Thermodynamics of Boron Removal from Molten Silicon with Silicate Slag

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Photovoltaic cells are one of the answers for the growing demand for clean energy. The silicon from which the photovoltaic cell is made, is an over grade or scrap of electronic grade silicon. This silicon of high purity is expensive, and in order to increase the production of photovoltaic cells, we need to find a cheaper process for the solar grade silicon production, and one possible way is the refining of the metallurgical grade silicon. In metallurgical grade silicon the main impurities are: Fe, Ca, Al, P and B. Processes that lead to the removal of those elements were already achieved by some researchers, however, the Boron removal is still a challenger. Most impurities in molten silicon (with exception of the P and B) have a very low segregation coefficient, and by this way, can be refined using directional solidification. Many researches are based on plasma refining of metallurgical grade silicon, however the use of plasma still a very costly process.

The objective of this research is to analyze the thermodynamics of boron removal from silicon using a slag treatment. With these results, we will be able to clarify the thermodynamics of boron in silicon.

Element	Content in MG-Si (ppmw)	Content in Solar-Si (ppmw)
B	3.00×10^{1}	3.00×10^{-1}
P	3.00×10^{1}	1.00×10^{-1}
C	1.00×10^{3}	5.00
O	1.00×10^{2}	5.00
Al	5.00×10^{2}	7.02×10^{-3}
Fe	8.00×10^{2}	3.00×10^{-4}

Thermodynamics Properties

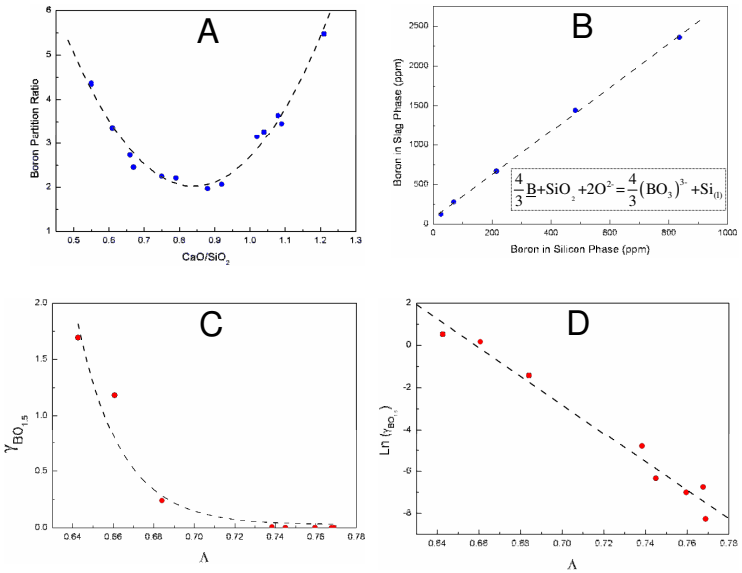


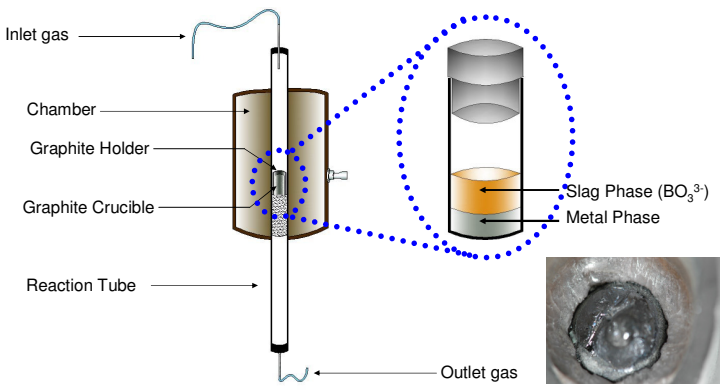
Figure A: Partition ratio of boron for the binary system SiO_2-CaO

Figure B: Relation Dependence between boron in Slag and silicon pahse

Figure C: Activity Coefficient of $BO_{1.5}$ for the ternary system SiO_2-CaO-CaF_2

Figure D: Linear dependence of activity coefficient as a function of optical basicity

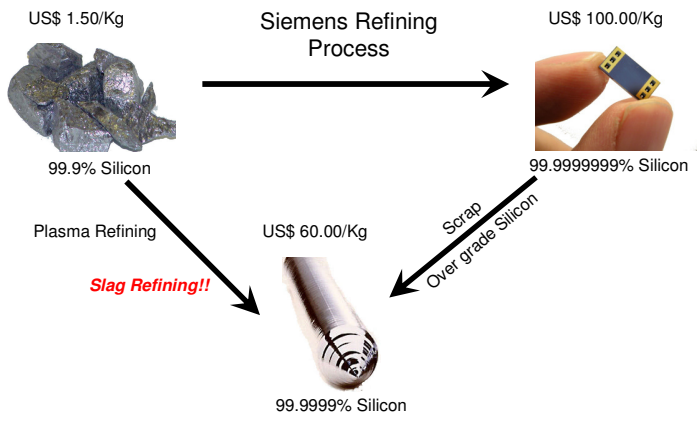
Laboratory Experiment



Experimental Apparatus

Slag Equilibrated with Silicon

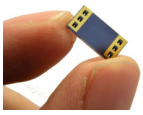
Silicon Purity Levels and Price



Metallurgical Grade Silicon: This material has purity around 98-99% and is mainly used on the production of alloys such as Si-Al, FeSi and others.

Chemical Grade Silicon: This material has purity around 99-99.9%. Produced in a electric arc furnace, is used on the chemical industry. It is reacted in a chemical reactor and is mainly used on the production of silicones.

Solar Grade Silicon: This material is made from the scrap and over grade of the electronic industry. Is used on the production of photovoltaic cells. Due to the low availability of this material in the market, the price is 3 times higher than the expected. Purity: 99.9999% Silicon.



Electronic Grade Silicon: This material is used on the production of computer chips. Produced by the so called Siemens Refining Process, a CDV (Chemical Vapor Deposition) process, is a very expensive material, with purity level of 99.9999999% Silicon.

Production process of Metallurgical Grade Silicon