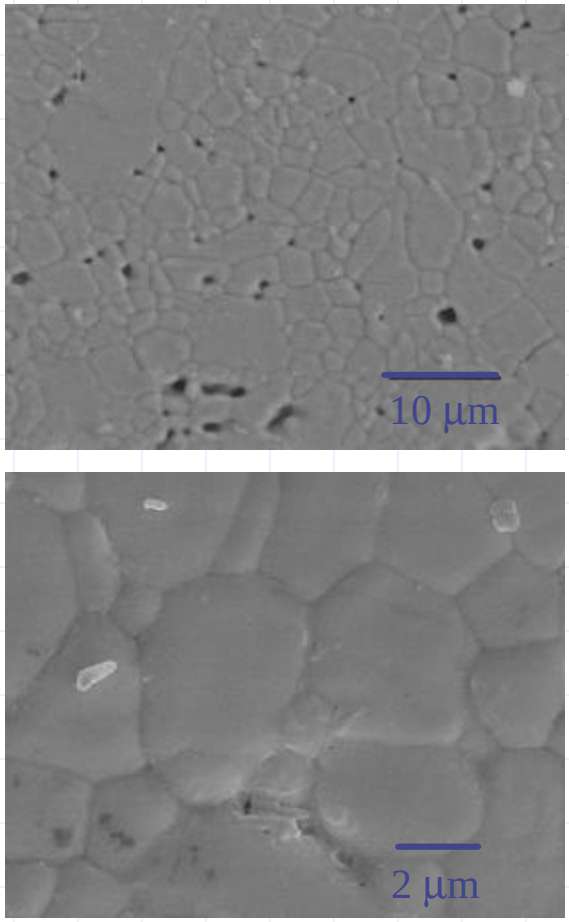


Trace α-Ta_2O_5 detected.

