OAK RIDGE National Laboratory

Project ID: mat183

High-Temperature Coatings for Valve Alloys*

*Subtask 2A3 under the Powertrain Materials Core Program (PMCP)

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Context overview: VTO Powertrain Materials Core Program

Timeline

- Lab Call Award: July 2018
- Program Start: Oct 2018
- Program End: Sept 2023
- 30% Complete

Budget

- $30M/5 years

Barriers to new alloys

- Higher power density, higher efficiency engines; resulting in increasingly extreme materials demands
- Cost of advanced engine materials
- Development time/cost of new materials
- Scaling new materials technologies to commercialization

FY20 Program Research Thrusts	FY20 Budget	Partners
Thrust 1. Cost Effective Lightweight High Temp Engine Alloys	$1.05M	ORNL
Thrust 2. Cost Effective Higher Temp Engine Alloys	$1.525M	ORNL, PNNL
Thrust 3. Additive Manufacturing of Powertrain Alloys	$1.075M	ORNL
Thrust 4A. Advanced Characterization (supporting Thrusts 1-3)	$1.025M	ORNL, PNNL, ANL
Thrust 4B. Advanced Computation (supporting Thrusts 1-3)	$0.6M	ORNL
Thrust 5. Exploratory Research: Emerging Technologies	$0.75M	ORNL, PNNL, ANL

Overview of SubTask 2A3: High-Temperature Coatings for Valve Alloys within the PMCP

