THE INFLUENCE OF CARBON AND BORON ATOMS ON THE OPTICAL AND ELECTRICAL PROPERTIES OF THIN FILM a-Si:H

Isik KARABAY

Yildiz Technical University, Physics Department
Davutpasa, Istanbul, TURKEY
+902124491880 karabay@yildiz.edu.tr

ABSTRACT

A series of undoped and p doped a-SiC:H samples have been made in the framework of a research plan for obtaining high quality p-type window layers by "Plasma Enhanced Chemical Vapor Deposition (PECVD)" technique from the mixtures of silane(SiH_4), methane(CH_4) and diborane(B_2H_6) gases.
For the optimization of the window layer, the dependence of the electrical (conductivity) and optical (bandgap) properties due to altered ratios of methane and diborane gases were investigated.

Keywords: framework, conductivity, dependence, optimization.

I. INTRODUCTION

Materials with wide band gaps above 2.0 eV are important for amorphous silicon based solar cells as the conversion efficiency is improved by using them as a window layer. This is due to their widely adjustable band gap in the visible range of energy spectrum. The advantages of these materials include a range of electrical and optical properties which can be controlled by changing the gas flow rates such as carbon and boron content in the material.

It is therefore important to investigate the conductivity and the energy gap of a-SiC:H[1] from the viewpoint of optoelectronic device applications, especially for p-i-n solar cells, by using films with wider optical gaps than that of a-Si:H. Due to the absorption of short wavelength photons in the deeper levels, the efficiencies of the p-i-n a-Si:H solar cells are quite low even when this layer is thin enough. The energy gap value of the a-SiC:H reached up to 2.54eV of our samples.

The present work aims at investigating the most appropriate conductivity and band gap values of these p layers of boron doped a-SiC:H, which are very important for a-Si:H based solar cells in which light enters and passes through this layer. The more the amount of carbon incorporated into the a-SiC:H network the more enhancement in the band gap of such materials. For this purpose, a-SiC:H layers were grown by mixing silane and methane and p type a-SiC:H samples were grown by using silane, methane and diborane gases, with different gas flow rates in both. The influence of the gas flow rates on the dark conductivity and the band gap were investigated.

II. EXPERIMENTAL

Silane (SiH4), methane (CH4) and diborane (B_2H_6) gases were decomposed by using the standard radio frequency ultra high vacuum PECVD technique. A more detailed description of the deposition system can be found elsewhere [2,3]. Thin films were obtained by depositing them on Corning 7059 glass substrates. All the undoped and p type doped samples were grown at 300°C and 260°C respectively in 1 hour period.

The dark conductivities, σ_d were measured for all samples on a planar gap-cell configuration with evaporated Al contacts in a vacuum cryostat. Currents were measured for temperatures varying from 293 K up to 453 K by using a picoammeter (Keithley 485).

A computer controlled Keithley source-measure unit system was used for the current-voltage (I-V) measurements and the ohmic nature of the contacts was confirmed in both forward and reverse bias directions of symmetrical current voltage characteristic curves

Optical measurements were carried out on ARC Spectra-Pro275 model monochromator in the wavelength range from 400 nm to 1100 nm, Bertan 205A-04R model high voltage supply and Hamamatsu R406 model photomultiplier. The optical band gap was determined from the absorption spectra through using the Tauc's model[4]. Intrinsic a-SiC:H thin film series were grown at different gas ratios and p type a-SiC:H series were obtained by changing the diborane gas ratio by 0.06 ranks at different methane gas ratios where methane gas ratio (X) is: methane(sccm)/{silane(sccm)+methane(sccm)} and diborane gas ratio (Y) is: diborane(sccm)/{silane(sccm)+methane(sccm)+ diborane(sccm)}

The deposition parameters were kept constant. For every preparation, the UHV, RF power density, deposition vacuum and period were 7.10^{-8}Torr, 30mW/cm^2, 800mTorr and 1 hour respectively.