Microstructural Stability of Ta_2O_5



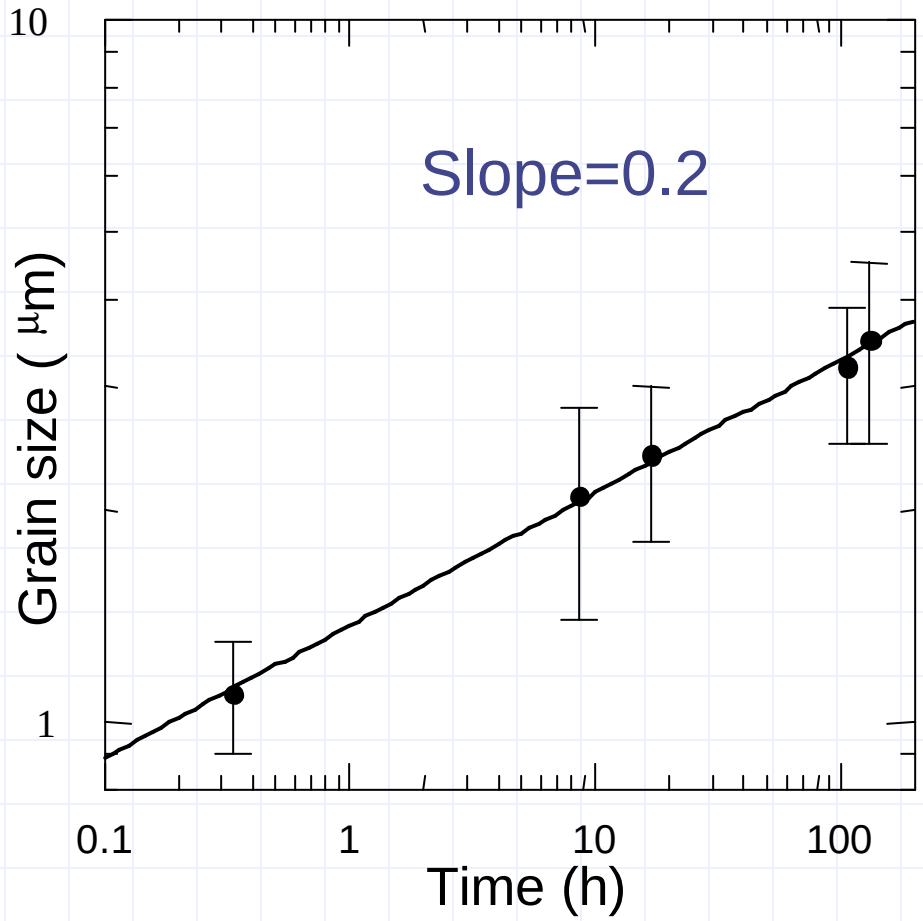
Ta_2O_5 as-sprayed



After 105 hours at 1200°C

Microstructural Stability

Grain Growth at 1200°C

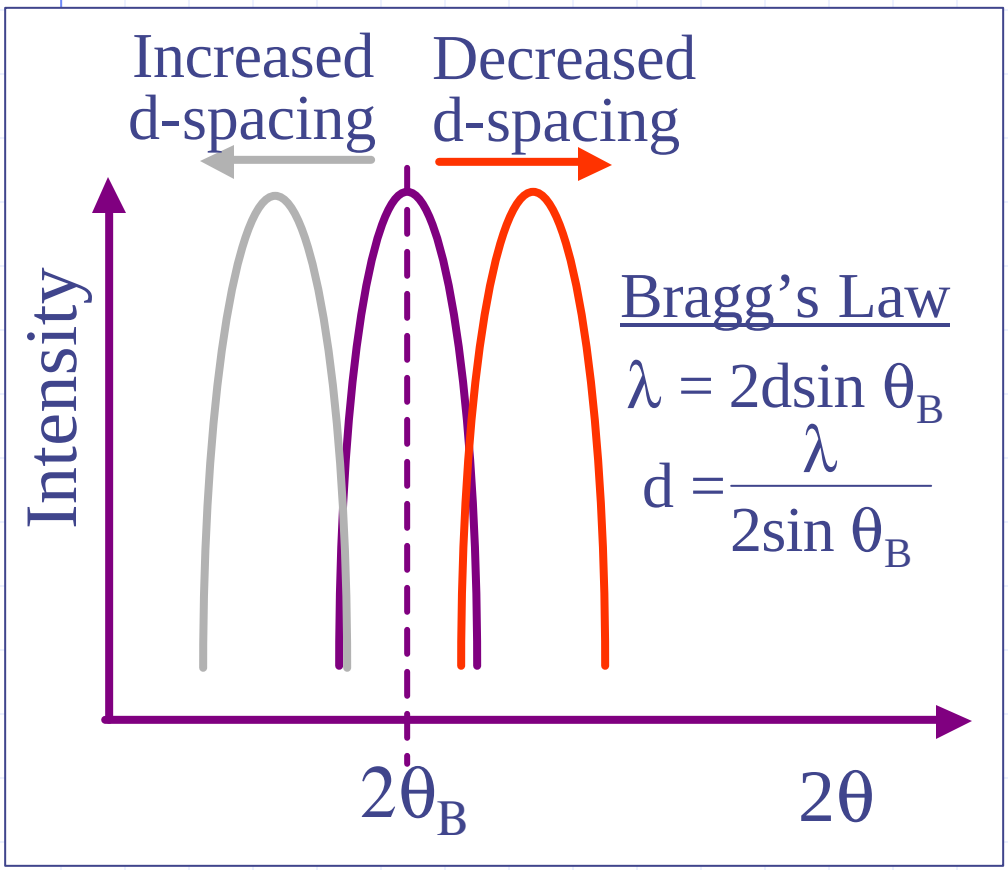


$d-d_o=$

$(2k)^{1/2}t^{1/2}$

X-ray Residual Stress Analysis

