JOURNAL OF OPTOELECTRONICS AND ADVANCED MATERIALS Vol. 12, No. 4, April 2010, p. 806 - 809

Characterisation of Au/n-Si and Pt/p-Si by HRTEM and XRD

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This material contains the TEM analyses of Pt and Au silicides compared with XRD. By using TEM microscopy we study the interfaces of Au/n-Si and Pt/p-Si. We can establish the phases of formation the gold and platinum silicides from Au and Pt deposed on n-Si and p-Si. For the Au/n-Si interfaces we study the formation of the interfaces and phases the modification of Au precipitates in Si monocrystalline through of treatment from 350 ^{o}C up to 459 ^{o}C. For the Pt/p-Si interfaces we study the formation of the interfaces and phases the modification of Pt precipitates in Si monocrystalline through of treatment from 400 ^{o}C up to 800 ^{o}C.

(Received April 7, 2010; accepted April 26, 2010)

Keywords: Silicides, diffraction X (XRD), electronic microscopy (TEM).

1. Introduction

The technique though X ray diffraction (XRD) and transmission electronic microscopy (TEM) are two very important methods which are used intensely for the analysis of thin films set down on monocrystalline silicon substrates. The study of thin films of gold on monocrystalline silicides plates of type n and the study of the films of platinum silicides on the plates of type p are very important for the detectors of photonic and nuclear radiation made on monocrystalline silicon. The detectors of monocrystalline silicon specially projected can be used for the detection of UV and X light radiation having similar performances or even better than that of the photo emissive detectors and they do not contaminate during the measurements.

The detection is mainly based on the absorption of the UV and X photon in monocrystalline silicon. The reason for which the photodiodes with semiconductors are still rarely used for the detection of UV and X light radiation is the powerful absorption of these in a thin stratum from the surface of the detector where the radiation do not contribute to the apparition of a significant photocurrent (called dead stratum). Thermionic solution of elimination of the oxide stratum from the surface of a photodiode with junction is the use of a photodiode with Schottky barrier instead of a pn junction and which uses as a metal Au with a thickness from 50 Å to 200 Å.

Diffraction must be made up of particles or granules of dimensions comprised between 0.1 and 2 μm (monocrystalline domains) which should present neither preferential orientation nor residua. The powder is presented under the form of a plate of 0.3-0.5 μm thickness which is enough to respect the condition of infinite thickness or under the turbo molecular pump with a target of pure platinum.

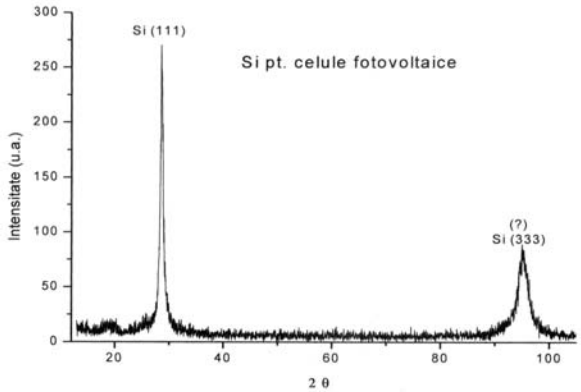
2. Results and discussions

The Si wafer do not present any line of diffraction which emphasizes the fact that these represent mono crystals cut in such a way that the surface plane do not correspond to none of the crystallographic plane of the lattice. We cover the ground the formation of Au/n-Si and Pt/p-Si barriers for photonic and nuclear detectors. For these detectors are very important the Schottky barriers which form at the interfaces between metal and semiconductor.

