B-2-8 Optimization of GD a-Si:H Film Property for Photovoltaic Devices by Means of the Cross Field Plasma Deposition Technique

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Amorphous Si:H films prepared by plasma deposition have been extensively studied for the purpose of practical applications to low cost solar cells [1]. Especially, a conversion efficiency more than 5% has recently come to be most commonly attained in a-Si:H solar cells[2]. However, for a further improvement of the efficiency, following film properties are essentially desired; (i) narrow optical gap and high photoconductivity for undoped films and (ii) wide optical gap and large dark conductivity as the window side junction electrode. We have found much improvement of the film properties by the cross field plasma deposition method which is applied dc bias voltage superimposed perpendicularly to the rf electric field during plasma deposition[3,4].

Figure 1 shows the normalized photoconductivity $\eta\mu\tau$ under 1.9 eV illumination (3×10^{14} photons/sec/cm^2) and activation energy $\Delta E\sigma$ as a function of the bias voltage and substrate temperature. As can be seen in this figure, for each substrate temperature, there exists a distinct optimum bias voltage for the photoconductive property of undoped films, and at this bias voltage the activation energy exhibits the maximum value. Moreover, the optimum bias voltage shifts from +50 to -100 V as the substrate temperature rises from 250 to 350 °C. Corresponding to this shift, the peak photoconductivity increases without any change of the activation energy. Figure 2 shows the absorption spectra near the fundamental edge of undoped a-Si:H as a parameter of the substrate temperature. At the wave length of 5000 Å (the peak of the solar radiation spectra), the absorption coefficient increases from 1.28×10^5 to 1.62×10^5 cm^{-1} as increasing the substrate temperature. The bonded hydrogen content in the films decreases from 17 to 9.5% and, in a result, the optical gap also decreases from 1.82 to 1.75 eV.

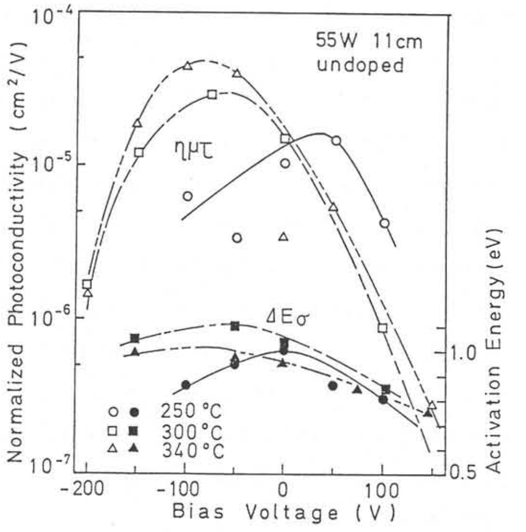

Fig. 1 Normalized photoconductivity ($\eta\mu\tau$) and activation energy (ΔE_σ) of undoped a-Si:H versus bias voltage as a parameter of substrate temperature.

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Figure 3 shows dark conductivity σ_d and $\eta\mu\tau$ of boron doped films versus the gas fraction B_2H_6/SiH_4 as a parameter of the polarity of the bias voltage; Ⓕ, ⊖ and ⊕ indicate the floating potential condition, negative and positive bias condition, respectively. The solid line in the figure shows the result reported by Spear et al.[5]. A clear enhancement of dark conductivity has been observed at the positive bias condition without the reduction of optical band gap, and the value far exceeds Spear's result obtained at the same gas fraction. While, those at the floating potential and negative bias conditions are less than Spear's. The boron doping generally causes defects into films and reduces photoconductivity, nevertheless, in our case the photoconductivity was kept not so largely reduced by boron doping under the positive bias condition as can be seen in this figure.

It might be possible to produce an efficient solar cell by employing the films possessing suitable film properties as solar cell elements, that is, wide-gap low-resistive p-type for the window side material and narrow-gap high-photoconductive undoped films for an active layer. In the talk, we will present a series of experimental data on the electrical, optical and optoelectronic properties of a-Si:H films deposited under the externally biased condition and show further possibility of improvement of cell performance with the cross field plasma deposition technique.

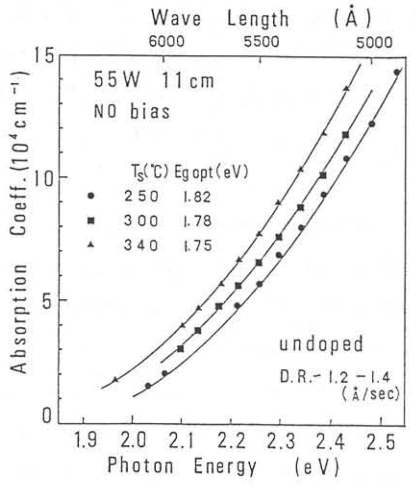

Fig. 2 Absorption coefficiency of undoped a-Si:H as a parameter of substrate temperature.

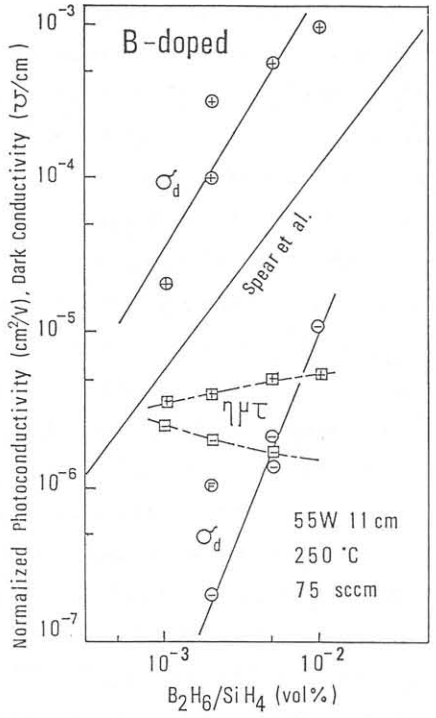

Fig. 3 Normalized photoconductivity ($\eta\mu\tau$) and dark conductivity σ_d of boron doped a-Si:H as a function of gas fraction B_2H_6/SiH_4 (vol.%).

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