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THE INTERFACES a-Si:H/Pd AND a-Si:H/ITO: STRUCTURE AND ELECTRONIC PROPERTIES

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a-Si:H/Pd and a-Si:H/ITO interfaces were examined by TEM. In the case of Pd, the influence of an oxide layer on silicide formation and the silicide structure were investigated. It is shown that the stability and electrical performance of the ITO contact on a-Si:H are mainly dependent on surface roughness and an interfacial oxide layer.

1. INTRODUCTION

Metal-semiconductor contact formation is an important problem in research of hydrogenated amorphous silicon (a-Si:H). Because such contacts form the main part of many devices, there is significant technological interest in understanding their properties.

Previous work has demonstrated that for image sensor applications of a-Si:H Schottky-type contacts and heterojunctions prove advantageous as compared with p-i-n structures (for review see Kempter[1] and references therein). Reverse-biased Schottky diodes show a saturated photocurrent and a low dark current in line with fast response behavior[2]. Fabrication is very easily possible without the need of doped films, which might cause cross contamination of the intrinsic material.

In this paper, we examine the structures of different transparent contacts, a-Si:H/Pd and a-Si:H/ITO (indium-tin oxide), to gain a further understanding of the interface formation process. In particular, using transmission electron microscopy (TEM), we have examined the structure of the interface and possible intermediate layers. Material composition is investigated by Auger electron spectroscopy (AES), X-ray diffraction and microprobe analysis. Between the barrier height as obtained from current-voltage measurements and the interface preparation we found correlations which have implications for the image sensor performance.

2. EXPERIMENTAL DETAILS

The samples were deposited on glass substrates or crystalline silicon wafers, the latter being required for TEM investigations. On Cr electrodes undoped a-Si:H films were deposited by glow discharge of pure silane. To remove any oxide layer on top of the a-Si:H, the samples were dipped in buffered HF prior to being loaded into the evaporation system. After treating the samples in an

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oxygen plasma, a distinct oxide layer on the a-Si:H surface was identified by microprobe analysis. Its thickness was found to grow approximately with the square root of the plasma time. Evaporated Pd (10 nm) and ITO (100 nm) served as top electrodes. Finally, the samples were annealed at 500 K. Diodes 2x10 mm^2 in size were structured by photolithography. To observe the interface by TEM, cross sections of the samples were thinned by argon ion-beam milling to foils that are suitable for electron penetration.

The barrier height was determined from current-voltage measurements at different temperatures at samples with an additional n^+-layer. The differential conductivity at zero bias was plotted versus the reciprocal temperature, yielding the barrier height from an Arrhenius plot[3]. For a-Si:H/Pd contacts it has been shown that this method gives the same results as internal photoemission.

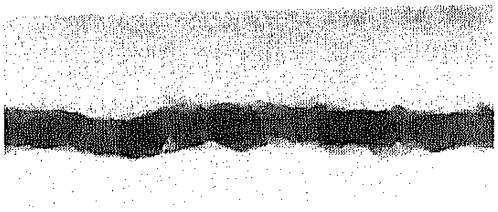
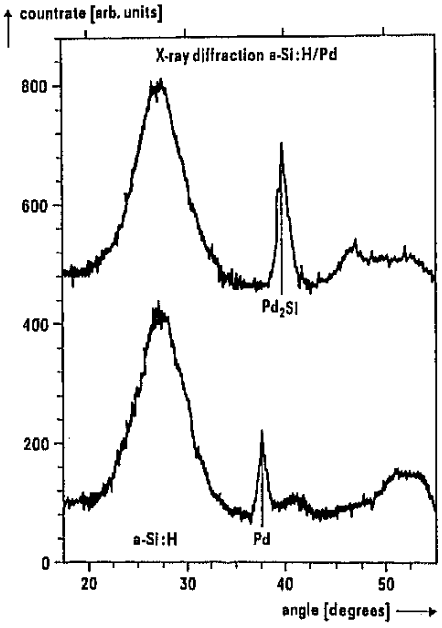


Fig.1a: TEM of a-SI:H(etched)/Pd_2Si. Fig.1b: TEM of a-Si:H/SiO_x/Pd.

3. a-Si:H/Pd INTERFACE

Micrographs of cross sections of two samples with Pd top electrodes are shown in Fig.1. After annealing of an etched sample, the Pd layer reacted to silicide, which is of crystalline structure with a grain size of about 20 nm



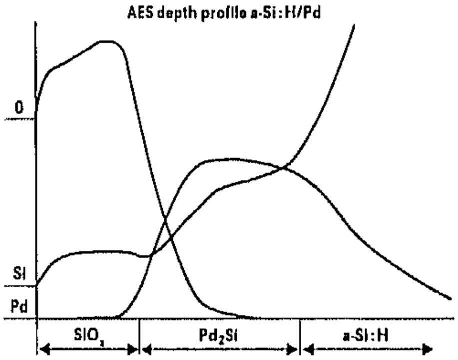


Fig.3: AES depth profile of the a-Si:H/Pd_2Si sample for O, Si, Pd. Si diffuses through Pd_2Si and forms an oxide layer on top of the silicide.

Fig.2: X-ray diffraction spectrum of a-Si:H/Pd_2Si (upper curve) and a-Si:H/Pd (lower curve).

(Fig.1a). The peak in the X-ray diffraction spectrum (Fig.2) can be clearly associated with Pd_2Si. The AES profile (Fig.3) indicates that Si atoms are the moving species in the Pd-Si system. Excess Si diffuses through the silicide, forming a silicon oxide layer on top of the sample.