Timeline

- Project start: Oct 2018
- Project end: Sep 2023
- Percent complete: 30%

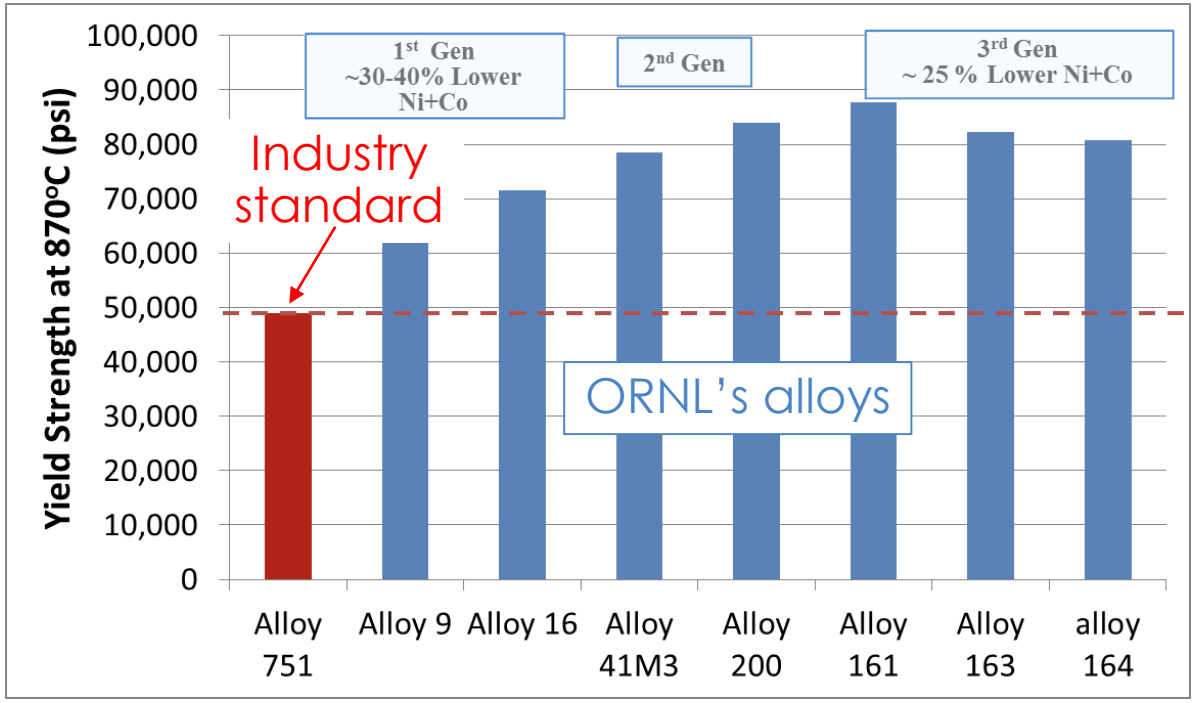
Barriers to High Temperature Coatings

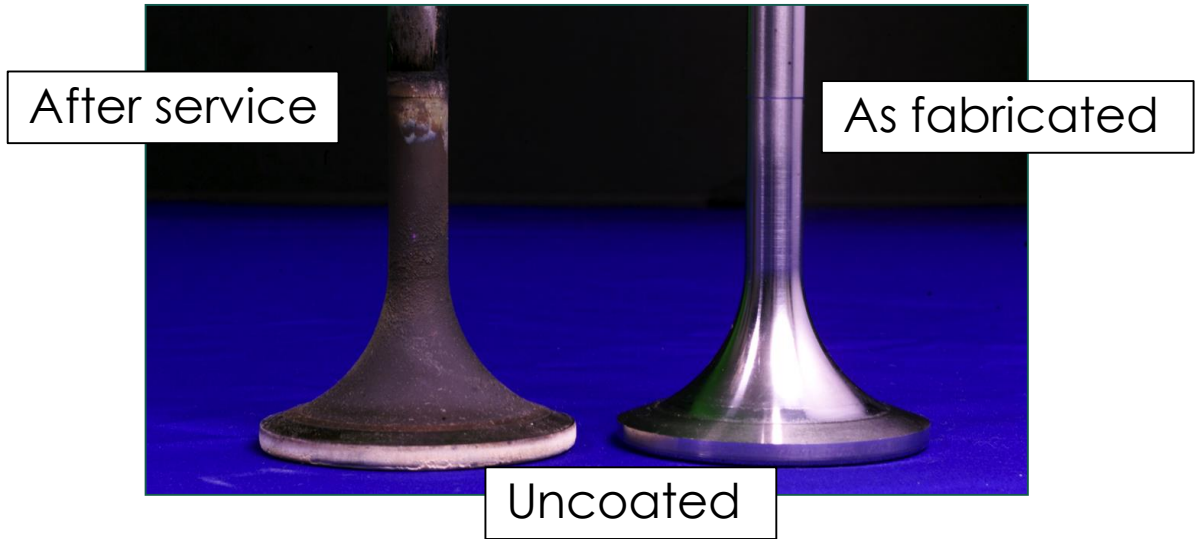
- Not used currently in engine
- Very limited data for coated valve alloys
- Coating cost
- Heat treatment compatibility with substrate

Partners	FY20 Budget
Subtask. 2A3: High-Temperature Coatings for Valve Alloys	**$175k**
Subtask 4B: Advanced Computation	**$22.5k**
Stony Brook University	
Flame Spray Inc.	

Relevance: Enable Higher Operating Temperatures For High Strength Valve Alloys

- Low-cost, higher-strength valve alloys have been developed at ORNL
- These alloys have limited oxidation resistance at T>850°C
- Oxidation-resistant coatings on the highest temperature regions of valves could improve significantly component lifetime at T>850°C





