Influence of Growth Conditions of Hydrogenated Amorphous Silicon Carbide on Optical Properties of the Interfacial Layer in SiC-Based Photodevice

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The attention has been focused on the optical properties of structures of the form Au/MS/a-Si$_{1-x}$C$_x$:H/Si(100)/Al as a function of the deposition temperature of the a-Si$_{1-x}$C$_x$:H films. The amorphous SiC:H films were obtained for different temperatures ranging from 150 °C up to 500 °C. By photoluminescence, blue emission from all the structures was observed at room temperature and a high emission was obtained for sample whose amorphous film was deposited at 500 °C. The spectral response of Au/MS/a-Si$_{1-x}$C$_x$:H/Si(100)/Al structures with a-Si$_{1-x}$C$_x$:H film deposited at 250 °C, exhibits a maximum value at $\lambda = 950$ nm while for structure with a-Si$_{1-x}$C$_x$:H film obtained at 150 °C, a maximum value of λ was observed at 400 nm.

1. Introduction

The presence of an interfacial layer at the metal–semiconductor structures plays an important role in the determination of the characteristic parameters of the devices [1, 2]. Amorphous silicon carbide has been extensively studied over this decade mainly in the Schottky diode. White-green, yellowish and red light electroluminescence were observed at room temperature in a-SiC/n-a-SiC diode [3, 4]. In this work, Au–SiC interface has been modified by a thin layer of metal sulfide, MS (PbS specifically). Synthesis of luminescent nanocrystalline MS (M = Pb, Cd) thin films were done in order to introduce them as interfacial layer [5]. Lead sulfide (PbS) is an important member of the chalcogenides which offers large tenability. Its narrow band gap can be varied in a wide range, up to 2.3 eV, from the bulk value of 0.41 eV, by changing the mean cluster size of the nanoclusters [6]. It permits size quantization effects of size confinement [7]. This semiconductor is an important functional material and has been used in several applications such as IR detector [8], solar absorber [9], Pb^{2+} ion-selective sensors [10], NO$_2$, NH$_3$ and H$_2$ gas sensors [11–13]. In order to study the possibility to develop heterojunctions which could be suitable for applications in optoelectronic devices such as light emitting diodes, heterojunctions based on nc-MS/a-SiC:H (with M = Pb) were investigated. Optical properties were investigated using optical response and photoluminescence.

2. Experimental procedure

Nanostructured thin films of metal sulfide (MS) (M = Pb) have been chemically deposited on small chips of (10 × 5 mm^2) a-Si$_{1-x}$C$_x$:H/pSi(100) substrates. a-Si$_{1-x}$C$_x$:H films were prepared in a magnetron dc sputtering system. The a-Si$_{1-x}$C$_x$:H films of 0.543, 0.72, and 0.76 µm thicknesses were deposited on single crystalline silicon (100) wafers and temperature deposition were 150, 250, and 500 °C, respectively. Optical transmittance measurements were carried out using an UV-VIS-NIR spectrophotometer (CARY 500 Version 8, 01) in the range of 250–2500 nm in order to calculate the SiC thin films thicknesses by using interference fringes method. Preparation of the MS deposition bath: M(CH$_3$COO)$_2$, trihydrate (with M = Pb) and 1% of polyethylene glycol 300 (PEG300) were dissolved in deionized water (100 ml), with NaOH and of thiourea. The deposition temperature of MS was 60 °C. Spectral response measurements were carried out by using a tungsten filament lamp with incident power 170 W with a JOBIN YVON monochromatic in the range 350–1100 nm wavelength. Photoluminescence spectra of samples excited with wavelength of 325 nm were measured using a PERKIN-ELMER LS 50B luminescence spectrometer.

3. Results and discussion

3.1. Spectral response

Nanostructured thin films of lead sulfide (PbS) have been chemically deposited on a-Si$_{1-x}$C$_x$:H/p-Si(100) substrates whose amorphous silicon carbide thin films were deposited at different temperatures. The fabricated samples, A: Au/PbS/a-Si$_{1-x}$C$_x$:H ($d = 0.72$ µm)/p-Si(100)/Al, and B: Au/PbS/a-Si$_{1-x}$C$_x$:H

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(d = 0.76 µm)/p-Si(100)/Al and the reference Au/a-Si$_{1-x}$C$_x$:H/p-Si(100)/Al, have been investigated. From Fig. 1b, the quantum efficiency, for sample B, increases with the increase of wavelength, reaching a maximum at λ = 950 nm and then decreases for values of $\lambda \geq$ 1000 nm. Contrary to sample B, sample A exhibits the opposite phenomena. The quantum efficiency reached a maximum at short wavelengths, λ = 450 nm and then decreases for higher wavelengths. The thickness of the amorphous thin film in sample B is d = 0.76 µm and in sample A, it was d = 0.72 µm. The forms of the two spectral responses of Au/MS/a-Si$_{1-x}$C$_x$:H/p-Si(100)/Al structures (samples A and B) indicates that the a-Si$_{1-x}$C$_x$:H films morphology varied from sample to other. Consequently, illuminating the different structures of Au/MS/a-Si$_{1-x}$C$_x$:H/p-Si(100)/Al from the side of the Au/MS/a-Si$_{1-x}$C$_x$:H junction, could present different responses as the amorphous films change.

Fig. 2. Room temperature photoluminescence spectra of a-Si$_{1-x}$C$_x$:H/p-Si(100) and MS/a-Si$_{1-x}$C$_x$:H/p-Si(100) (M = Pb).

