

# Enhancing Superalloy Performance Using Electronic Affinity in Thermal Barrier Coatings (TBCs)

## Abstract

This white paper explains how electronic affinity improves the performance of superalloys by enhancing thermal barrier coatings (TBCs). Using computational methods in COMSOL Multiphysics, we analyze various coatings applied to steel surfaces to determine their heat resistance and stability. This paper presents the results in simple terms so that anyone, even non-experts, can understand how these findings are applied in industries such as aerospace, automotive, and power generation.

## 1. Introduction

Superalloys are high-performance metals used in extreme temperature environments, such as jet engines and power plants. However, these metals degrade over time due to heat stress. To protect them, scientists apply thermal barrier coatings (TBCs), which act like heat shields. The goal of this research is to find the best TBC by analyzing how electronic properties like electronic affinity affect heat resistance.

### What is Electronic Affinity?

Electronic affinity is the ability of a material to absorb and hold electrons. In superalloys, adjusting this property improves how well a coating resists heat and oxidation.

## 2. Research Approach

We used COMSOL Multiphysics, a simulation tool, to model and analyze different TBCs. The coatings we tested included:

- Pure Zirconia ( $\text{ZrO}_2$ ) with Yttria Stabilization (YSZ)
- 7-8% YSZ composite
- $\text{MoO}_3$  and  $\text{Al}_2\text{O}_3$ -based coatings

### Testing Process

1. Create a 3D Model: Built a digital model of a superalloy with TBCs.
2. Apply Heat Simulation: Exposed the model to high temperatures, similar to jet engines.
3. Measure Heat Dissipation: Tracked how well each coating reduced heat transfer.
4. Analyze Electron Affinity Effects: Adjusted electronic properties to evaluate heat resistance improvements.

## 3. Key Findings

- Best Heat Resistance: Pure  $\text{ZrO}_2$  with YSZ provided the highest heat protection.
- Lower Temperature Transfer: 7-8% YSZ significantly reduced heat reaching the metal.
- Enhanced Electron Affinity Boosts Protection: Materials with optimized electron affinity values improved heat shielding.

#### Implications for Industry

- Aerospace: Jet engines last longer, reducing maintenance costs.
- Automotive: Cars can use more heat-resistant parts for better fuel efficiency.
- Power Plants: Turbines perform better and require fewer repairs.

#### 4. Conclusion & Future Applications

This research proves that modifying electronic affinity in TBCs enhances heat protection. By using advanced coatings, industries can create stronger, more heat-resistant materials, reducing costs and improving efficiency. Future research will focus on real-world applications.

#### Next Steps

- Conduct real-world testing on jet engines and turbines.
- Explore new coating materials for extreme environments.
- Develop commercial applications based on this research.

#### 5. Contact Information

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