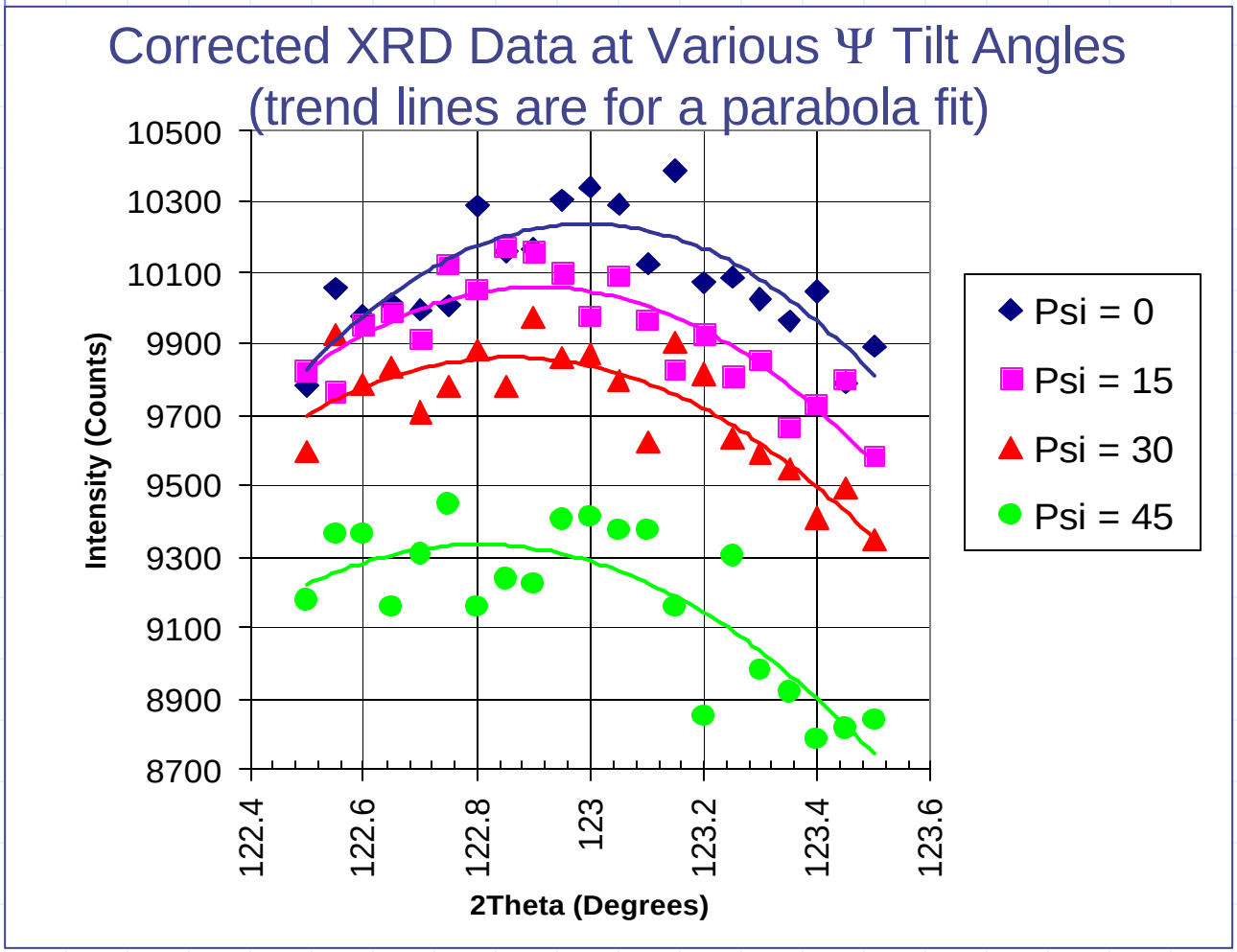
$$\frac{d_{f\Psi} - d_O}{d_O} = \frac{1+\nu}{E} s_f \sin^2 \Psi - \frac{\nu}{E}(s_{11} + s_{22})$$



$d_{f\,?}$ = stressed lattice spacing
d_o = unstressed lattice spacing
s_f = stress component in f direction
? = tilt angle
E = elastic modulus
ν = Poisson's ratio

