Progress in Solidification Refining of Si with Si-Al melt

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Phase diagram for the Si-Al binary system



Solidification at low temperature.



Enhanced segregation with Si-Al melt at low temperature.

Solidification refining of Si with Si-Al melt at low temperature,



High purification ability of solidification with Si-Al melt.





- Si crystal growth from Si-Al melt to prevent melt contamination.
- Investigation of the growth condition of bulk Si crystal from Si-Al melt.
 - Directional solidification Cooling rate Temperature gradient
 Classification of interface Growth rate





Experimental procedure1





Solid phase ratio

0.139

Temperature (K)

1173

1273

Fig. Schematic description of the experiment.



Si growth from Si-Al melt



Temperature gradient : 1.5 K/mm Cooling rate : 0.062 K/min



Bulk Si crystal can be obtained from Si-Al melt.

FOFINDUS Effect of cooling rate and temperature gradient



TEOF INDUS **Classification of Si crystal / Si-Al melt interface** ENCEOUTO



Growth rate of Si crystals and temperature gradient



Cooling rate 0.062 K/min Temperature gradient 1.5K /mm Length of Si crystal 3.1 mm Experimental time 1925 min Growth rate 1.6 × 10⁻³ mm/min





Temperature Gradient (K/mm) Fig. Relationship between temperature gradient, Si growth rate and interface types.

Estimation of Si growth rate under diffusion control condition





Diffusion control condition

Estimation of Si growth rate under diffusion control condition





Temperature Gradient (K/mm)

Fig. Relationship between temperature gradient, Si growth rate and interface types.

Good agreement with experimental results.



Si growth under diffusion control condition.

Impurity contents in refined Si



Table Impurity contents in Si (ppmw) and removal fraction.(ICP atomic emission spectroscopy)

Sample	Fe	Al	Ti	В	Р
MG-1	6040	1950	896	59	-
MG-2	1500	523	414	70	178

Sample	Source	Fe	Al	Ti	В	Р
Re-1	MG-1	31.8(99.5%)	232(88.1%)	1.7(99.8%)	6.9(88.3%)	-
Re-2	MG-2	17.3(98.8%)	427(18.3%)	1.3(99.7%)	7.3(89.6%)	16(91.0%)

Solid solubility of Al : 1173K 160ppmw, 1273K 260ppmw

Melt contamination was prevented. High removal ratio could be obtained.

Conclusion



- Bulk Si crystal could be obtained from directional solidification of Si-Al melt with very low cooling rate.
- Growth rate of Si crystal, which has flat Si crystal / Si-Al melt interface, is controlled by diffusion of Si in the melt.
- Al content in refined Si was about solid solubility and other impurity elements can be removed efficiently.



Thank you for your kind attention.