Motivation

Previous Studies in MnO-SiO2-TiO2-Ti2O3 System

Complete phase diagram in the wide range of P02 and temperature has not been known for MnO-TiO2, and MnO-SiO2-TiO2 systems!

Scope of Present Study

Experimental and Thermodynamic Modeling

Experimental Condition

- Phase diagram in MnO-SiO2-TiO2-Ti2O3 quaternary system under controlled oxygen partial pressure

- Experimental Method
  - High Temperature Equilibration
  - Quenching and Polishing
  - Examination samples using microscope

- After Experiment
  - EPMA measurement for equilibrium compositions of phases

Thermodynamic Modeling and Optimization

- Binary
  - MnO-SiO2, SiO2-TiO2, SiO2-Ti2O3, MnO-TiO2

- Ternary
  - SiO2-TiO2-Ti2O3, MnO-SiO2-TiO2, MnO-SiO2-Ti2O3

- All thermodynamic calculations and optimizations were performed by FactSage database.

Results – Selected experimental results with thermodynamic calculation (lines)

MnO-TiO2-Ti2O3 system

Composition vs log P02 diagram in the MnO-TiO2-Ti2O3 system at 1200°C

MnO-SiO2-TiO2-Ti2O3 system

Liquids projection of the MnO-SiO2-TiO2-Ti2O3 system

As P02 decreases, phase equilibria changes dramatically. Pseudobrookite s.s. appears at low P02.

Application – Inclusions Evolution in Mn-Si-Ti containing Steels

Morphologies and phases of inclusions in steels varying Ti content

Comparison with experimental data by Kim et al., ISIJ Int., 2002

Oxide Metallurgy

Intra Granular Ferrite (IGF) formation using non metal inclusions as nucleation site

Amount of Mn absorbed into TiOx from steel matrix (94.1°C-101.8°C) decreased at 1000°C

Mn is austenite stabilizing element so MDZ results in ferrite transformation around the inclusion.

ABSTRACT

Phase equilibria of the system MnO-SiO2-TiO2-Ti2O3 under controlled atmosphere have been measured in the temperature range from 1200°C to 1550°C and in the range of log P02, atm, from -7.2 to 2.0 (C-CO2 equilibrium). High-temperature equilibration, quenching and electron probe microanalysis (EPMA) were employed to obtain equilibrium compositions of liquid and several solid solutions. It was found that phase equilibria is strongly dependent on the oxygen partial pressure. No ternary compounds or ternary solid solutions were observed. Based on the newly obtained phase diagram data with a number of reliable thermodynamic data in literature, a thermodynamic optimization of phase diagram and thermodynamic properties of the MnO-SiO2-TiO2 ternary system at 1 bar pressure are presented. The molten oxide phase was described by the Modified Quasichemical Model. The Gibbs energies of several solid solutions (spinel, pyrophanite, pseudobrookite, manganosite and rutile) were modeled with the Compound Energy Formalism. Furthermore, inclusions chemistry of Mn/Si/Ti deoxidized steel was studied through thermodynamic computation and compared with experimentally reported data. Inclusions evolutions in Mn/Si/Ti containing steels by thermodynamic prediction were in good agreement with the experimental data.

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