

Molten Chloride Salts for Thermal Energy Storage in Concentrated Solar Power Plants

Dr. Wenjin Ding¹, Dr. Alexander Bonk¹, Dr. Thomas Bauer²

¹ Institute of Engineering Thermodynamics, German Aerospace Center (DLR). Pfaffenwaldring 38, 70569 Stuttgart, Germany.

² Institute of Engineering Thermodynamics, DLR. Linder Höhe, 51147 Cologne, Germany.

Corresponding author: Wenjin Ding, Tel.: +4922036013162, E-mail: wenjin.ding@dlr.de.

Recently, more and more attention is paid on applications of molten chloride salts in concentrated solar power (CSP) plants as thermal energy storage (TES) and heat transfer fluid (HTF) materials due to their high thermal stability limits (>800°C) and low prices, compared to the commercial TES/HTF materials in CSP - nitrate salts (decomposed at ~550°C). Over the course of the SunShot Initiative, the U.S. Department of Energy (DOE) has supported the molten chloride salt development for the next generation CSP (Gen-3 CSP) [1]. A higher TES/HTF operating temperature in CSP leads to higher efficiency of thermal to electrical energy conversion of the power block. However this causes additional challenges, particularly increased corrosiveness of metallic alloys used as containers and structural materials. This presentation outlines our current development progress of molten chloride salts as TES/HTF materials in the next generation CSP [2-6], including in-depth investigation on corrosion behaviors and mechanisms of metallic alloys in molten chlorides at operating temperatures of 500-800°C, and development of corresponding corrosion mitigation strategies towards realization of commercial applications of molten chlorides in CSP.

Our works [2-3] indicate that corrosion of metallic alloys in molten chlorides at high temperatures is a complex process consisting of interaction between atmosphere gas with molten chlorides, interaction of species within the molten chlorides and interaction between molten chlorides and structural materials. It is mainly driven by the corrosive impurities in the molten chlorides like H and O containing species from hydrated water in the chloride salts or the atmosphere [3]. An electrochemical method based on cyclic voltammetry (CV) was developed to fast in-situ measure the concentration of the corrosive impurities in molten MgCl₂/KCl/NaCl (60/20/20 mole%) salts at 500-700°C [4-5]. Corrosion mitigation methods such as adding corrosion inhibitors in molten chloride salts or forming a protective layer on alloys were investigated [3]. In our current work [6], Mg metal was used as the corrosion inhibitor to mitigate corrosion of commercial Cr-Fe-Ni alloys in molten chloride salts (MgCl₂/NaCl/KCl 60/20/20 mole%) under inert atmosphere. The experiment results at 700°C for 500 h immersion time indicate that the corrosion rates of commercial alloys in the molten chlorides with 1wt.% Mg were reduced to ~10% of those in the molten chlorides without Mg. The corrosion mitigation mechanisms were studied via microstructural analysis on exposed alloy samples with SEM, EDX and RXD. The CV and corrosion inhibitor methods can help to develop an advanced technology, which could effectively and affordably control the concentration of the impurities in operating molten chloride salts, and thus the corrosion of structural metallic components in contact with the molten salts. Besides adding a corrosion inhibitor, in an alternative approach a protective oxide layer was formed on two Fe-Cr-Al model alloys via pre-oxidation [6]. The corrosion test results of these Fe-Cr-Al alloys immersed in molten chloride salts at 700°C for 500 h show that the protective oxide layers can successfully inhibit the outer diffusion of Cr and inner penetration of corrosive impurities.

References

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