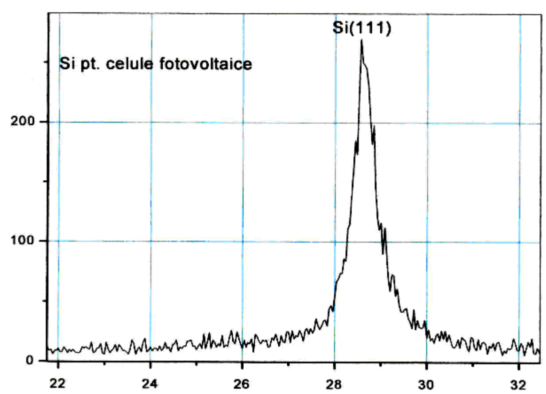
Au/n-Si barrier

The Si wafer (n or p type) for the photovoltaic cells with Schottky barrier, have a monocrystalline cubic structure with centred facets orientate in such a way that the crystallographic plane with Miller (111) indications is parallel with the plate surface. The diffraction line from $2\theta \sim 95^{o}$ respond to an interplane distance d=1.04Å which represents a third from the value of interplane distance corresponding to the line (111) (fig.1a,b).

The Au-Si/n-Si barrier is the essential element for the function of the photodiodes to detect the photonic radiation. That is why a great attention is given to the setting down of Au stratum and the realisation of the barrier. Both the thickness of Au stratum and its analytic are analysed after the thermo-ionic treatment of alloy with silicon. We can check what is going on at the Au interface with monocrystalline silicon (Fig. 2).



a



b

Fig. 1(a,b). - The diffraction lines of monocrystalline silicon.

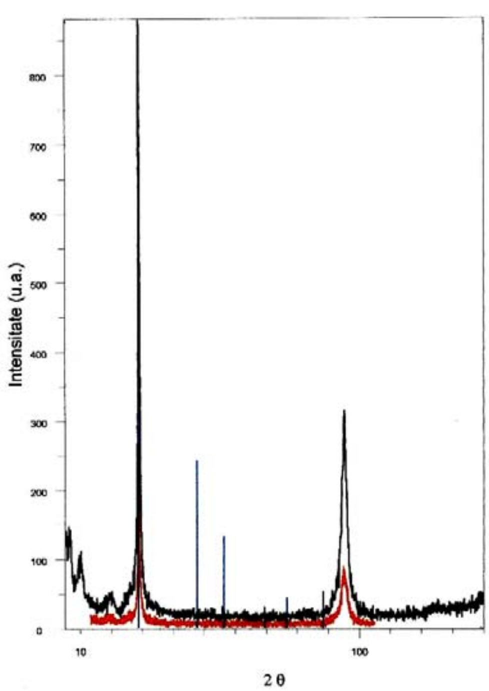


Fig. 2. - The diffraction lines of Au-Si/n-Si.

We can notice in figure 3 the presence of Au in Si probe (with drips K_{α} *and* K_{β}). The intensity relatively very big which is obtained for $2\theta = 44^0$ as compared with the drip $2\theta = 38^0$, emphasis the presence of the domains with interplane distance corresponding to the angle $2\theta = 44^0$ at the probe surface.

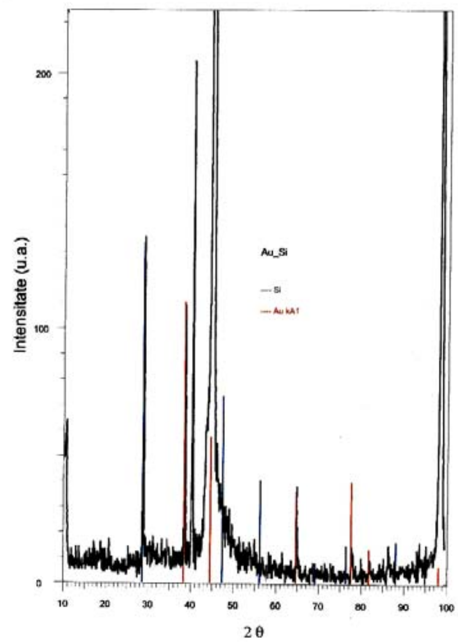


Fig. 3. The diffraction lines of Au/n-Si, Si and Au.

The film image of gold set down on silicon and the formation of AuSi alloy after a treatment at 350°C for a period of time of 30 minutes impure nitrogen is presented in the Fig. 4.