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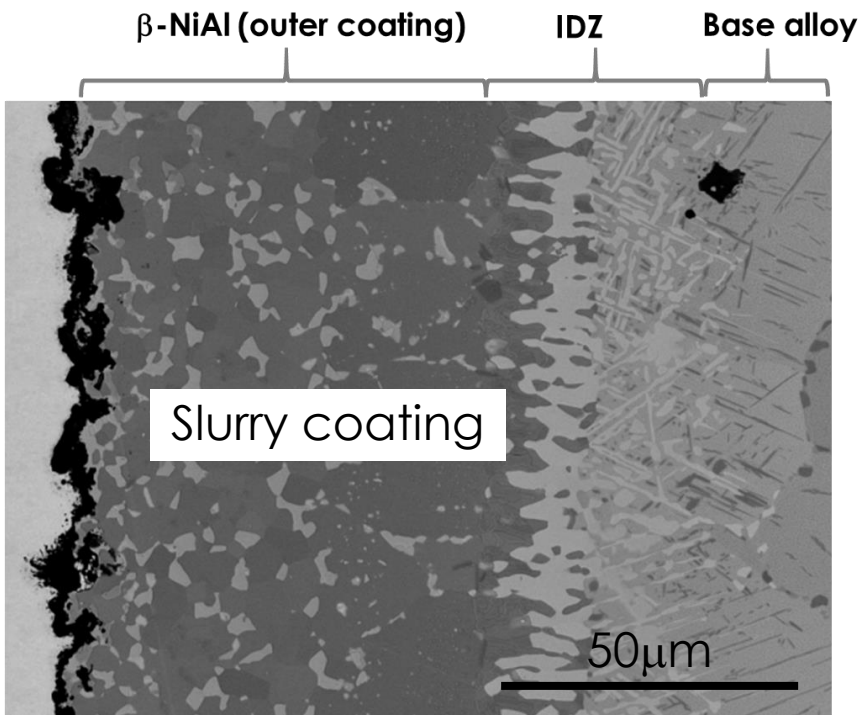
Approach: Develop Coatings For High Strength Valve Alloys For Improved Oxidation & Fatigue Resistance

- Deposit coatings on oxidation coupons and fatigue specimens
- Optimize the deposition process/heat treatment using a coupled thermodynamic and kinetic model (Thrust 4B: Adv. Comp.)
- Compare bare and coated specimens:
  - Cyclic oxidation resistance
  - High cycle Fatigue (HCF) Behavior
- Predict coated component lifetimes