III. RESULTS AND DISCUSSION

In this series of samples deposited, the dark conductivity σ_d decreased while X increased. Fig.1 shows the variation of the dark conductivity as a function of X. The maximum conductivity was $\sim 10^{-11}(\Omega.cm)^{-1}$ for the a-SiC:H samples with minimum carbon content which was $\sim 10^{-9}(\Omega.cm)^{-1}$ in the a-Si:H samples.

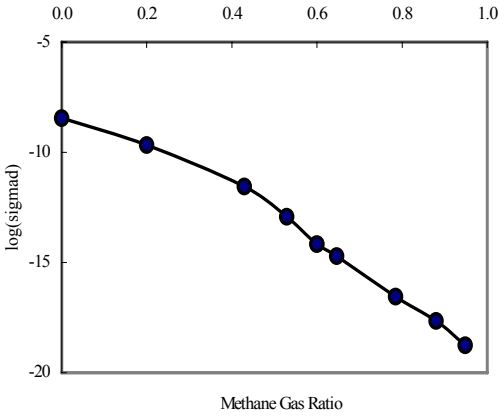

Figure 1. Conductivity vs. Methane Gas Ratio (X)

By using the same technique the conductivity decrease on films deposited was consistent with the previous reports[5] .

Fig.2. shows the variation of the dark conductivity as a function of Y . Conductivity had no regular variation with the increase in the diborane level when the methane gas level was kept constant at $X = 0.6$. However, the conductivity increased as the diborane level was varied from $Y = 0.06$ to $Y = 0.22$ with steps of 0.06 at constant methane level of $X = 0.948$. In this case the maximum conductivity was $\sim 10^{-10}\,\Omega.cm)^{-1}$.

Band gaps were estimated from a plot of $(\alpha h\nu)^{-1}$ vs. $(h\nu)$ where α is the absorption coefficient and $(h\nu)$ is the photon energy.

As shown in Fig.3, when X increased in the range of 0 to 0.948 with steps of 0.04, E_g also increased. The widening of E_g with increasing X was 0.76 eV which was 1.72 eV in the intrinsic (a-Si:H) case. This is a clear indication that more carbon is incorporated into the network. The addition of carbon atoms into the silicon network caused substitution of the weak Si-Si bond with a stronger Si-C bond. Widening of the band gap by incorporating carbon is in agreement with the previous works [6,7,8].

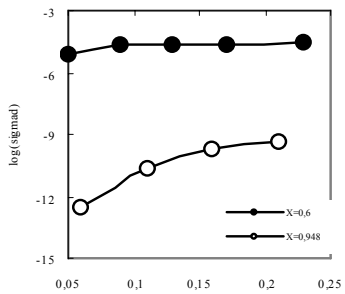

Figure 2. Conductivity vs. Diborane Gas Ratio at 2 different Methane Gas Ratios(X=0.6 and X=0.948)

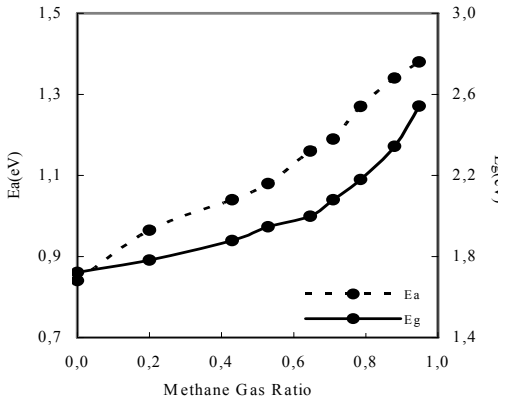

Figure 3.Variation of E_a and E_g with Methane Gas Ratio (X)

Besides this, we also illustrate in Fig.4, the variation of the optical band gap of the p doped samples at different gas ratios.

As has also been reported previously [9] it can be seen from the figure that E_g slightly decreases due to boron doping. A decrease in the band gap in a-SiC:H films prepared by using PECVD at high diborane levels was also reported by Demichelis et. al.[10] who attributed this effect to a drastic broadening of the absorption edge caused by the creation of defects due to boron atoms in the present case. In this case doping in the a-SiC:H films shifts the absorption curves to lower energies causing a decrease in the band gap.