As shown in Fig.1b, a silicon oxide layer, about 2.5 nm thick, on top of the a-Si:H prevents silicide formation. In the X-ray diffraction spectrum (Fig.2), only the peak of crystalline Pd is found.

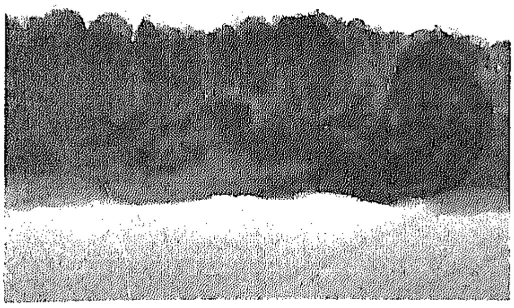


Fig.4a: TEM of a-Si:H(etched)/ITO.

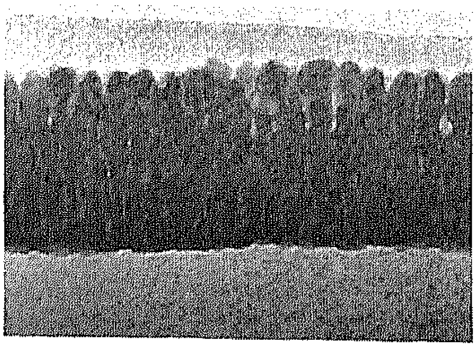


Fig.4b: TEM of a-Si:H/SiO_x/ITO.

4. a-Si:H/ITO INTERFACE

Cross sections of samples with ITO top electrode are shown in Fig.4a (etched surface) and Fig.4b (oxidized). The ITO layer shows a columnar structure and is amorphous, as is demonstrated by X-ray diffraction. The etched a-Si:H shows an interface roughness of about 10 nm, which is much greater than the 2.6 nm found on the free surface[4]. In some places crystallites are found in the amorphous ITO film. We suppose a chemical reaction between the bare a-Si:H and ITO[5], as Si is very reactive on O. However, no silicon oxide layer could be detected.

Oxidized a-Si:H (Fig.4b) leads to a very smooth interface which does not develop nuclei so that the ITO layer is found to be uniform. X-ray diffraction yields the same amorphous structure as above, but without crystallites.

5. BARRIER HEIGHTS

The Schottky-barrier height of a junction is one of the most important parameters for image sensor applications, as it determines the dark current which is crucial for a good S/N ratio. From current-voltage measurements we have taken the differential conductance at zero bias and plotted it against the reciprocal temperature, Fig.5 shows the different results for Pd and ITO contacts. The a-Si:H/Pd_2Si barrier has a height of 0.97 eV, which is a well-established value[6]. Concerning ITO contacts on a-Si:H only one isolated result exists up to now[7], but no dependencies on different preparation conditions have been investigated. On etched a-Si:H, only a rather low Schottky barrier, 0.72 eV in height, can be formed. These diodes show a poor blocking behavior with reverse-current densities of up to $8\cdot10^{-7}$A/cm^2. With an oxide layer in between, the resulting MIS diodes reach barrier heights of 0.86 eV, and reverse current densities lower than $5\cdot10^{-10}$A/cm^2 can be obtained reproducibly.

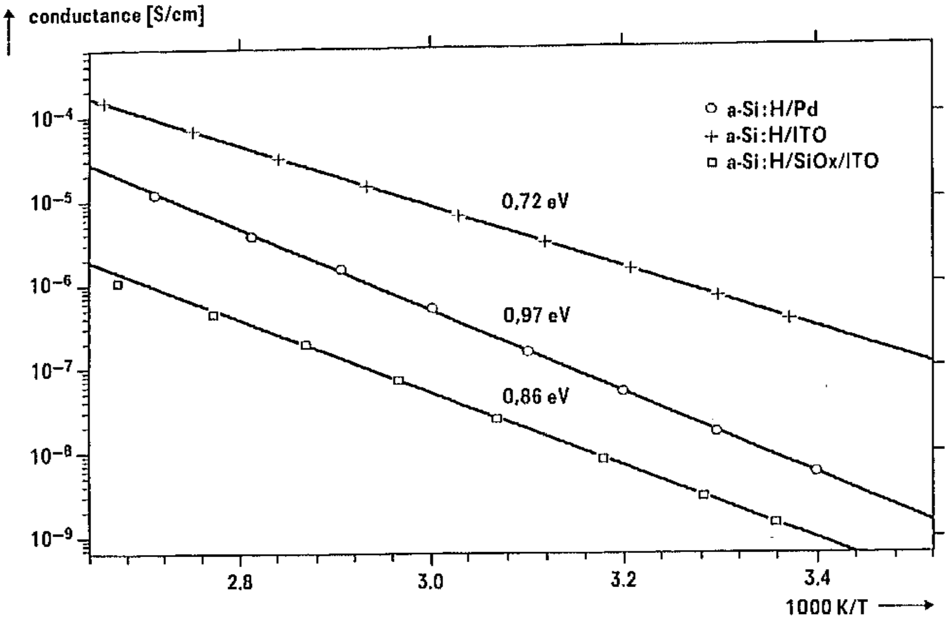


Fig.5: Zero-bias conductance of a-Si:H/Pd$_2$Si, a-Si:H/ITO, and a-Si:H/SiO$_x$/ITO samples with activation energies 0.97 eV, 0.72 eV, and 0.86 eV, respectively.

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