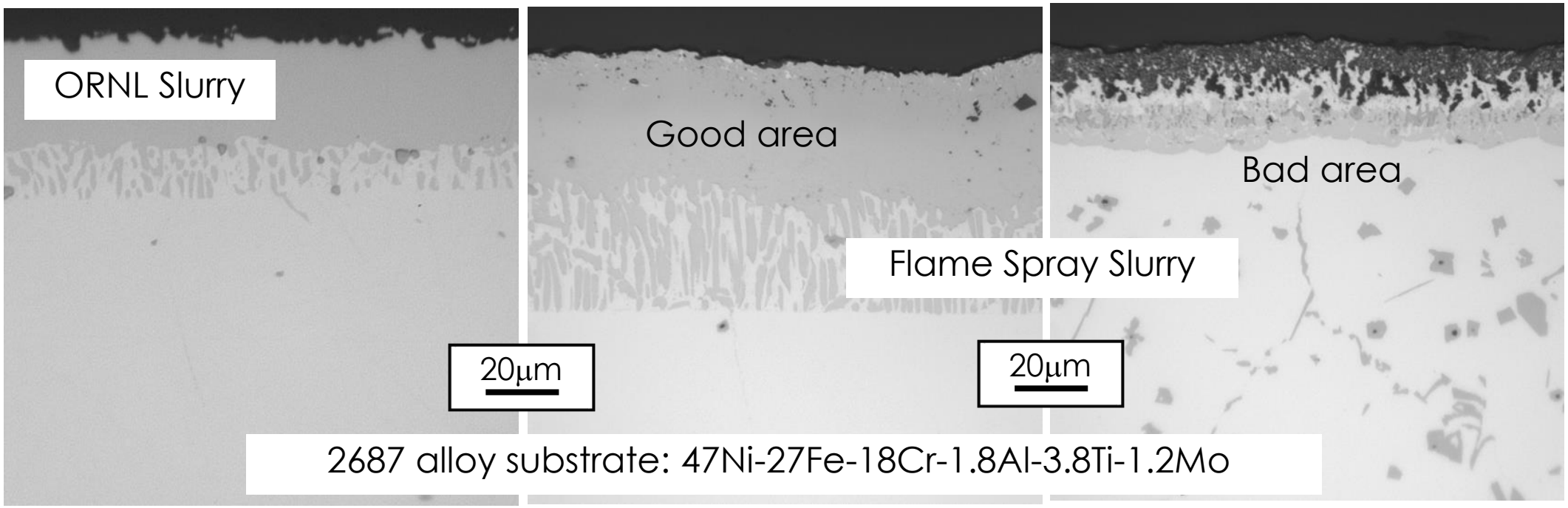
Milestones

- Q2. Initiate HCF testing of high strength coated valve alloy Complete
- Q4. Write a paper on on the HCF properties of coated valve alloys On target

