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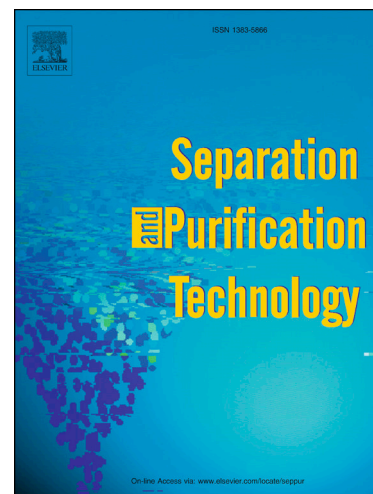
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The behavior of Ca and its compounds in Si during the slag refining with CaO-SiO₂-CaF₂ system under air atmosphere

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Abstract

A simulative industrial processing, slag refining under open air atmosphere conditions, has been established to observe the removal efficiency of impurities from molten Si at 1823 K. The behavior of Ca and its compounds in Si are investigated. The results show that, CaSi₂ is a key compound on removing Fe, Al, Ca and P from Si. Ca in molten Si is produced from the reaction between CaO and Si at the melting stage of slag and Si, as well as at the beginning refining period of around 10 min, which is largely depends on the net content of single CaO phase. With the temperature going down to 1303 K gradually, most of Si is solidified and Ca percentage is increased, then species CaSi₂ phase is generated from the melt composed of 61.4 wt% Si, while Fe is precipitated at the boundary between phases CaSi₂ and Si. Furthermore, it is determined that, part of P in Si is oxidized to PO₄³⁻ not by SiO₂ but by CaO to form CaO·P₂O₅ slag phase, the other is more likely to be reduced to Ca_xSi_yP_z than to Ca₃P₂. Therefore, a slag rich in CaO will be much easier to produce Ca in Si and more efficient to remove impurities by acid leaching.

Keywords: Impurities; Calcium; Silicon; Slag treatment; Gibbs free energy; Segregation

1. Introduction

Global photovoltaic production in 2016 was amounted to 82.6 GWp, where 94% was made of crystalline silicon.^[1] In the foreseeable future, silicon will continue to dominate the photovoltaic market. Phosphorus (P), acting as a donor dopant, is sensitive for the performance of silicon solar cell,^[2] The P content in solar grade silicon (SoG-Si) is generally accepted below 0.1 ppmw (1×10⁻⁷).^[3,4] It is hard to remove P from Si by directional solidification due to its relative large segregation coefficient of 0.35^[5]. Vacuum treatments with electron beam (EB) melting^[6-8] or induction refining^[9,10] are normally carried out effectively on P removal based on its high vapor pressure. However, the rigorous experiment conditions, such as high vacuum condition at high temperature, make it

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