HIGH EFFICIENCY, LARGE-AREA PHOTOVOLTAIC DEVICES USING AMORPHOUS Si : F : H ALLOY
A. Madan, W. Czubatyj, J. Yang, J. Mcgill, S. Ovshinsky

To cite this version:

HAL Id: jpa-00220954
https://hal.archives-ouvertes.fr/jpa-00220954
Submitted on 1 Jan 1981

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
HIGH EFFICIENCY, LARGE-AREA PHOTOVOLTAIC DEVICES USING AMORPHOUS Si:F:H ALLOY

A. Madan, W. Czubatyj, J. Yang, J. McGill and S.R. Ovshinsky

Energy Conversion Devices, Inc., 1675 West Maple Road, Troy, Michigan 48084, U.S.A.

Abstract.- Overall conversion efficiency of 6.6% has been obtained for a photovoltaic device over an active area 0.73 cm\(^2\) using amorphous Si:F:H alloy in a MIS configuration.

Introduction.- The possibility of low-cost thin film photovoltaic cells using amorphous silicon (a-Si) based alloys has generated an intense amount of interest in the past few years. Previously, we have reported on the properties of a-Si:F:H alloy (1,2) as a useful photovoltaic material. We also reported an overall device conversion efficiency of 6.3% over an active area of 0.042 cm\(^2\) (3). In this paper we consider the level of reproducibility that has been obtained and latest data on MIS (metal-insulator-semiconductor) devices which have yielded conversion efficiencies of 6.6% over a much larger active area.

Photovoltaic Properties of a-Si:F:H Alloy.- In previous publications we have reported that an a-Si:F:H alloy with a low density of states and a high photoconductivity can be fabricated using the radio frequency glow discharge of mixed SiF\(_4\) and H\(_2\) gases (1,2). We have also shown that this type of material can be doped easily by introducing small amounts of PH or AsH\(_3\) in the gas phase to obtain conductivities (for the n+ layer) \(\sim 10\) (\(\Omega\) cm\(^{-1}\)).

Typical MIS device structures were fabricated as follows: a thin, highly conductive n+ layer (~ 200-500 Å) was deposited onto a reflecting bottom contact such as Mo, Cr, etc; next, ~ 5000 Å of active photoconductive a-Si:F:H layer was deposited using a volume gas ratio of SiF\(_4\)/H\(_2\) = 5/1. (The photoconductivity under AM-1 excitation of this component is typically in the range 10\(^{-4}\) - 10\(^{-3}\) (\(\Omega\) cm\(^{-1}\)), which provides for a low series resistance in operation.) Then a 20 Å thick layer of oxide such as Nb2O5 was thermally evaporated and contact was made to the device using 70 Å of high work function Au:Pd (90:10) or Pt metal. Finally, a layer of 350 Å thick ZnS served as an antireflection coating.

Fig. 1: Forward and reverse J-V characteristics of a typical MIS device.
Figure 1 shows a typical dark current density-voltage (J-V) characteristics for forward and reverse bias. We note that the rectification ratio at 0.5V bias is about 10^5. The dark diode ideality factor for the device is n = 1.2. We have previously shown (4) that the value of n is dependent on the oxide layer thickness (i.e., for δ = 0 (corresponding to a native oxide) n = 1.05 and for δ = 30 Å; n = 1.2) and can be interpreted in terms of a low surface state density.

The cell response under simulated AM-1 illumination exhibits the following characteristics: $V_{OC} = 0.8$V, $J_{SC} = 12.9$ mA cm$^{-2}$, $FF = 0.61$, yielding an overall conversion efficiency of 6.3% over an active area of 0.042 cm$^2$.

The presence of the insulator enhances the open circuit voltage, $V_{OC}$, due to the suppression of the majority carrier (electron) current without any effect on the minority carrier (holes) density which constitutes the short-circuit current. This is shown in Figure 2(a) and (b) where $J_{SC}$ and $\Delta V_{OC}$, the enhancement in $V_{OC}$, are plotted against the insulator thickness, δ. We should note that for δ = 30 Å, $\Delta V_{OC} \approx 250$ mV.

Since performing the above work (3), Gutkowicz-Krusin et al (5) have suggested that the introduction of the insulator could also enhance the $J_{SC}$, primarily at the blue end of the spectrum, due to the reduction in the thermal diffusion of electrons against the electric field. The above data, shown in Figure 2(b), indicates that $J_{SC}$ is possibly enhanced. Figure 3 shows the spectral response of a cell with and without the insulator. We note that the spectral response of the cell is improved toward the blue end of the spectrum when an insulator is introduced in agreement with Gutkowicz-Krusin et al's suggestion.

Fig. 2 : (a) Short-circuit current density as a function of oxide thickness (δ).
(b): Open-circuit voltage enhancement as a function of oxide thickness (δ).
Reproducibility.- In Figure 4(a), we show the data from numerous devices of active area 0.042 cm$^2$ ostensibly fabricated from identical conditions. We note that the fill factor is typically 0.55 - 0.6, $V_{oc} = 0.78 - 0.88$, $J_{sc} = 12 - 14$ mA cm$^{-2}$ with A.R. coating; the device efficiency, as shown in Figure 4(b), is between 3-4% without A.R. coating, and 5.5% - 6.6% with A.R. coating.

In Figure 5, we show the overall conversion efficiency for larger area devices. The total area of the device is 0.81 cm$^2$ and has utilized a grid pattern (Ag), and the active area is 0.73 cm$^2$, which was used in the calculation to obtain the overall conversion efficiency. We note that the efficiencies, with antireflection coating,
for these large-area devices is the same as for the small areas. The best efficiency obtained is 6.6% with the following characteristics, $V_{oc} = 0.88$ V, $J_{sc} = 13.1$ mA cm$^{-2}$, $FF = 0.57$. Recently, Hamakawa (6) has reported that a conversion efficiency of 7.1% over an area 0.033 cm$^2$ has been obtained, using glass/ITO/Si:C/a-Si:H/n+/Al structure in which the fill factor was 0.65. It is therefore interesting to note that with a similar fill factor, the active area efficiency for our best device would be 7.5%. Indeed, when the illumination intensity is decreased, the fill factor in our devices does improve which suggests a sheet resistance effect coming into play. Therefore, the lower fill factor in our devices is not a materials problem, but a simple technological problem which should be easily remedied.

![Fig. 5: Device efficiency for large-area (0.73 cm$^2$) cells.](image)

Conclusion.- In summary, we have shown that high efficiency, large-area cells can be reproducibly made using a-Si:F:H alloy.

Acknowledgements.- We wish to thank Ronald Himmler, Lynn Bement, Robin Stiers, Orest Iwasiuk, and Larry Christian for their help in measurements and sample preparation. The authors also appreciate stimulating discussions with Professors M. Shur and M. Shaw. We also wish to thank ARCO for its assistance and cooperation during the course of this work.

References.-
6. HAMAKAWA, Y., Private Communication.