IDZ = Interdiffusion zone

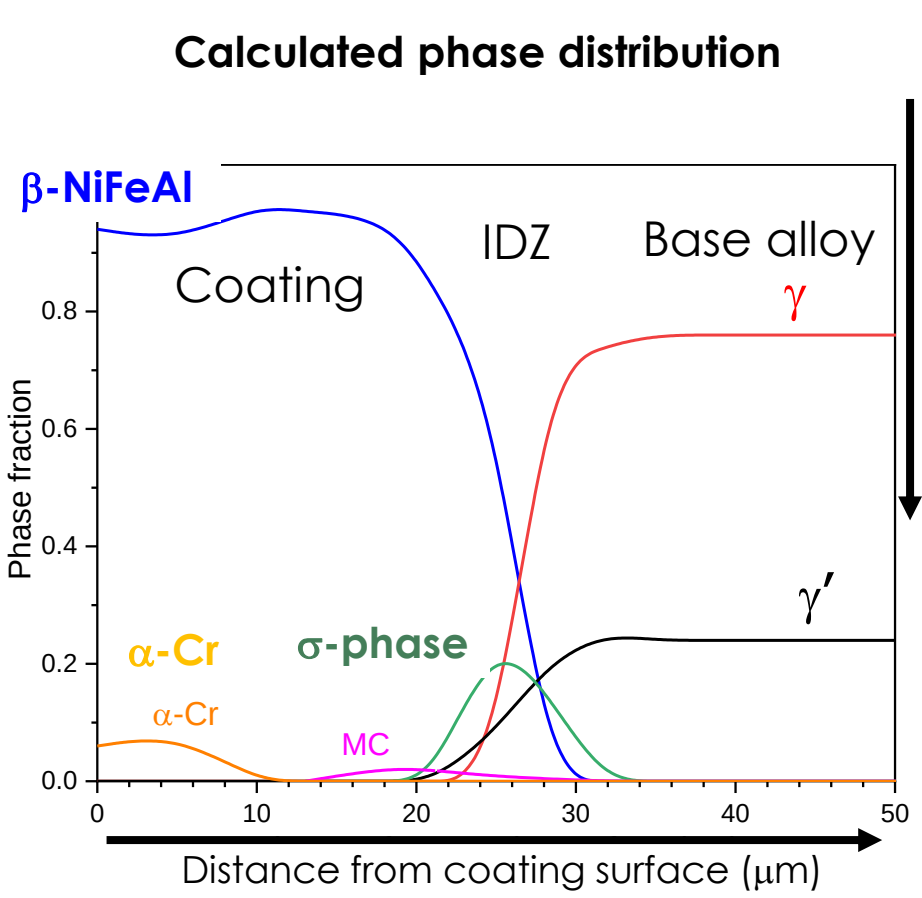


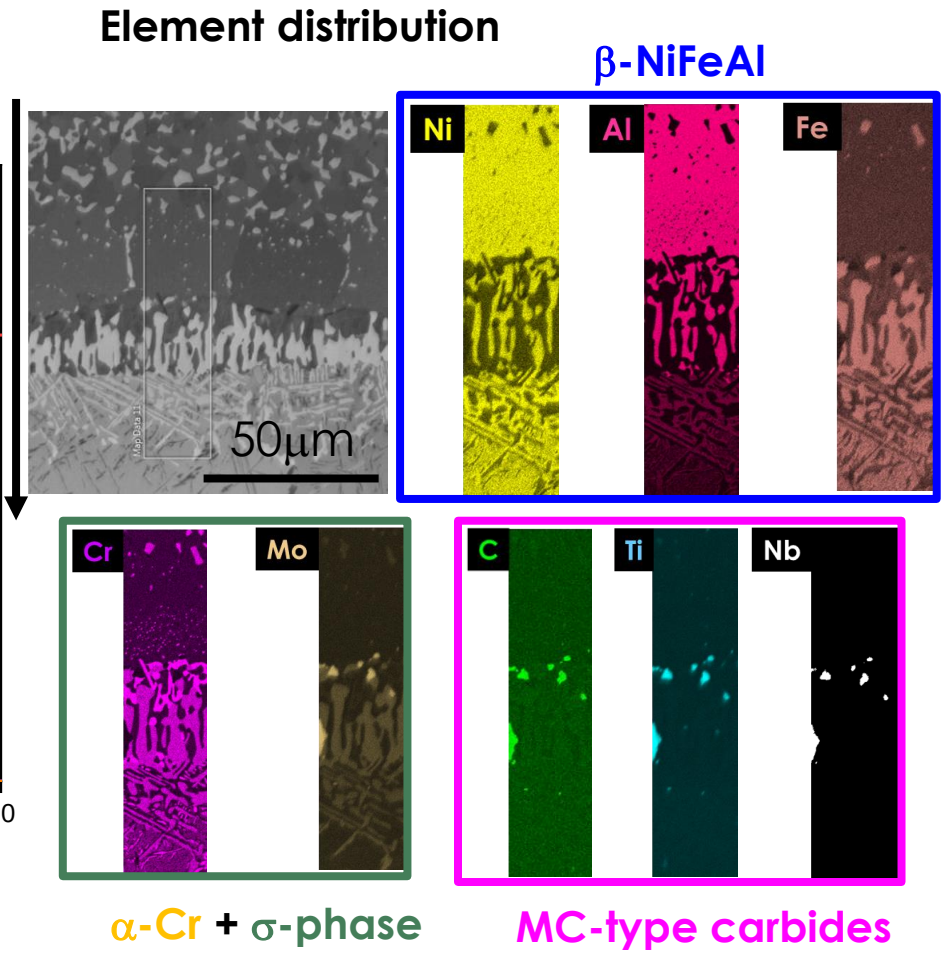
Tech. Accom.: Slurry Coatings and Thermal Spray MCrAlY Coatings Were Deposited on ORNL Valve Alloys

