B — 6 — 8 High-efficiency GaAs MOS Solar Cells by Anodization in Active Region

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INTRODUCTION : It is now well established that the performance of Schottky barrier solar cells can be improved by introducing a thin insulating layer with the use of a suitable process.[1] Anodization of GaAs in various modes is investigated in this paper in view of such an application. In contrast to previous negative results on anodic oxidation,[2] it is found that anodization in the active region (active dissolution region) is very effective for increasing the solar cell open-circuit voltage V_{oc}, giving reproducibly 0.7 - 0.8 V. It requires no external bias supply in the photo-excited mode, and is a simple, low-cost, short-time and large-area-oriented process, as compared with the oxidation in H_2O/O_2 ambient (50-100 hrs[2]) or with the evaporation of Sb_2O_3.[3] It also allows external monitoring of anodization by means of the photo-voltage of GaAs-electrolyte system.

Process/Performance : The AGW electrolyte[4] was used for anodization. Occurrence of active and passive regions in the anodization of GaAs with this electrolyte, was described elsewhere.[4] Single-crystal HB bulk n-GaAs wafers were anodized under various conditions. Then, thin gold films (50 ohm/sq.) with gold finger electrodes were formed by vacuum evaporation on the anodized surfaces, and the solar cell performances were compared. For comparison, Schottky cells and thermally oxidized cells were also prepared. Device notations, process conditions and cell performances are summarized in Table 1 and Fig.1. Except for AP devices, the solar cell short-circuit current density did not depend on the processes used. The AA devices posses V_{oc} comparable or even higher than those for TH devices. On the other hand, AP devices show anomalous cell

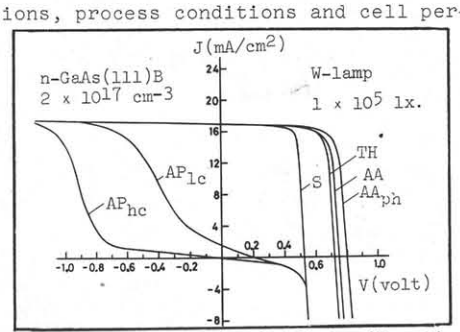

Fig.1 V-I characteristics(no AR coating)

TABLE 1. (c.d.= current density)

notations	processes	conditions	light(W-lamp, 10^5lx) V_{oc}(V)	light F.F(av.)	dark n	dark ϕ(eV)
S	Schottky	chemically etched	0.45-0.54	0.78	1.1-1.2	0.90-0.95
TH	thermal oxidation	H_2O / O_2, 114°C 17 hrs.	0.67-0.72	0.77	1.3-1.6	1.01-1.03
AA	anodization in active region	c.d. = 0.05 mA/cm² 2.5 hrs.	0.70-0.75	0.77	1.1-1.3	1.03-1.07
AA_{ph}	AA with photo-excitation	c.d. = 0.02 mA/cm² 1 hr., 10^5 lx(W-lamp)	0.70-0.80	0.77	1.1-1.3	1.03-1.07
AP_{hc}	anodization in passive region (high c.d.)	V_f= 1.0 V (20 Å) c.d. = 1.5 mA/cm²			1.7-3.0	
AP_{lc}	AP (low c.d.)	1.0 V, 10^{-3} mA/cm², 36hrs.			1.3-2.0	

behavior with photo-currents appearing only at high reverse biases.

Discussion/Conclusion: To clarify the relevant physical and chemical mechanisms, anodization current density-overpotential relations under dark and light conditions, dark I-V and C-V characteristics, and AES in-depth-profiles were investigated in detail. AES profiles of TH, AA and AP devices are shown in Fig.2. Main conclusions of the investigations are listed below :

(1) AA devices posses a very thin interfacial layer, and the dominant mechanism of V_{oc} increase is barrier-height increase due to the change in the pinning position by interface states.

(2) The above change in the pinning position is associated with the composition change of the surface oxide layer caused by the active dissolution. The AGW electrolyte has a smaller dissolution rate for As_2O_3 than for Ga_2O_3, and therefore the anodic dissolution leads to As_2O_3-rich surface composition, i.e., a situation which is also found in the best thermal oxide.[1)]

(3) The open-circuit photo-voltage of the GaAs-electrolyte system in the AA_{ph} process has a strong correlation with V_{oc} of the metal-(anodized)GaAs solar cell, and therefore, the former can be used as the process monitor during anodization.

(4) As for AP devices, high-density interface states near midgap, which are reported in the thick oxide interface,[5)] are also present in the thin AP oxide interface, and cause anomalous I-V and C-V behavior. Photocurrents appear at such biases where holes are accelerated sufficiently, and can pass the interface region without recombining with electrons via interface states.

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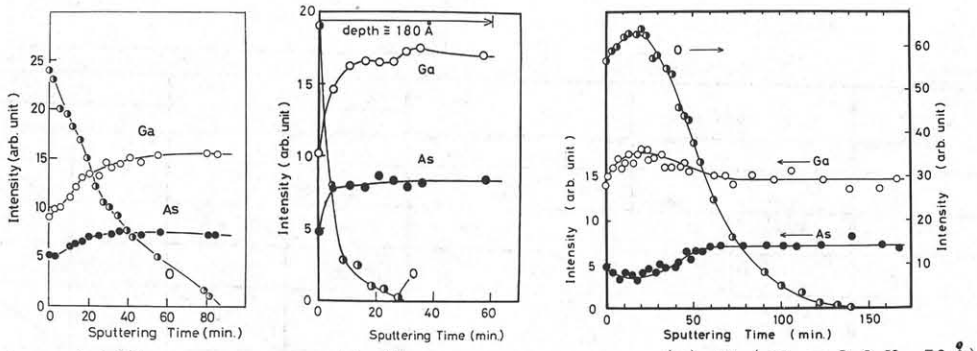

Fig.2 (a) TH (b) AA (c) AP (V_f = 2.0 V, 50 Å)