In the case of samples prepared at $X = 0.6$ methane gas ratio, the band gap shortened and conductivity increased slightly. However, in the case of samples prepared at $X = 0.948$ the band gap also diminished but conductivity increased reasonably.

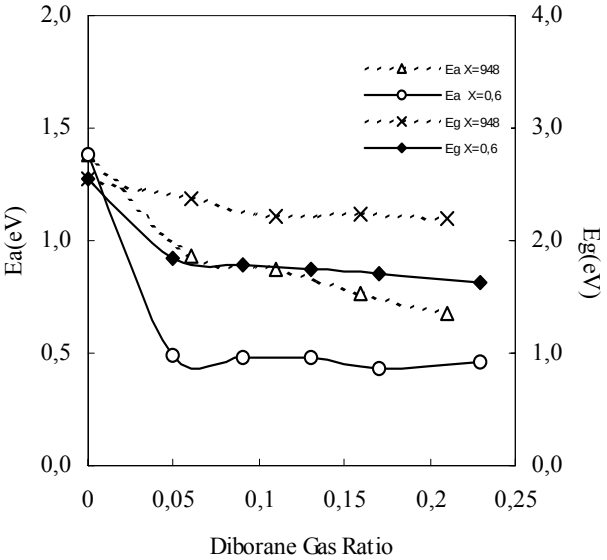

Figure 4. Variation of Ea and Eg with Diborane Gas Ratio(Y) at two different Methane Gas Ratios(X=0.6 and X=0,948)

IV. CONCLUSION

In this study, results concerning the electrical and optical properties of the a-SiC:H films prepared by PECVD at

various methane and diborane gas ratios were discussed in relation to their relevance in determining the optimum p layers that may be used in pin solar cells.

For the intrinsic a-SiC:H films, the maximum bandgap and conductivity values obtained were $E_g = 2.54$ eV and $\sigma_d = 6.1x10^{-11}$ $(\Omega.cm)^{-1}$ corresponding to $X = 0.95$

By boron doping, the maximum band gap values obtained for $X = 0.6$ and $X = 0.95$ were 1.85 eV for $Y = 0.05$ and 2.34 eV for $Y = 0.06$ respectively.

Maximum conductivity values obtained for $X = 0.6$ and $X = 0.95$ were $\sigma_d = 2.84x10^{-5}$ $(\Omega.cm)^{-1}$ ($Y = 0.24$) and $\sigma_d = 5.1x10^{-10}$ $(\Omega.cm)^{-1}$ $Y = 0.22$.

This optimization study with cross variation of gases may allow more precise and reliable values which can be used more accurately in the window layers of the solar cells.

REFERENCES

1. Y.Tawada, K.Tsuge, M.Kondo,et.al. *J.Appl.Phy*. **1982** 53 5273
2. M.N.P.Carreno, J.P.Bottechia, I.Pereyra *Thin Solid Films* **1997** 308 219
3. H.Yoshihara, H.Mori, M.Kiuchi, *Thin Solid Films* **1981** 76 1
4. J.Tauc, *Amorphous and Liquid Semiconductors*, Plenum, New York, Ch.4 **1974**
5. F.Demichelis, G.Crovini, F.Giorgis, et.al.*Diamond and Related Materials* **1995** 4 473
6. A.Desalvo, F.Giorgis, C.F.Pirri,E.Tresso *J.Appl.Phys*. **1997** 81 7973
7. S.Zhang,L.Ranier, E.Fortunato et.al. *Journal of Non-Crystalline Solids* **2004** 338-340 530
8. A.Tabata, M.Kuroda, M.Mori, T.Mizutani, Y.Suzuoki, *Journal of Non-Crystalline Solids* **2004** (338-340) 521
9. F.Demichelis, C.F.Pirri, E.Tresso, et.al. *Semicond.Sci.Technol*. **1991** 6 1141