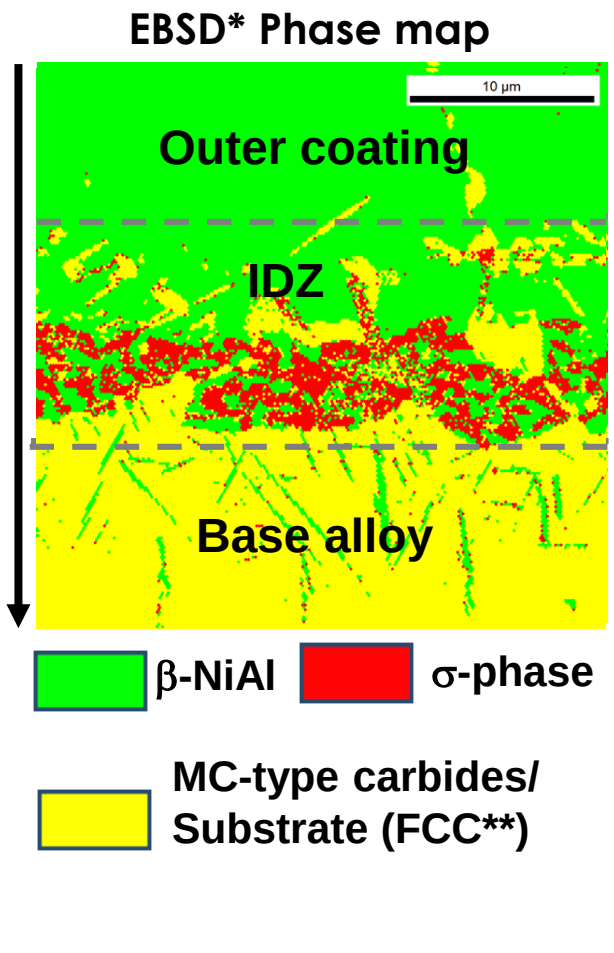


- Variation in successful coating deposition on 2687 high strength alloy
- Deposition parameters/heat treatments need to be optimized
- High Ti content makes the alloy sensitive to O_2 during annealing
- First batch of thermal spray coatings had homogeneity issues

Tech. Acc. Thrust 4B: Successful Prediction of Microstructure Using Coupled Thermodynamic and Kinetic Model



