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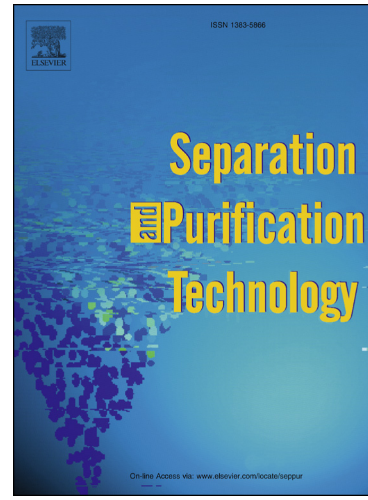

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Use of a thermal plasma process to recycle silicon kerf loss to solar-grade silicon feedstock

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Abstract: The objective of this study was to recycle the dust generated in the slicing of silicon wafers (silicon kerf) by means of a two-stage thermal plasma process. In the first stage, the silicon particles are injected in a plasma jet where silicon oxides and carbon impurities are removed by vaporization. In the second stage, the purified silicon droplets are collected in a silicon bath maintained in a hot-wall crucible. The optimal operating conditions for reduction were determined by injecting into the plasma jet a commercial silicon powder of known degree of oxidation and measuring the attained degree of reduction. Also, silicon powders from wafer slicing were processed in the two-stage plasma set-up. The results of these tests showed that the deoxidation rate of the final silicon ingot was as high as 80% and the initial carbon concentration decreased by 85%. The purification was essentially controlled by the residence time of particles in the hottest zones of the plasma jet and the partial pressure of oxygen in the processing atmosphere.

Keywords: *Silicon kerf, thermal plasma, waste recovery, solar-grade silicon*

Nomenclature

SoG-Si : solar-grade silicon
DC : direct current
slm : standard-liter per minute
mm : millimeter
ppm : parts-per-million
SEM : Scanning Electron Microscopy
O_f : Final oxygen content (%)
O_i : Initial oxygen content (%)
h : mean enthalpy of the plasma jet (MJ/kg)
$\bar{u}$: average velocity at the nozzle exit (m/s)
U : arc voltage (V)
I : arc current (A)
D : plasma gas mass flow rate (kg/s)
η : thermal efficiency of the plasma torch (%)
γ : gas isentropic coefficient
P_a : atmospheric pressure at nozzle exit (Pa)
S : nozzle cross section (m^2)

1. Introduction

Silicon is currently the most used semi-conductor in solar panels. The solar-grade silicon (SoG-Si) is produced by the carbothermal reduction of quartz in arc furnace followed by a chemical purification process. After crystallization, the silicon ingots are cut into strips a few hundreds of microns thick (wafers) that are the base of solar cells.

Two routes are currently used for the slicing of wafers: the conventional "slurry-based" method that uses abrasive particles (silicon carbide) suspended in an organic coolant (glycol) carried with the moving wire and, the emerging "diamond-fixed" method that uses a wire coated with diamond particles. Whatever the slicing technology, the kerf loss is about 40% of the crystallized silicon ingots [1] and is formed as a sludge made up of the coolant liquid (e.g. glycol or water), oxidized silicon