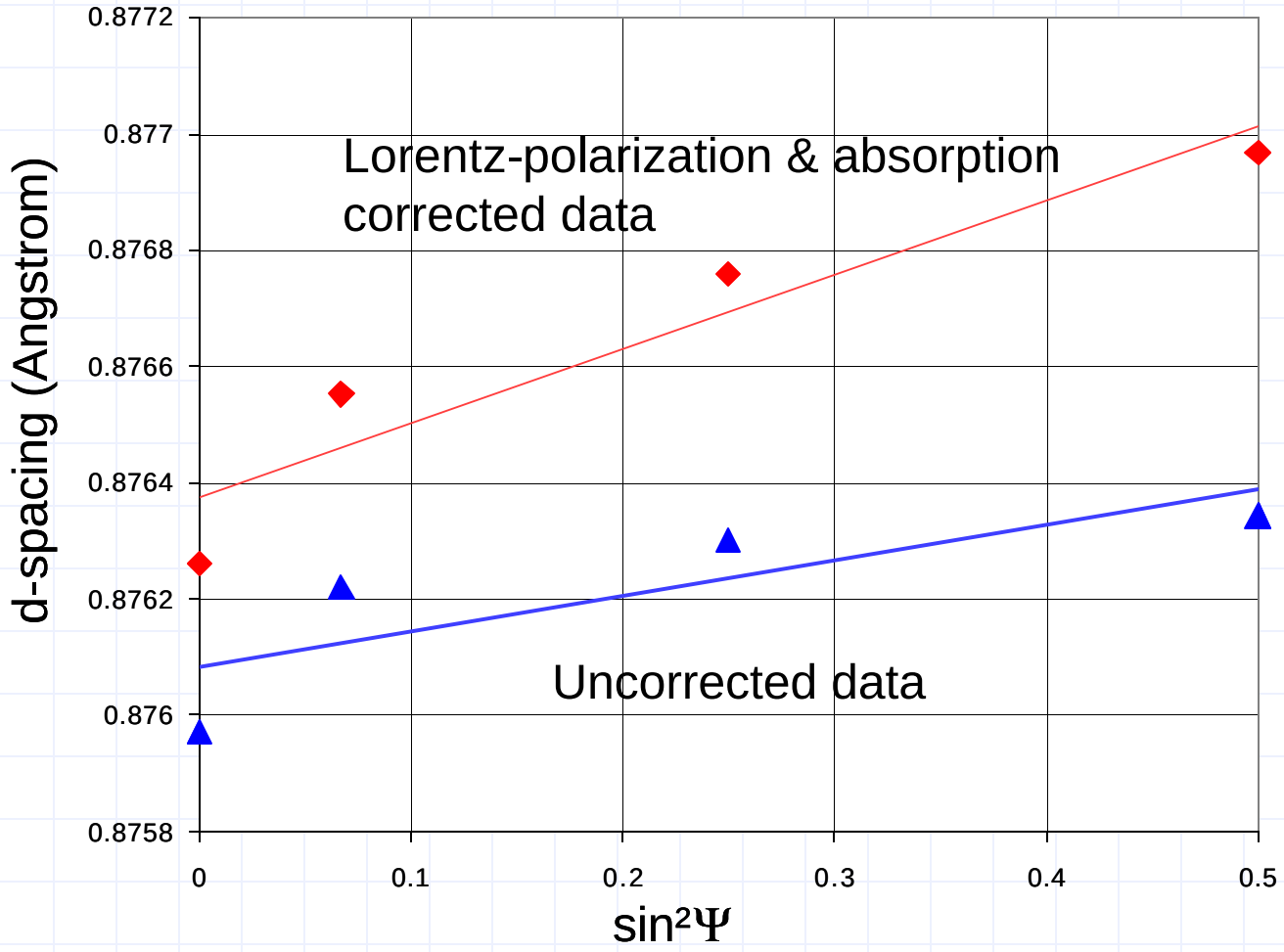
Measure d for a series of ? tilts to determine stress.