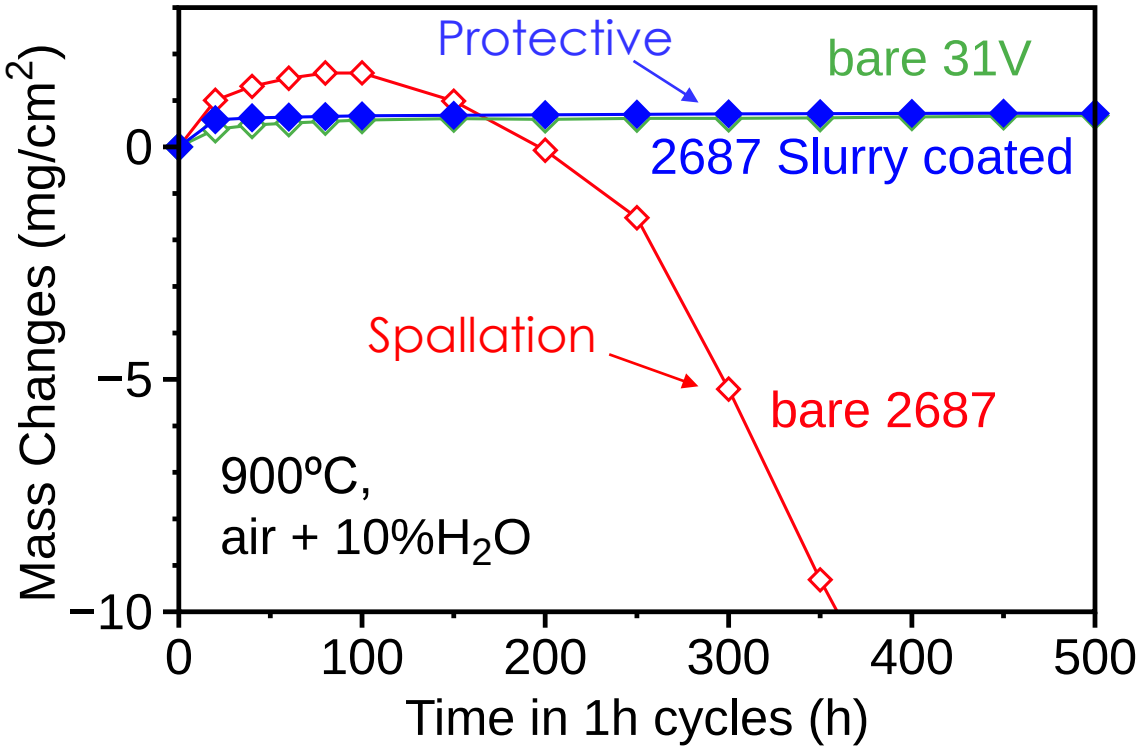


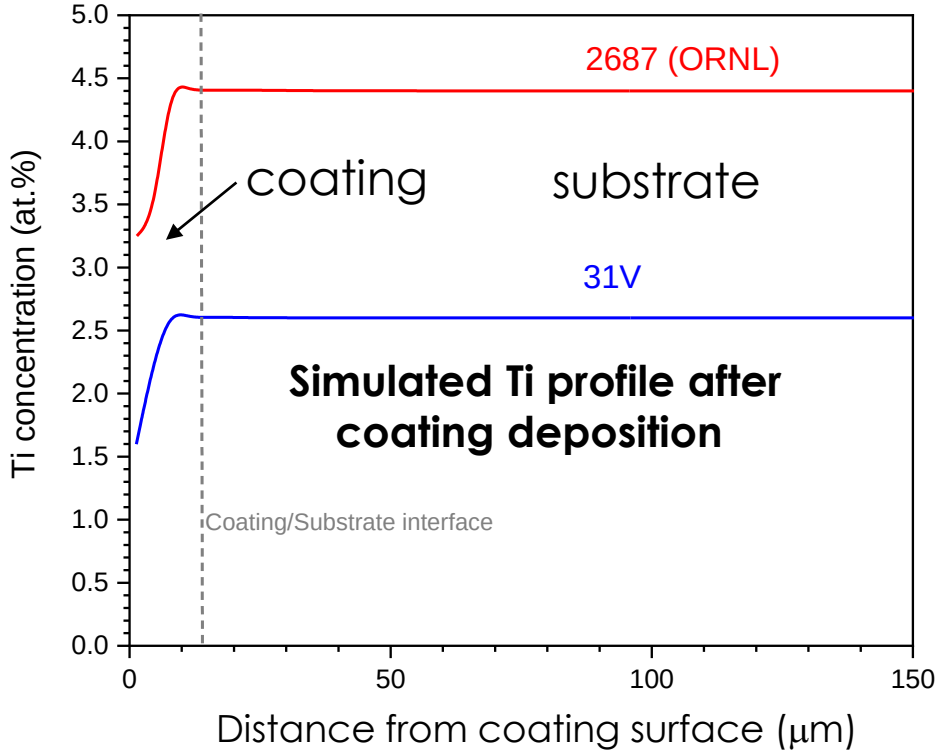


- Calculated **phases** are consistent with element and EBSD phase mapping for slurry coating deposited on alloy 31V

*EBSD : Electron backscattered diffraction
**FCC : Face centered cubic structure

Tech. Accom.: Demonstrate Great Oxidation Resistance at 900°C for Non-optimized ORNL Slurry Coating

