Halide and Oxy-Halide Eutectic Systems for High-Performance, High-Temperature Heat Transfer Fluids

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PROJECT OBJECTIVES

Goal: This project seeks to optimize ternary and quaternary compositions of alkali halides (ionic salts) and metal halides (covalent salts) in eutectic system in order to develop a high temperature heat transfer fluid that has a low melting point (< 250°C), and high temperature (> 800°C) thermal stability, as well as favorable thermal and transport properties.

Innovation: Alkali-Halide/Metal-Halide systems offer the design tunability to achieve integrated optimization. Oxy-Lewis acid/base and network-forming additives may be added into the system to reduce the vapor pressure and corrosion, and deliver favorable thermal and transport properties. All proposed salts are chemically very stable with low cost. The main issues are vapor pressure and corrosion reduction, which will be addressed.

Milestones: Binary, ternary eutectic compositions and melting temperatures for three systems KCl-NaCl-$AlCl_3$, KCl-NaCl-$ZnCl_2$, and KCl-NaCl-$FeCl_3$ were identified and tested.

APPROACH

- General experimental measurement of melting temperatures and vaporization of species at high temperatures in ambient pressure.
- STA—combined DSC/TGA, and Raman experimental tests and analysis for the salt candidates of singles, and eutectics.
- High temperature corrosion test has been undergoing using Tafel Polarization studies.
- High temperature fluid properties (salts mixtures with or without additives) are mainly experimentally measured with the assistance of theoretical analysis and prediction.
- Computer simulation for studies of vapor pressures of eutectics of binary, ternary systems.

KEY RESULTS AND OUTCOMES

Salt System	Eutectic (mole fraction)	Melting point (°C)	Open Pan TGA mass loss starting point (°C)
$AlCl_3$/KCl/NaCl	50 / 14 / 36	132	550
	49 / 51 / 0	248	640
	50 / 0 / 50	157	520
$ZnCl_2$/KCl/NaCl	44.3 / 41.9 / 13.8	210	600
	60 / 20 / 20	200	480
	48.4 / 51.6 / 000	240	600
$FeCl_3$/KCl/NaCl	53 / 13 / 34	139	500
	74 / 17.5 / 8.5	200	500

Salt (mole fraction)-metal	T- atm.	Corrosion rate (µm/year)
NaCl-ZnCl2 (40-60) Stainless steel 430	300 °C open air	12
NaCl-KCl-$ZnCl_2$ (13.4-33.7-52.9) Stainless steel 430	250 °C open air	45
NaCl-KCl-$ZnCl_2$ (13.4-33.7-52.9) Hastelloy (C276)	500 °C open air	38

NEXT MILESTONES

1. Conduct additional DSC/TGA tests for all the salt candidate at temperatures up to 1000°C. Mass loss will be examined to study the vaporization of compositions in salt systems. A candidate salt composition will be identified for property studies.
2. Establish the corrosion rate for Stainless Steel and Hastelloy at high temperatures (250–650°C for Stainless Steel, and 500–1300°C for Hastelloy) by using traditional gravimetric weight loss measurements and Impedance Analysis.
3. Conduct thermal conductivity measurement using hotwire at temperatures up to 800°C. For temperatures above 800°C, collaboration with Oak Ridge National Laboratory is planned to redesign the sample cell in its laser flash instrument for use with molten salts.
4. Viscosities and densities of the primary targeted salts liquid will be measured.