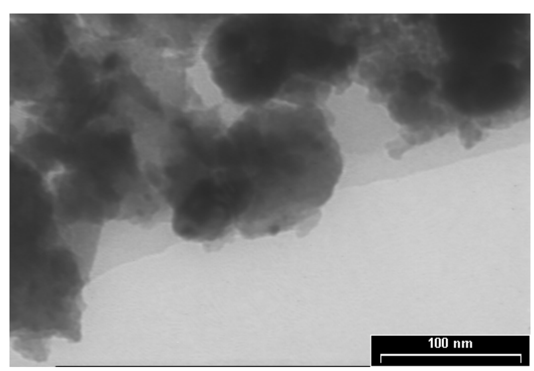


Fig. 4. TEM images for AuSi alloy after a treatment at 350 [°C].

We can notice the precipitates of gold dimensions between 10 nm and 100 nm. The introduction and the removal of the plates in the furnace of treatment were made at a very small speed for the elimination of the sudden variations of temperature.

A temperature of alloy of 450°C and a sudden variation of this modifies the dimensions of the Au precipitates in Si monocrystalline. The image of Au/n-Si at 450°C, 30 minutes impure nitrogen is presented in Fig. 5.

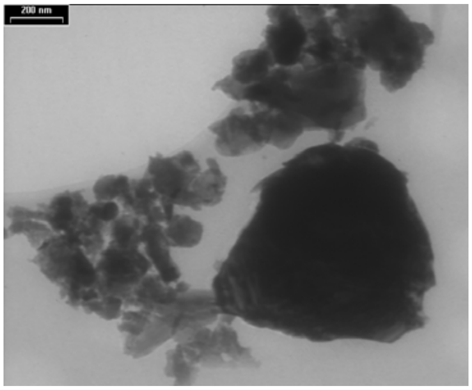


Fig. 5. TEM images for AuSi alloy after a treatment at 450 [° C] PtSi/p-Si silicides.

We deposit Platinum by sputtering on p silicon monocrystalline, 1.5 Ωcm - 65 Ωcm resistivity, 76.2 mm diameter, 500 µm thickness. The thickness of Pt was between 100 Å and 400 Å. After this deposition we was made the treatment in the pure Nitrogen at temperature between 400°C and 830°C. After this annealing, we were measuring the energy of barrier and were made the XRD and TEM spectroscopy. The high of the PtSi/p-Si barrier was 0.23 eV, the same for the all thickness of the Pt and all temperature for annealing. The thickness of the silicides depends of the temperature and the time for annealing. There has been identified 3 phases for Pt_xSi_y/p-Si silicides during process of thermal treatments.

1) Pt_2Si is formed up to 400° and a period of time smaller than 30 minutes in pure Nitrogen. First phase appears at the PtSi interface and then advances to the Pt surface. The thickness Pt_2Si *d* varies with temperature and the period of treatment with the expression:

$$d^2{}_{PtSi} = D_{PtSi} t_t \text{ [cm}^2\text{]} \quad (1)$$

where D is coefficient for diffusion of Pt, and t_t is time of treatment. At the 400°C and 30 minutes for annealing we obtained 20 Å thicknesses for Pt_2Si.

2) A PtSi layer, which also advances towards the metal surface is formed at a higher temperature (400°C and 600°C). The thickness *d* of the PtSi layer grows proportionally with the period of the time after expression:

$$d_{PtSi} = R_{PtSi}(t_t - t_1) \text{ [cm]} \quad (2)$$

where R_{PtSi} is reactivity of PtSi at the interface and t_1 is time for initiation into PtSi. For 550°C temperature and 60 minutes annealing we obtained 35-45 Å.

3) $PtSi_2$ appears at very high temperature (over 650°C). Its formation is due to the concentration of Pt in PtSi and it is helped by the apparition and the growth of some. $PtSi_2$ granules in PtSi volume after some diffusion at small distances was activated to high temperatures.

In the Fig. 6 we observe the diffraction lines for Pt_2Si and in the figure 7 we represent the TEM image for the same sample. Trough XRD we obtain an intensity peak for $2\theta = 32^0$ due to both the PtSi crystal and also the Pt_2Si .