X-Ray Residual Stress Results



- CuKα Radiation
- Peak shift to left

Residual Stress in Ta_2O_5 on AS 800



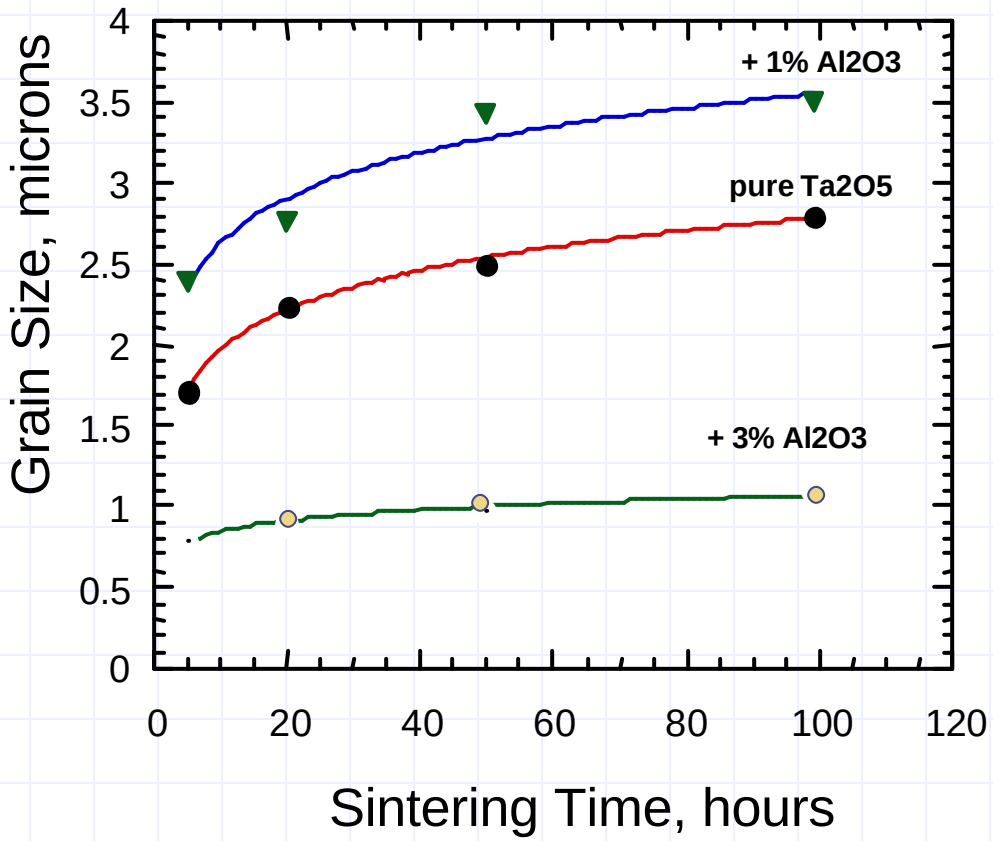
- Calculated residual stress:-39 MPa
- Measured residual stress: 215±16 MPa
- Re-measure after Keiser Rig exposure.

Ta_2O_5 Alloys and Composites

- Use oxide additions for
  - limiting grain growth
  - stabilizing ß-Ta_2O_5
- Size mismatch is critical
- Choices: Al_2O_3 and La_2O_3
  - monitor solid solubility
  - monitor second phase formation

