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Evaluation of Solar Cells Made of Si Ribbon Crystals

Akimichi Hojo, Yasuo Ikawa and Masashi Nakagawa Toshiba R and D Center, Electron Devices Lab. 1 Toshiba-cho, Kawasaki, Japan

The use of Si ribbon crystal as a starting material for production of solar cells is a promising approach for the cost down of the devices⁽¹⁾ The Si ribbon crystals have a tendency to show electrically inferior characteristics because of crystal defects when compared with crystals grown by Czochralski method. Therefore, it has not been quite certain whether the ribbon crystal can be used for the efficient solar cell. This paper describes (1) electrical characteristics of solar cells fabricated from the Si ribbon crystals, (2) results of minority carrier lifetime measurements, (3) preliminary observation of electron beam induced current (EBIC) of p-n junction formed in the Si ribbon crystals and (4) the correlations between the solar cell performances and the lifetime characteristics deteriorated the performances.

The Si ribbon crystals were grown by the capirally method, in which the crystals were pulled from a gap between a pair of carbon dies into which a sheet of molten Si rose by capillary action. The crystals were arsenic doped n-type. Resistivities were about 0.3 Ω ·cm and Hall mobilities were in the range of 500 \sim 900 cm²/V·sec. The crystals included various types of defects, such as linearly extending crystal boundaries (type A), irregular crystal boundaries (type B) and SiC inclusions (type C).

Figure 1 is surface structure of the solar cell tested. The device has a p^+ -n structure. The depth of the junction is about 2 μ m, which was formed by boron diffusion. The surface is antireflection coated with the SiO film.

Figure 2(a) is a V-I curve of a good device which gives 9% efficiency at AM1 condition. Figure 2(b) is that of a poor device of 2% efficiency at the same condition. By comparison, it is apparent that the poor performance corresponds to a large leakage current. The poor device was separated into sections, each of which contained only one finger electrode to investigate the mechanisms of the leakage current. It was found that the leakage current was associated with the type B and C defects.

Specimens used for the lifetime measurements and EBIC observations had identical junction structures to those of the solar cells.

Minority carrier (hole) lifetime was measured by observing a transient behaviour of the diode currents immediately after the diode bias voltage was switched from forward to reverse polarity⁽²⁾ In Table 1, the correlations between the lifetime and type of crystal defects are summarized. The values of the lifetime for the ribbon crystals distribute from 0.1 µsec to 1 µsec, which are shorter than those in CZ grown crystals. It is noticed that the type B defect makes the lifetime short whereas the type A defect does not deteriorate the lifetime.

Figure 3 is an EBIC image of the ribbon crystal with its photomicrograph. Dark lines in the EBIC image indicate regions of short minority carrier lifetime in the crystal. Type B defects are seen dark in the EBIC image indicating the short lifetime about the defect. Whereas type A defects in the photomicrograph can not be detected in the EBIC image, meaning the lifetime is not deteriorated about the defect. These observations are consistent with the results of the life-

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time measurements.

As well as the type B defects, type C defects were seen dark in the EBIC image. The leakage current and the EBIC image of the sectioned solar cells were correlated and the high leakage current was assigned to type B and C defects.

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(Ref.) (1) K. V. Ravi et al, 11th IEEE Photovoltaic Specialists Conf., 280 (1975)
(2) R. H. Kingston, Proc. IRE, <u>42</u>, 829 (1954)

Type of crystal defects	Carrier Lifetime (µsec)	
	Range	Average
No defect	0.43 ~ 0.88	0.55
Type A defect	0.31 ~ 0.66	0.47
Type B defect	0.10 ~'0.46	0.24

Table 1



Fig. 1



Fig. 2(a) Efficiency = 9% Input radiation = 80.2 mW/cm² Area = 12.48 cm²



Fig. 3(a) EBIC image $(1 - 1 - 100 \ \mu m)$



Fig. 2(b) Efficiency = 2% Input radiation = 80.2 mW/cm² Area = 12.30 cm²



Fig. 3(b) Photomicrograph (→ 100 µm)