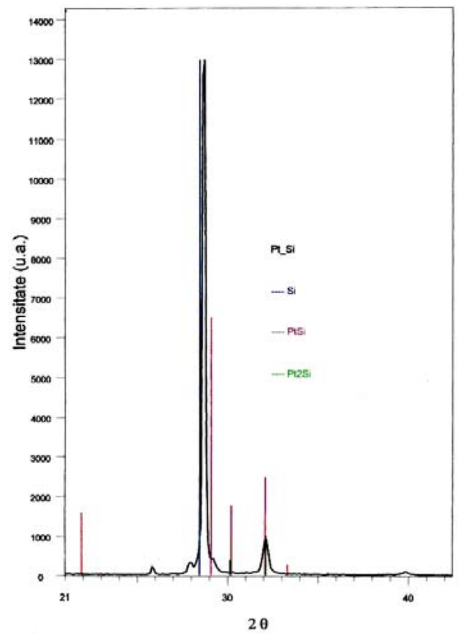


Fig. 6. XRD for Pt_2Si/p-Si.

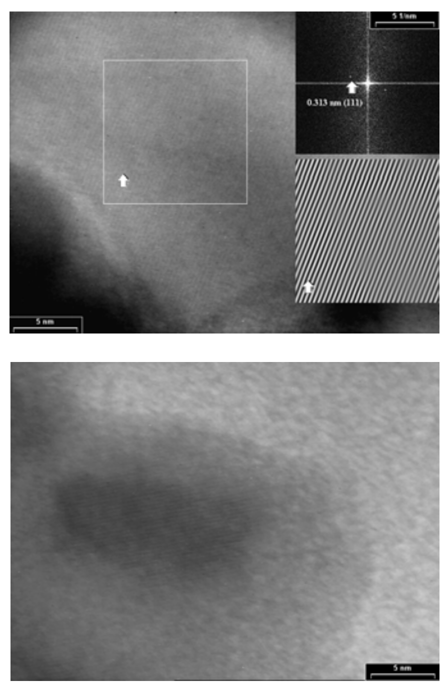


Fig. 7. TEM image for Pt_2Si..

We was obtained a maximum of diffraction at $2\theta = 28,5^0$ for between the lattice of Si crystal and its PtSi crystal.

In the Fig. 8 are represented the TEM images for $PtSi_2$/p-Si, at the 800 °C temperature for annealing and 30 minutes for treatment.

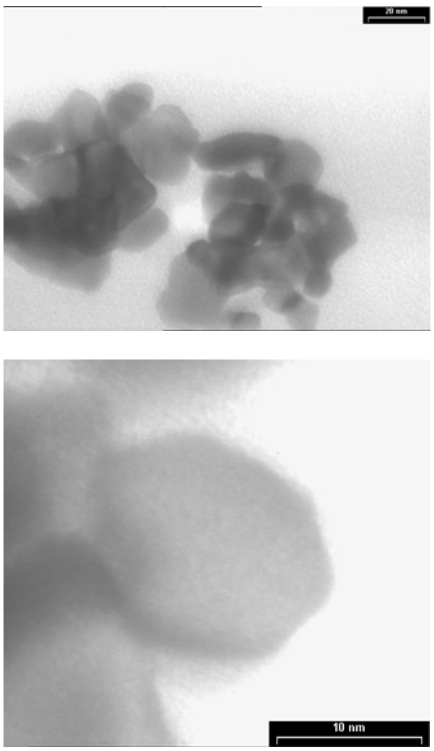


Fig. 8. TEM images for $PtSi_2$/p-Si..

3. Conclusions

The electronic microscopy trough transmission (TEM) and X-Ray Diffraction (XRD) constitutes modern methods of investigation of thin films (nanometric) from different materials. We obtained good resolution of some nanometres materials (less than 5 nm) thus allowing for the analyse materials (composition). We can control the mechanisms for formation (especially for alloys materials). We obtained the thin films of gold (Au) on the singlecrystal silicon for Schottky barrier used in the UV and X-Ray Detectors. We prepared a Schottky barrier with Pt/p-Si for IR detectors in the 2.5 μm - 3.5 μm windows. We approached the basis of the formation of Au/n-Si and Pt/p-Si barriers for photonic and nuclear detectors.

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