Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 124 (2017) 734–739

Energy Procedia

www.elsevier.com/locate/procedia

7th International Conference on Silicon Photovoltaics, SiliconPV 2017

Controlling impurity distribution in quasi-mono crystalline Si ingot by seed manipulation for artificially controlled defects technique

Yusuke Hayama[a,]*, Isao Takahashi[a], Noritaka Usami[a]

[a]*Graduate School of Engineering, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-8603, JAPAN*

Abstract

We report on our attempt to control impurity distributions by locally introduced high density of dislocations based on seed manipulation for artificially controlled defect technique (SMART). To grow a quasi-mono crystalline Si ingot to demonstrate the impact of SMART, seed arrangement was designed to have SMART and conventional parts in a single ingot. After crystal growth, the ingot was cut in half and the half one was annealed at 600 ℃ for 1 week. Photoluminescence imaging clarified that impurities are efficiently trapped at functional defects after annealing, which led to improvement of the crystal quality along the functional defects. This result suggests that combining SMART with annealing after crystal growth is the effective way to obtain a higher manufacturing yield of quasi-mono crystalline Si ingot for solar cells.

Peer review by the scientific conference committee of SiliconPV 2017 under responsibility of PSE AG.

Keywords: Defects, Impurities, Solar cells, Semiconducting silicon, Industrial crystallization, Diffusion

1. Introduction

Crystalline Si (c-Si) is the most dominant material in all PV market with about 90 % share in recent years [1]. C-Si is generally categorized into monocrystalline Si (mono-Si) and multicrystalline Si (mc-Si). Each one has its own merit for PV production. Since mono-Si is free from defects to act as recombination centers, high-efficiency solar cells could be achieved. On the other hand, high production yield of mc-Si can reduce the manufacturing cost. To take both merits of mono-Si and mc-Si, quasi-mono crystalline Si, which is directionally grown from multiple mono

* Corresponding author. Tel.: +81-52-789-3243; fax:+81-52-789-4516.
E-mail address: hayama.yuusuke@d.mbox.nagoya-u.ac.jp

Peer review by the scientific conference committee of SiliconPV 2017 under responsibility of PSE AG.
10.1016/j.egypro.2017.09.088

crystalline Si seeds in a large scale crucible, was contrived and studied a lot [2-4]. Quasi-mono crystalline Si is expected as high quality and low cost starting material for solar cells. However, crystal growth of quasi-mono crystalline Si has several issues, i.e. dislocation generation at the seed joint, inhomogeneous nucleation at crucible walls to result in multicrystallization, and the increase in the duration of ingot growth process to lead to larger impurity diffusion [5-9]. To solve these problems, we have originally developed quasi-mono crystalline Si growth method named as "seed manipulation for artificially controlled defect technique (SMART)" [10]. In SMART, defect distributions in a Si ingot can be artificially designed by arranging seeds with proper size and orientation. High density of defects is intentionally introduced in a tiny part of the ingot to act as gettering sites of impurities. We call such intentionally introduced defects as "functional defects". Crystal defects in mc-Si are known to act as internal gettering sites for impurities during the ingot crystallization process [11,12]. In this study, we studied controlling impurity distribution in quasi-mono Si ingot which was grown by SMART.

2. Experimental method

We made a boron doped Si ingot by using SMART and conventional method. A fused silica crucible with inner dimensions of 11 cm × 11 cm × 19 cm was used. The crucible was coated by Si_3N_4 and then annealed at 950 ℃ in Ar atmosphere for 9 h to evaporate polyvinyl alcohol in the coating. Then, seed crystals were put on the crucible bottom as shown in Fig.1 (a) to illustrate the top view of the arrangement. The growth direction of all the seeds is chosen as <100> as shown in Fig. 1 (b). The concept of SMART is implemented to the left side of the seed arrangement. Around the edge of the mono-Si seed, four pieces of wafers were put to make artificial small angle grain boundaries for generating high density of dislocations. The boundary between the most inner wafer and mono-seed make a large-angle tilt boundary to block the propagation of dislocations. In addition, the space between seed crystals and crucible wall were filled with Si chunks as shown in Fig. 1 (c). The Si chunks act as the seed for fine grains, which help to prevent multicrystallization from the crucible wall [13]. On the other hand, the right side is used for conventional method of quasi-mono crystalline Si. After that, Si feedstock at the weight of 2050 g was put on the seeds. After the feedstock and an upper part of the seeds were melted, an ingot was directionally grown in a temperature gradient by pulling down the crucible position at 0.3 mm/min. Ar (5L/min) and N_2 (2L/min) gases were flowed during the crystal growth. The height of the grown ingot was ~11 cm.

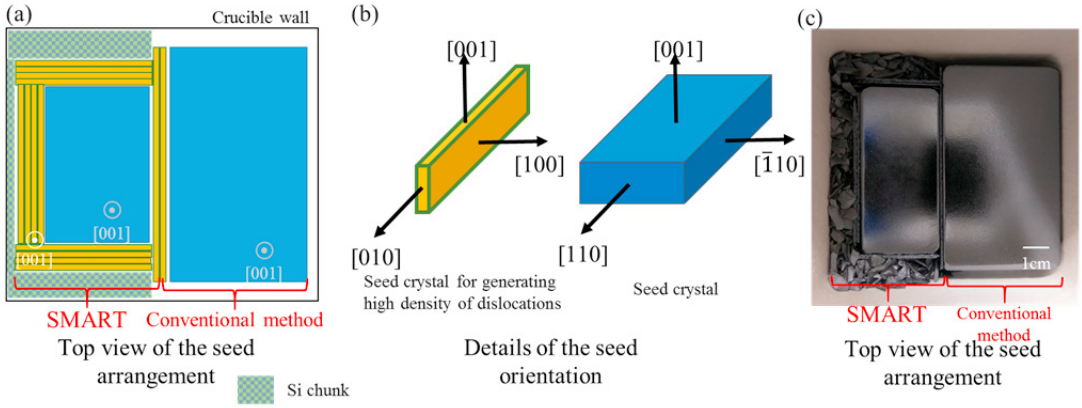

Fig. 1 The schematic images for (a) the top view of seed arrangement and (b) details of the seed orientation, and a photo for the seed arrangement from the top.