Computational Predictions and Experimental Characterization of Cobalt and Copper Based Solid Oxide Fuel Cell Brazes

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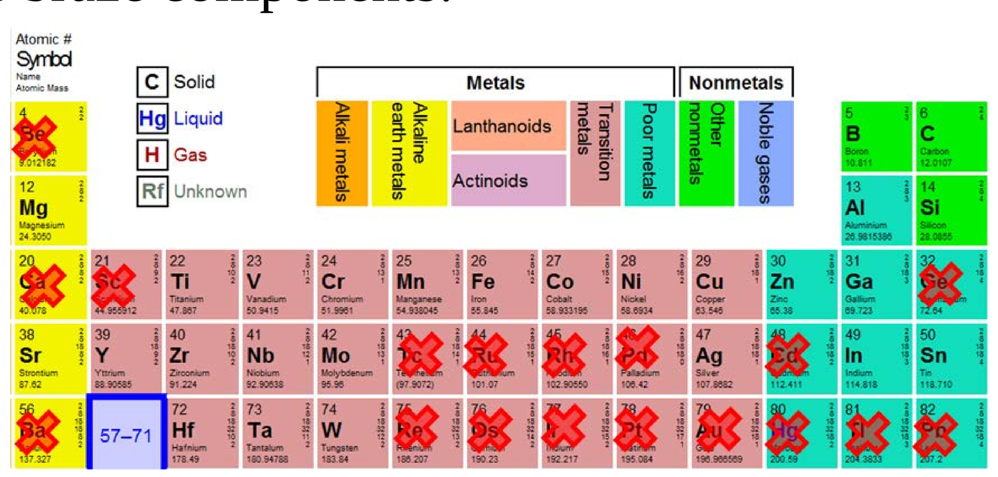
Introduction

Solid Oxide Fuel Cells (SOFCs) are a desirable clean energy conversion technology, due to their fuel flexibility, high efficiency, and relatively low cost [1]. However, long term stability is a issue than needs to be considered when designing a SOFC stack. Sealants often display durability problems. For standard silver-based brazes, the high diffusivity of hydrogen and oxygen create pores inside the braze after long-term operation, leading to mechanical failure and hermetic seal failure [2]. In this work, promising cobalt and copper-base braze systems were computationally identified using Thermo-Calc. Samples were fabricated via arc-melting, oxidation tested via thermogravimetric analysis (TGA), and melting point analyzed with differential scanning calorimetry (DSC).

Element Selection

All elements from the periodic table meeting the criteria that they are 1) non-toxic 2) non-radioactive 3) cost effective (≤ 50$/g) were included in the Thermo-Calc simulations as possible braze components:

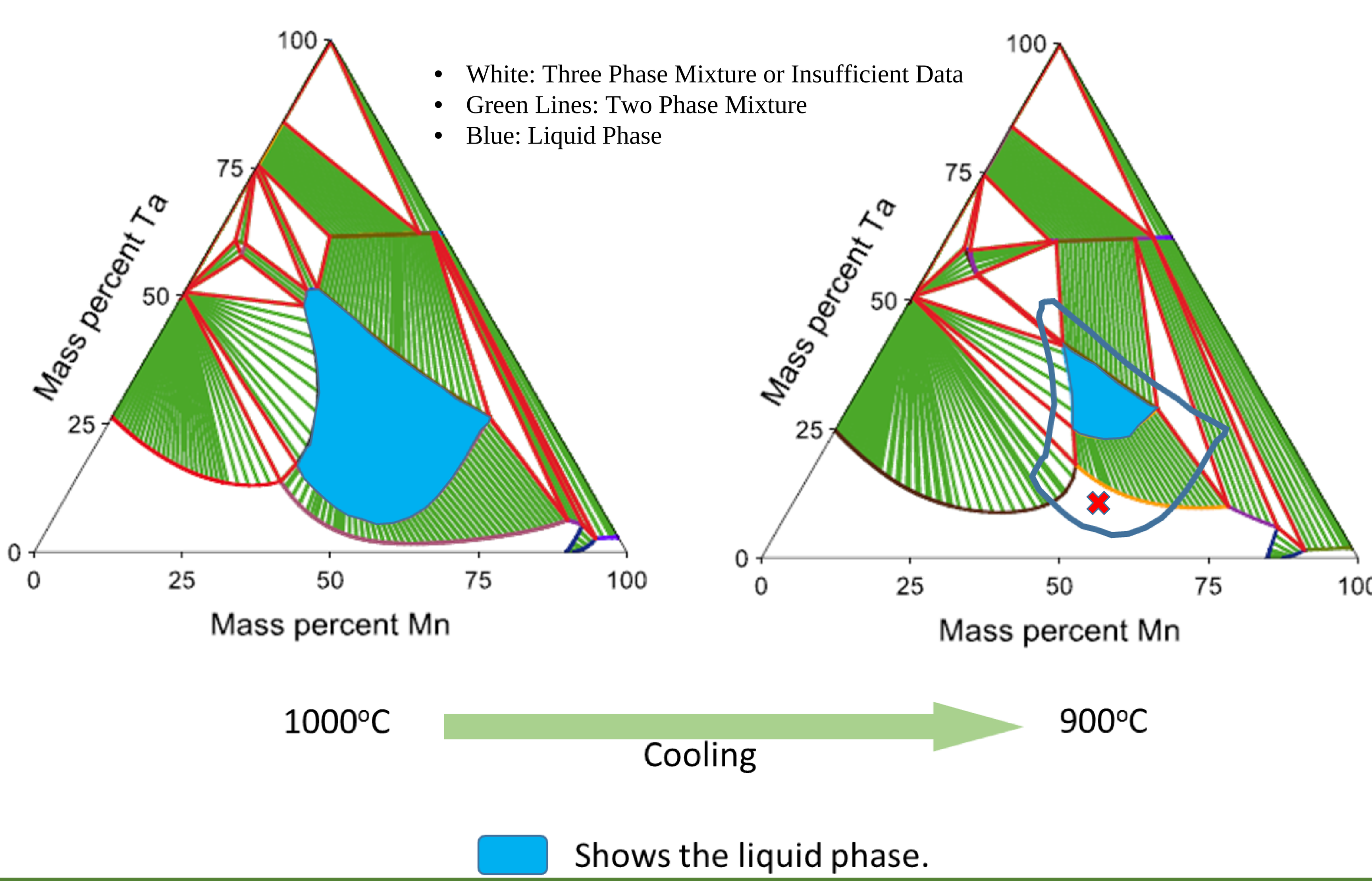


Target Braze Properties

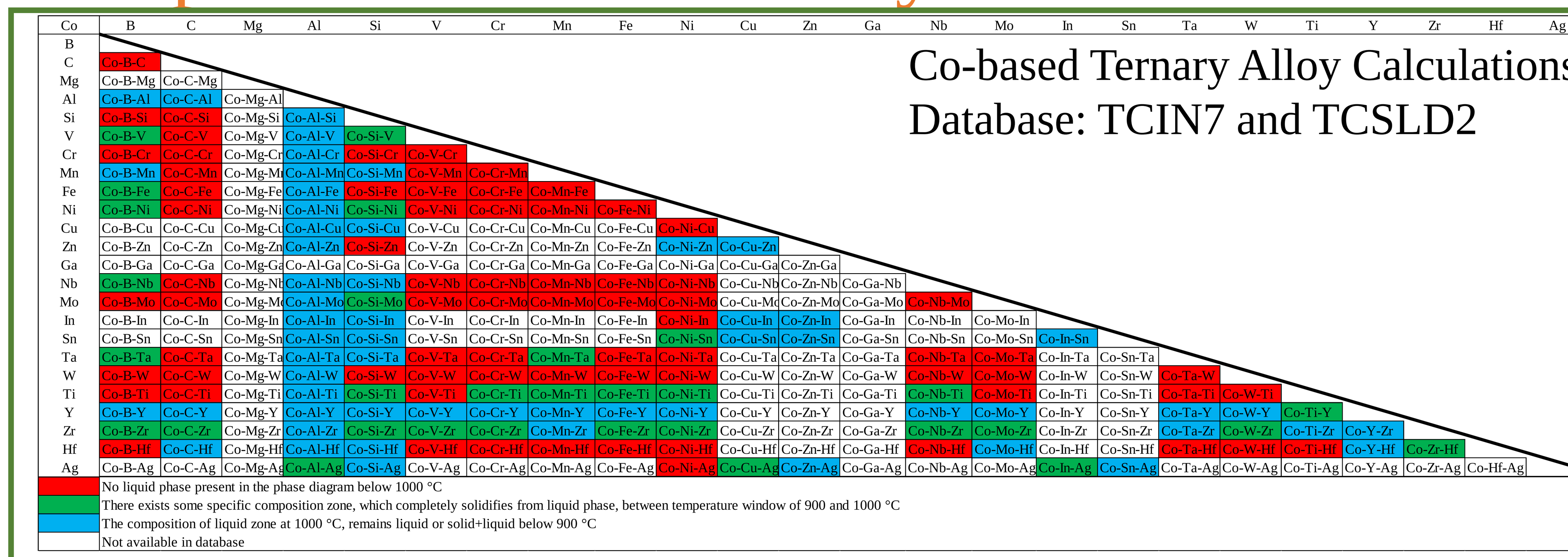
- 900°C ≤ Solidus temperature ≤1015°C
- Oxidation resistance similar to commercial alloy BNi2
- Wetting and Bonding on YSZ and Stainless Steel 441