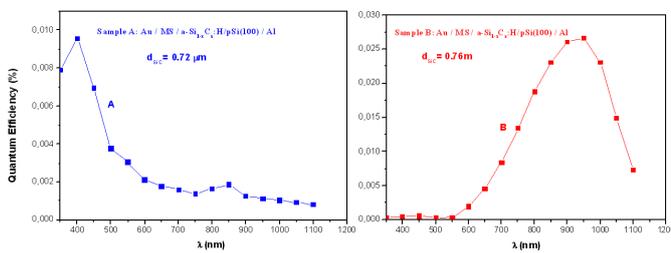Fig. 1. Quantum efficiency of the Au/MS/a-SiC:H/p-Si(100)/Al structures as function of the wavelength, λ, for two different temperatures of deposition the a-SiC:H thin films: (a) 150 °C and (b) 250 °C.

We could suggest that, in sample B, the high energy photons may be absorbed near the surface of the MS, resulting in the generation of electron–hole pairs which cross (electrons and holes moving in opposite directions) the PbS/a-SiC junction and they are collected. As the wavelength, λ increases, the main region where absorption of photons takes place is shifted towards the neutral part of a-SiC, and the photogenerated carriers disappear by recombination [14]. By the same way, the high energy photons may be absorbed, in sample A, near the surface of the nanostructured MS films but this time, the generation of electron–hole pairs which cross the MS/a-SiC junction takes place in MS side where the photogenerated carriers disappear by recombination.

3.2. Photoluminescence

Figure 2 shows the photoluminescence (PL) emission spectrum of a-Si$_{1-x}$C$_x$:H/p-Si(100) control sample (without MS) excited at a wavelength of 325 nm. We observed a broad emission band at 438 nm and a shoulder at 522 nm. The blue emission is the result of the quantum size confinement effect as suggested by Xu et al. for porous SiC [15, 16], whereas the green luminescence emission centered at 522 nm has been found to be similar to that observed in bulk 3C-SiC and on porous silicon samples [17].
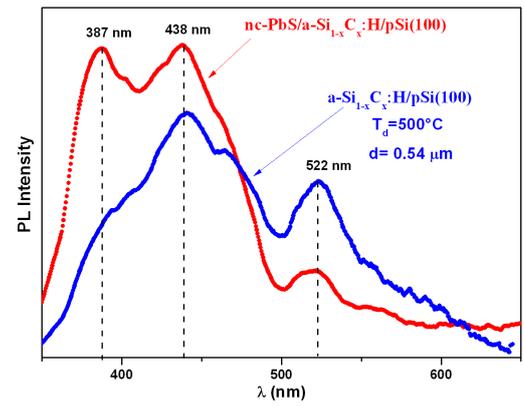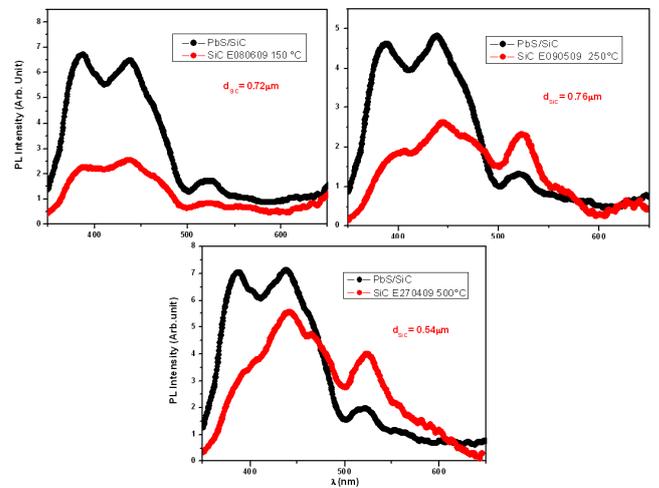

Fig. 3. Room temperature photoluminescence spectra of MS/a-Si$_{1-x}$C$_x$:H/p-Si(100) with M = Pb at different temperatures of the deposited amorphous SiC thin films.

In Fig. 3, the spectrum shows two strong peaks at 387 nm and at 438 nm and a shoulder at 522 nm. As was expected previously, we have found that the peaks were attributed to the emission of SiC films. Consequently, the peak at 387 nm is ascribed to the nanostructured MS thin films. This deduction also learns on our previous study [18–20], in which nanocrystalline MS thin film emission was compared to that of MS nanopowder. We have reported that the main emission for the both nature of MS was at λ = 387 nm. It shows that as the deposited amorphous film thickness increases, the intensity of the PL of the heterostructure decreases, while its maximum PL peaks position remain unchanged. In addition we note that the deposition temperature of the amorphous film a-Si$_{1-x}$C$_x$:H affects aleatory the intensity of PL of the heterostructures. In other words, there is no correlation in the variation of the PL intensity with the deposition temperature. It could indicate that the

amorphous films morphology was not the same for all the samples.

4. Conclusion

In this study, we demonstrate a UV–blue PL from MS/a-SiC/p-Si heterostructures. The properties of the heterojunctions were strongly influenced by the deposition conditions of the amorphous silicon carbide thin films. According to the optical response results, the existence of inhomogeneities in a-Si$_{1-x}$C$_x$:H, which lead to highly disordered surface layer, become an evidence and can alter the films morphology of PbS. This fact could affect the reproducibility of data.

Acknowledgments

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