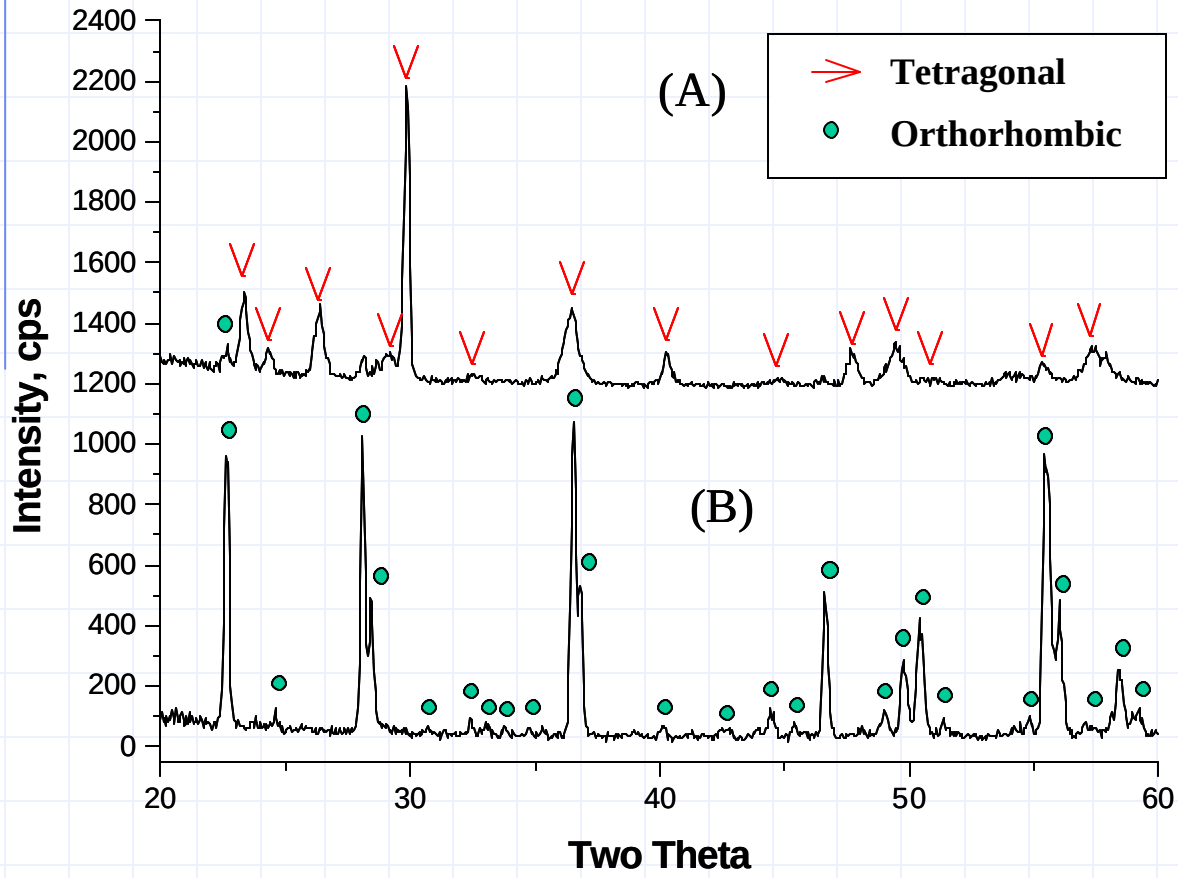
Ref: C.-W. Li, D. Raybould, L. Xue (Honeywell Inc.) Patent Pending

Al_2O_3 Stabilizes Grain Size



Sintered at 1300°C in air.

