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B—6—9 High Efficiency (Al_xGa_{1-x})-GaAs Solar Cells with High Open-circuit Voltage and Fill Factor

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The GaAs solar cells with a high conversion efficiency have been reported, wich employed the (Al_xGa_{1-x})As-GaAs heteroface structure.[1] The conversion efficiency has been improved in some ways. In one approach, a high quality n-GaAs buffer layer is grown on the n-GaAs substrate by the liquid phase epitaxy (LPE) prior to growth of the (Al_xGa_{1-x})As layer.[2] In another approach, the thin (Al_xGa_{1-x})As window layer(0.05μm)[3] is grown on the GaAs subsrate to reduce absorption in the (Al_xGa_{1-x})As layer. In these developments, mainly the short-circuit current is improved. However, the high open-circuit voltage and high fill factor have not been always achieved.

We have reproducibly fabricated (Al_xGa_{1-x})As-GaAs heteroface solar cells with a high efficiency of about 21% at air mass AM=1.4 ,that have high open-circuit voltage (1.00-1.01$_{(V)}$) and high fill factor (0.83-0.84), in the following way:

1. driving the p-n junction, which is formed by diffusion from the Al-Ga-As Zn-doped melt, to about 3-5μm depth below the (Al_xGa_{1-x})As-GaAs interface.

2. using the (111)B-oriented GaAs substrate.

In this paper we report on controlling method of the junction depth, and relation between the junction depth and performance. Fig.1 shows the cross section of the (Al_xGa_{1-x})-GaAs solar cell. The window layer of p-(Al_xGa_{1-x})As is grown by LPE on the (111)B-$_n$GaAs substrate. A p-n homojunction is formed by driving Zn from the Al-Ga-As Zn-doped melt into the $_n$GaAs substrate before growing the (Al_xGa_{1-x})As window layer. The junction depth is controlled by varing the soaking time, when a substrate is allowed to soak isothermally in the saturated Al-Ga-As Zn-doped melt, at fixed Zn content. Fig.2 and 3 show respectively the short-circuit current density and the open-circuit voltage vs. the junction depth. In Fig.2 and 3, open circles show mean values of 20 cells. The short-circuit current densities decrease with increasing the junction depth. However, the open-circuit voltage (Voc) increases with increasing the junction depth until about 5 μm. As shown in Table 1, the fill factor(F.F.) and forward voltage(V_F) at low current dnsity (1.5mA/cm^2) in the dark also increase as the junction depth increases. Hence, the high open-circuit voltage owes to the reduction of the dark current by driving the junction depth deeper. Fig.4 shows the conversion efficiency (η) at AM1.4 vs. the junction depth. The measurment was made with a solar simulator and calibrated using standard Si solar cells. The highest conversion efficiency of 21.6% is obtained for

the junction depth of around 3 μm. The cell performancies at AM 1.4 are summarized in Table 1. For comparison, in Table 1 are shown the cell performancies with the p-$(Al_xGa_{1-x})As$ window layer grown by LPE on the (100)-$_n$GaAs substrate. The (111)B-$_n$GaAs substrate is found to be superior to (100)-$_n$GaAs substrate.

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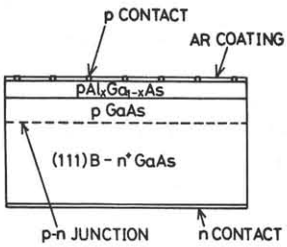

p-CONTACT : Au-Zn

n-CONTACT : Au-Ge-Ni

AR COATING: SiO 900-1000Å

p-$Al_xGa_{1-x}As$: x 0.86

Fig.1 The (AlGa)As-GaAs solar cell

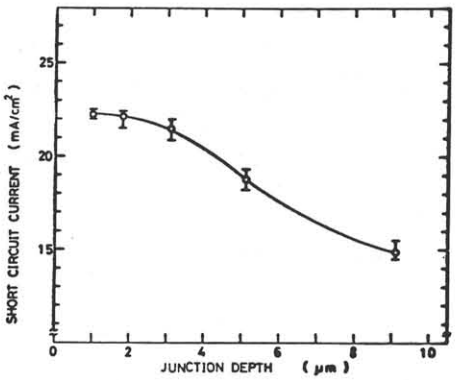

Fig.2 Short circuit current vs. junction depth

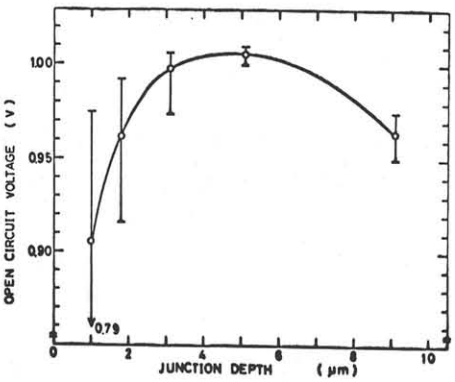

Fig.3 Open-circuit voltage vs. junction depth

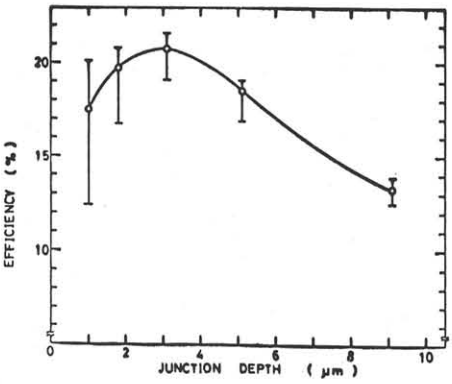

Fig.4 Efficiency vs. junction depth

Table 1 $(Al_xGa_{1-x})As$-GaAs solar cell performance

CRYSTAL ORIENT.	JUNCTION DEPTH (μm)	V_F (DARK) (V)	Voc (V)	Jsc (mA/cm^2)	FF	η (%) AM 1.4
	1.8	0.875	0.984	22.4	0.804	20.8
(111)B	3.1	0.901	1.006	21.9	0.835	21.6
	5.1	0.906	1.010	19.1	0.841	19.0
(100)	3.0	0.847	0.971	21.6	0.792	19.5

References: [1] J.M. Woodall, and H.J. Hovel, Appl. Phys. Lett. 30 492 (1977)
[2] G.S. Kamath, J. Ewan, and R.C. Knechtli, IEEE Trans. ED-24 473 (1977)
[3] R. Sahai, D.D. Edwall, and J.S. Harris, 12th IEEE Photovoltaic Specialist Conference 989 (1976)