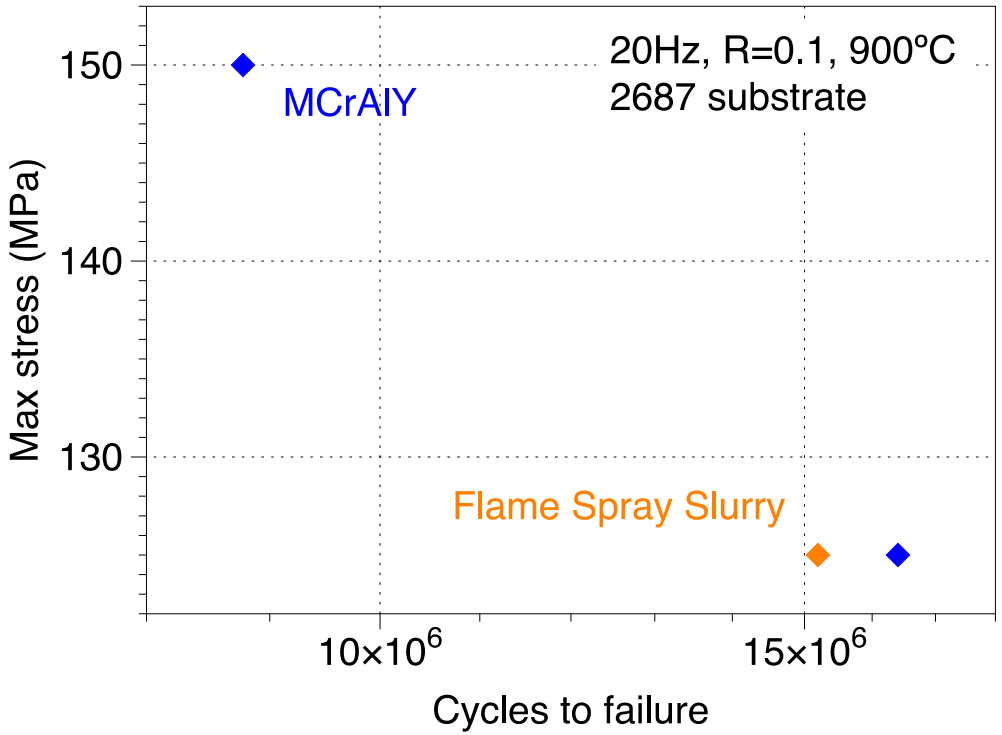


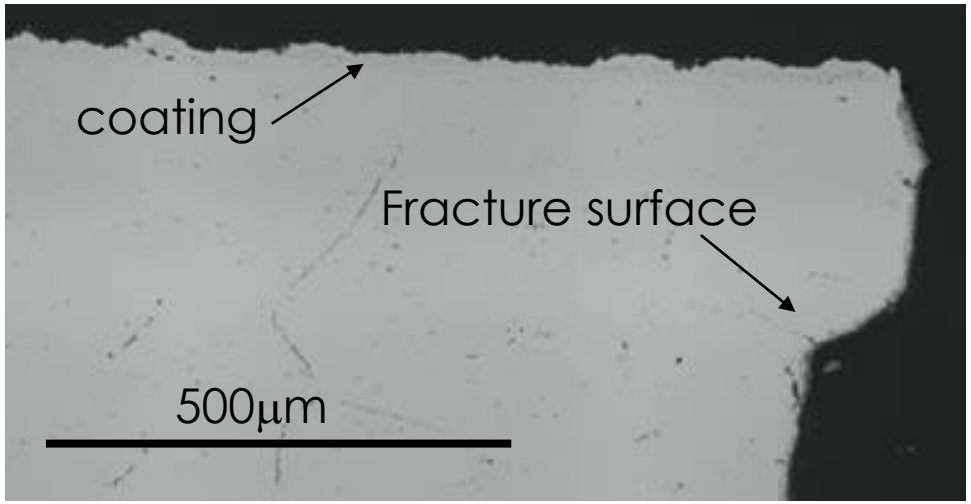


- Significant spallation at 950°C for bare 2687 alloy
- Protective oxide layer forms on coupons coated with slurry aluminide
- Ti required for strength - but not good for oxidation. Also an issue for coatings due to diffusion from substrate to coating surface

Tech. Accom.: Initial High Cycle Fatigue Tests of Coated Specimens Show Good Behavior

- 6 fatigue specimens were MCrAlY coated and 2 specimens were Slurry coated by Flame Spray
- Initial HCF results are consistent with bare alloy data
- No cracks in the coating





Collaboration

- Stony Brook University: MCrAlY thermal spray coatings
- Flame Spray Inc: Flame slurry coatings
- Thrust 4B, Advanced Computation: Coupled thermodynamic & kinetic simulations

Future Research

- Optimize coating fabrication
- Evaluate strategies to mitigate deleterious effect of Ti on oxidation
- Continue cyclic oxidation and HCF testing at 900-950°C
- Use coupled thermodynamic and kinetic model for lifetime prediction
- Collaboration with Thrust 4a for advanced characterization of microstructure coatings (electron probe micro analyzer)

Any proposed future work is subject to change based on funding levels.

Project Summary

- Evaluating deposition of Slurry and MCrAlY coatings on higher strength valve alloys
- Initial cyclic oxidation and high cycle fatigue data shows good behavior at 900°C with non-optimized coatings
- Applying advanced modeling and characterization tools to optimize coating deposition processes
- Coatings may offer cost-effective solutions for valves operating at T>850°C

Backup Slides

Responses to Previous Year Reviewer's comments

- Project was not reviewed last year