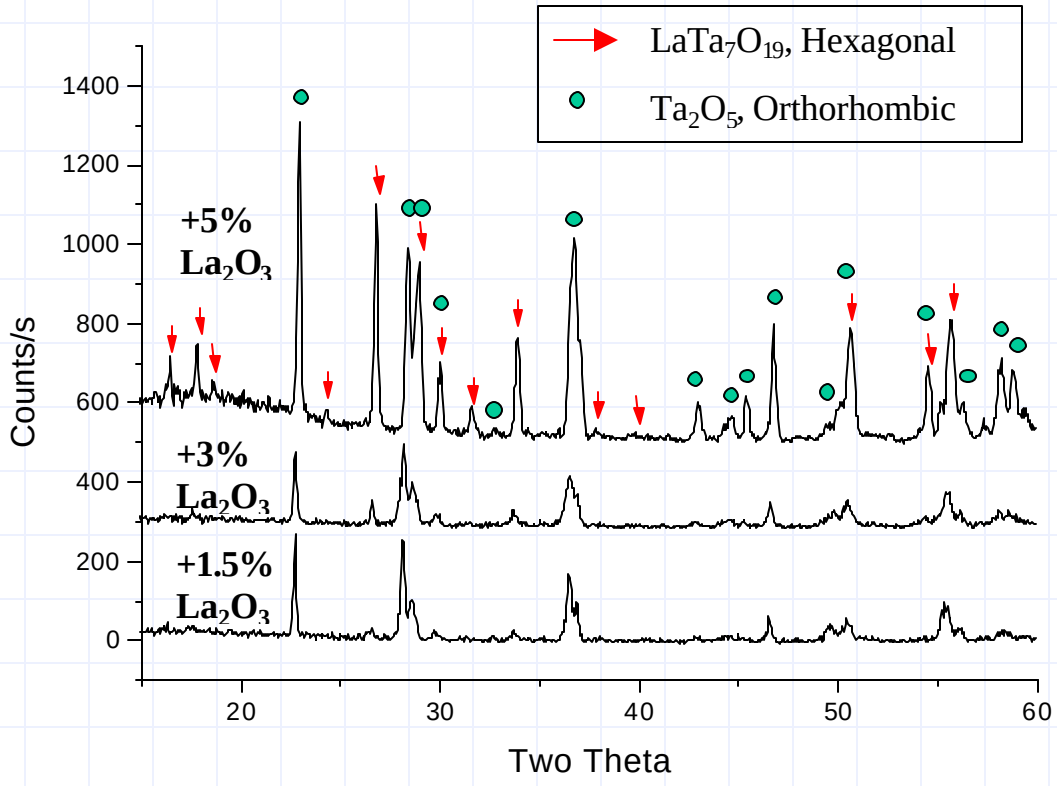
Al_2O_3 Stabilizes β-Ta_2O_5



(A) Pure Ta_2O_5, 1360°, 5 h.

(B) Ta_2O_5 with 3% Al_2O_3, 1400°C, 5 h.