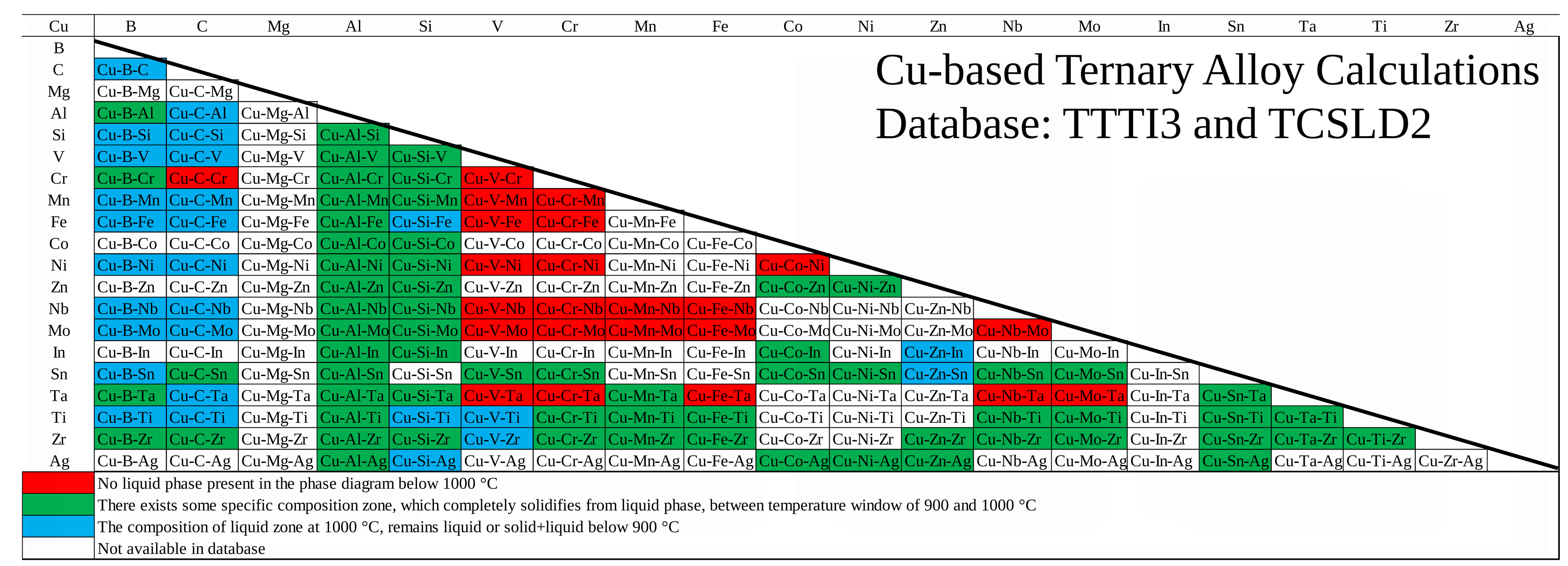
Computational Braze Alloy Selection I

Sample image showing composition selection based on the solidus temperatures:

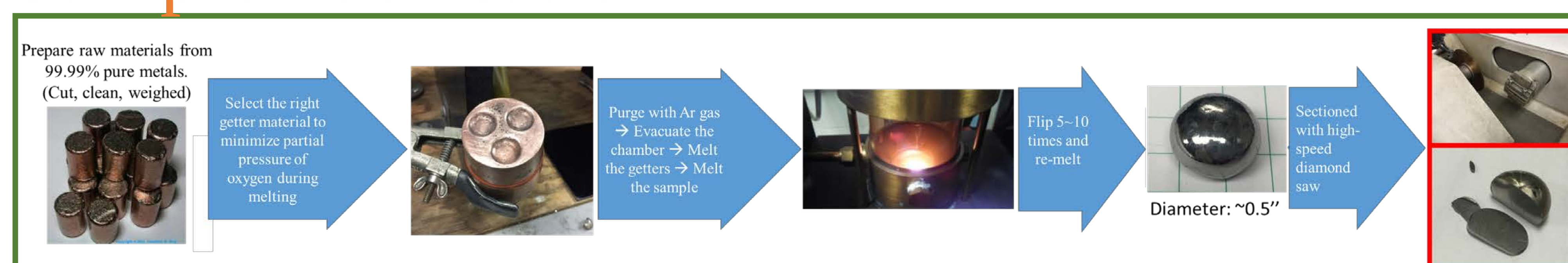


Computational Braze Alloy Selection II

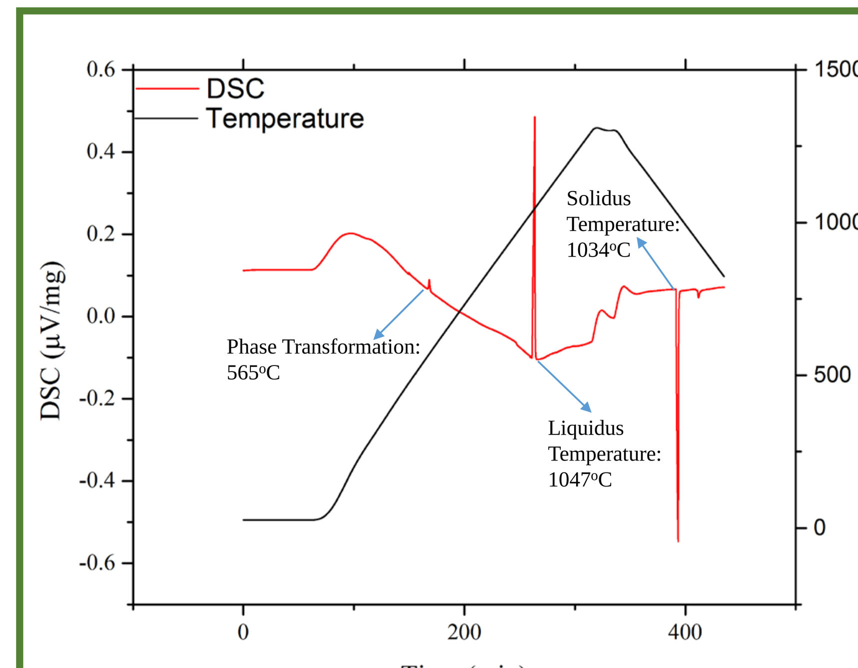




Sample Fabrication



DSC Results

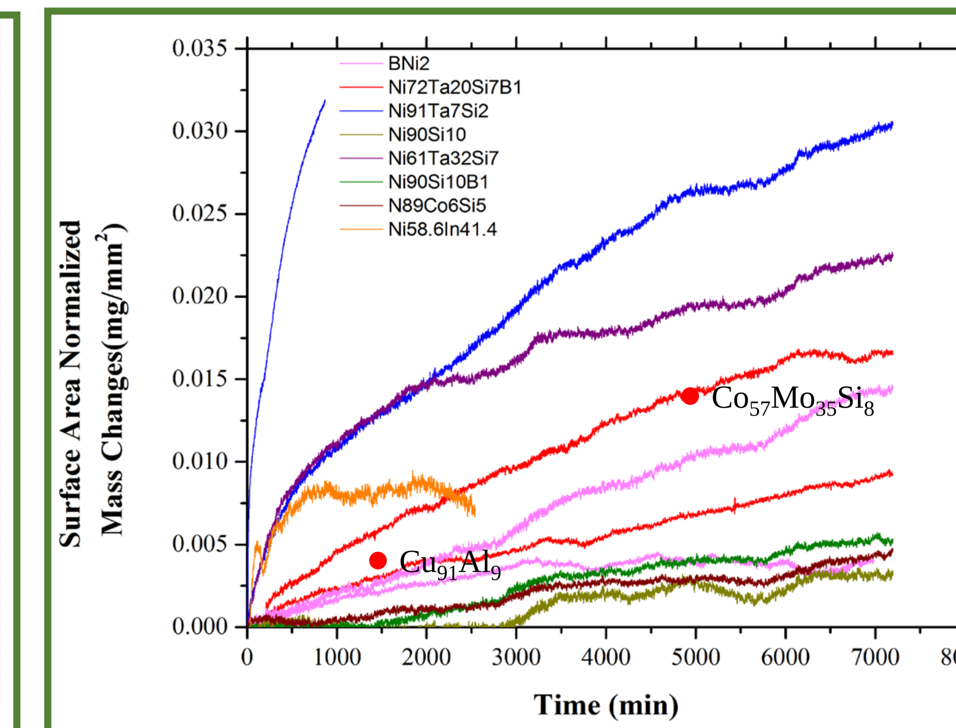


Sample DSC Data for the $Cu_{91}Al_9$ Braze:
Liquidus Temperature: 1047°C
Solidus Temperature: 1034°C

Alloy Composition	Liquidus Temperature (°C)	Solidus Temperature (°C)
$Cu_{91}Al_9$	Good (1047)	Good (1034)
$Cu_{95}Si_5$	Good (861)	Good (974)
$Cu_{98.5}Cr_{1.5}$	Good (1075)	Good (1086)
$Ni_{89}Co_6Si_5$	Bad (>1300)	Bad (>1300)

- Nominal Ramp Rates: 5°C/min Heating and Cooling
- Maximum Temperature: 1300°C

TGA Results



Testing Conditions: 5°C/min Heating and Cooling; holding at 750°C for 2~5 days

- $Ni_{89}Co_6Si_5$ and $Cu_{91}Al_9$ showed good oxidation resistance

Conclusions

- $Ni_{89}Co_6Si_5$ showed good oxidation resistance after 5 days of oxidation testing, but further composition adjustment is needed to lower the melting point
- Most of the computationally identified copper-based alloys from computational results were modifications of either Cu-Al or Cu-Si.
- $Cu_{91}Al_9$ composition showed good oxidation resistance after 24 hrs of oxidation
- Future work is aimed at testing the wetting, bond strength and long term stability of these, and additional, Co and Cu based brazes

References

[1] Wachsman E D, Lee K T. Lowering the Temperature of Solid Oxide Fuel Cells. Science, 2011, 334 (6058): 935-939.

[2] Bause T, Malzbender J, Pausch M, et al. Damage and Failure of Silver Based Ceramic/Metal Joints for SOFC Stacks. Fuel Cells, 2013, 13 (4): 578-583.

Acknowledgements

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