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Present status and future of crystalline silicon solar cells in Japan

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Abstract

Crystalline silicon solar cells show promise for further improvement of cell efficiency and cost reduction by developing process technologies for large-area, thin and high-efficiency cells and manufacturing technologies for cells and modules with high yield and high productivity.

In this paper, Japanese activities on crystalline Si wafers and solar cells are presented. Based on our research results from crystalline Si materials and solar cells, key issues for further development of crystalline Si materials and solar cells will be discussed together with recent progress in the field. According to the Japanese PV2030 road map, by the year 2030 we will have to realize efficiencies of 22% for module and 25% for cell technologies into industrial mass production, to reduce the wafer thickness to 50–100 μm, and to reduce electricity cost from 50 Japanese Yen/kWh to 7 Yen/kWh in order to increase the market size by another 100–1000 times.

Keywords: Crystalline silicon; Solar cell

1. Introduction

Dissemination of photovoltaic (PV) systems has been advanced and solar cell module production has also been significantly increased in Japan as a result of research and development programs, such as the New Sunshine Project under the Ministry of Economy, Trade and Industry (METI), Residential PV System Dissemination Program and others. Fig. 1 shows Japanese cumulative installed capacity based on the rated DC power of PV systems by year (Yamaguchi, 2001). The total installed capacity of PV systems in 2003 reached 222.8 MW and the cumulative installed capacity recorded 859.6 MW, with the 1 GW level already in sight for 2004. The PV market in Japan is working toward a target of 4.82 GW by 2010. As a result of discussion at the Committee for the 2030 PV Road Map in Japan organized by the New Energy and Industry Technology Development (NEDO) and METI, we also expect about 100 GW cumulative installed capacity (Kurokawa and Aratani, 2004), about 10% of Japanese electricity consumption by 2030.

Table 1 shows the production capacity of major solar cell manufactures in Japan (Ikki et al., 2004). Manufacturing companies of solar cells and modules have been

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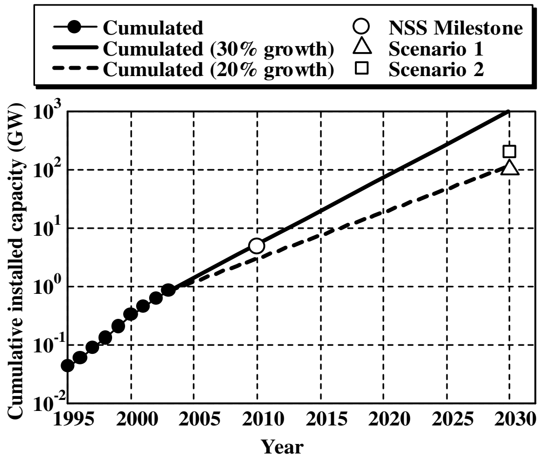

Fig. 1. Cumulated installed capacity of PV systems in Japan by year. NSS is the New Sun-Shine program in Japan.

Table 1
Production capacity of major solar cell manufactures (Ikki et al., 2004) (unit: MW)

Solar cell manufacture	2002	2003	2004–05[a]
Sharp	200	248	300
Kyocera	72	100	120–200
Sanyo Electric	35	68	160
Mitsubishi Electric	35	50	90–130
Kaneka	20	20	40
Mitsubishi Heavy Industries	10	10	20
Matsushita Ecology	3	3	–

[a] Plan.

repeatedly enhancing their production capacity to meet the rising demand and to proceed further with cost reduction. 2003 shipment volume and the value of solar cell modules have rapidly increased by 48.7% since 2002 to 407.7 MW. However, multi crystalline silicon (mc-Si) and single crystalline silicon (sc-Si) solar cell and module technologies have dominated the Japanese PV market with a share of about 95%. That means that crystalline Si solar cell and module technologies will have to contribute further to PV market growth and PV system installation. Further development of Si materials, processing, solar cell and module technologies is necessary for realizing cell efficiency improvement and cost reduction.

In this paper, Japanese R&D activities on crystalline Si wafers and solar cells are presented. Based on our research results of crystalline Si materials and solar cells, key issues for further development of crystalline Si materials and solar cells will be discussed together with recent progress in the field.

2. Japanese development activities on crystalline silicon wafers and solar cells

2.1. Multi crystalline silicon (mc-Si) wafers

Mc-Si solar cells are promising candidates for further increasing cell efficiency and cost reduction. Improvement in the quality of mc-Si wafers is very important in order to achieve high conversion efficiency mc-Si solar cells.

KAWASAKI Steel (presently JFE Steel) has developed high quality mc-Si wafers by various methods such as purification (by purifying atmosphere, mold and coating material) and enlargement of grain size by controlling solidification speed (Nara and Sakaguchi, 2003). Fig. 2 shows correlation of the resistivity and lifetime of mc-Si wafers in comparison with those of sc-Si wafers. The diffusion lengths of mc-Si wafers were measured by SPV method. In order to reduce the effect of surface recombination without pretreatment, mc-Si wafers with thickness of 3 mm were used for the measurements. The average diffusion length of mc-Si wafers with area of 100 cm^2 and resistivity of 0.4–0.6 Ω cm obtained was over 250 μm (lifetime of more than 30 μs) and the maximum diffusion length was 780 μm. As described below, by using mc-Si wafers developed by JFE Steel, SHARP has obtained 19.0% efficiency for 1 cm^2 cells (Komatsu et al., 2003), and most recently Fraunhofer ISE has succeeded in fabricating high efficiency mc-Si solar cells of 20.3% efficiency with an aperture area of 1 cm^2 (Schultz et al., 2004).

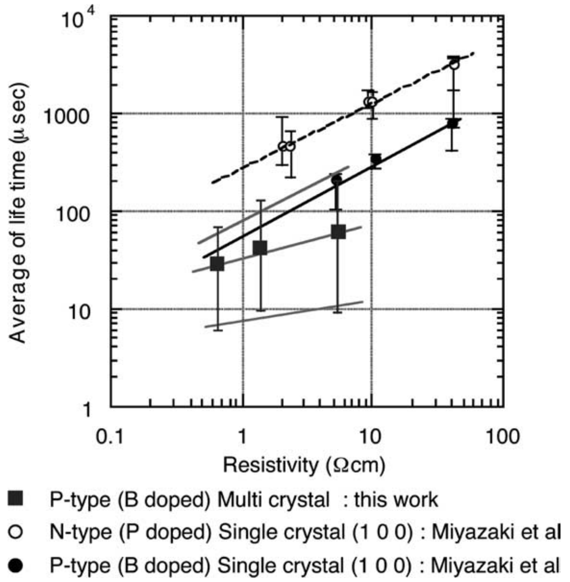

Fig. 2. Correlation of the resistivity and lifetime of mc-Si wafers in comparison with those of sc-Si wafers (Nara and Sakaguchi, 2003).