La_2O_3 Stabilizes β-Ta_2O_5

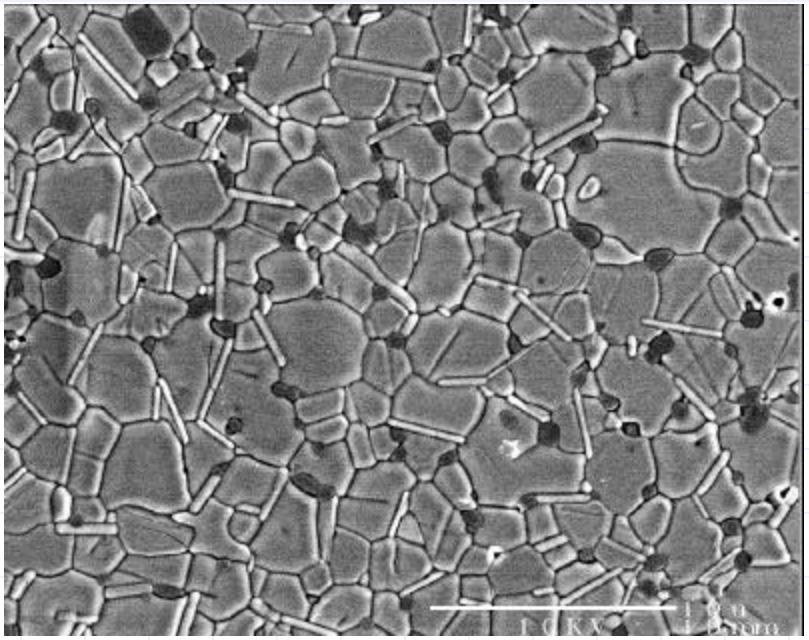


1400°C

5 hours

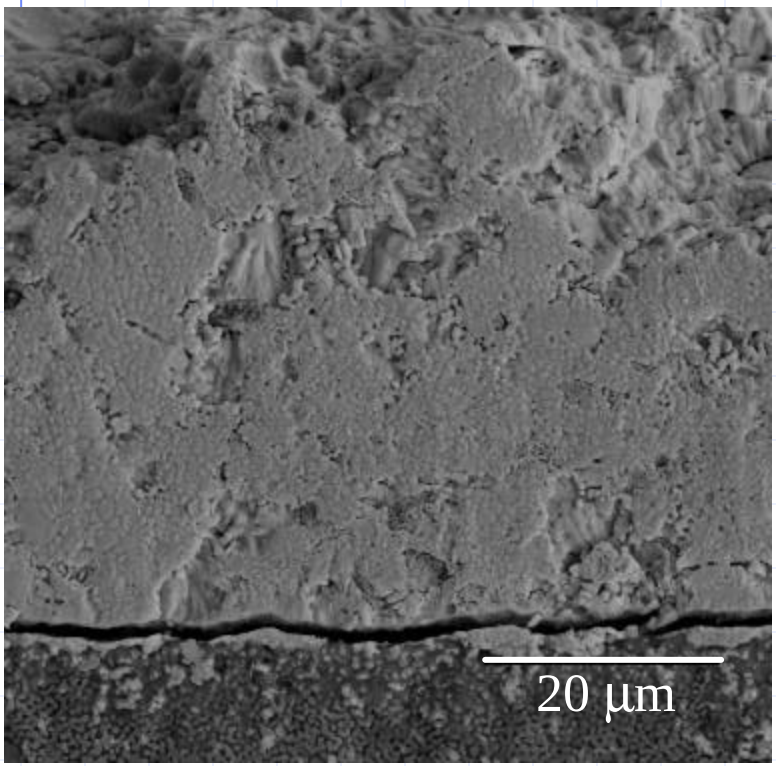
No traces of α-Ta_2O_5 at concentrations > 3% dopant.

Co-doping of Ta_2O_5 with Al_2O_3 and La_2O_3

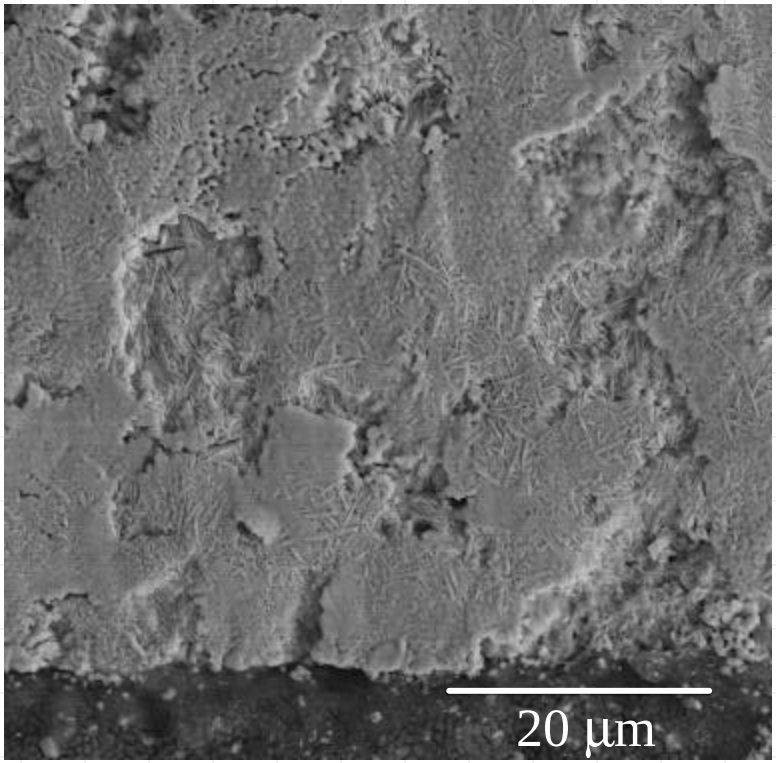


- 2% γ-Al_2O_3 and 1% La_2O_3
- 95% Dense
- Needle-like grains: $LaTa_7O_{19}$
- Dark, equiaxed grains: $AlTaO_4$

Alloys/Composites Translated to Plasma-Sprayed Coatings



3% Al_2O_3 Addition



3% La_2O_3 Addition

Summary

- Ta_2O_5 shows promise as an interlayer in Honeywell's next generation EBC system for AS800 from thermal mismatch and compatibility considerations.
- Plasma-sprayed Ta_2O_5 has been optimized for density for EBC applications.
- Alloys of Ta_2O_5 shown promise for stabilizing the ß polymorph and grain size.