Integrated Wavelength Division Photo-Sensor Using GaAs on Si

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A new wavelength division photo-sensor, using GaAs on Si by MOCVD, is described. The response of this sensor has a good linear relationship with wavelength of incident light from 620nm to 900nm. The sensitivity and the operating wavelength region of the sensor can be easily varied by changing the thickness and the material of the top sensor.

1. Introduction

In recent years, the heteroepitaxial growth technology of GaAs on Si has been received a great attention for the possible monolithic integration of GaAs on Si devices[1),2),3)]. In this paper, the wavelength discrimination ability of a new GaAs/Si 3-terminal monolithic integrated wavelength division photo-sensor is demonstrated. The sensor consists of two photodiodes, i.e., GaAs top sensor and Si bottom sensor. The top sensor performs as a short wavelength cut filter for the bottom sensor. It can be used to measure the wavelength of incident monochromatic light without using any filter or dispersive elements[4)].

2. Preparation of the Sensor

In order to make the incident light of wavelength from 600nm to 900nm penetrate through the top sensor and the intermediate layer between the top sensor and the bottom sensor, we have desinged the structure of the very thin active layer for top sensor and $Al_{0.4}Ga_{0.6}As$ translucent layer as the intermediate layer. On the other hand, an $Al_xGa_{1-x}As$ layer with the Al content varying from 0.25 to 0.05 was grown between the active layer of top GaAs sensor and $Al_{0.4}Ga_{0.6}As$ layer for the reduction of the residual tensile stress. P^+-$Al_xGa_{1-x}As$ graded band gap layer with Al content varying from 0.05 to 0.25 was also grown between $Al_{0.85}Ga_{0.15}As$ window layer and the GaAs active layer for improvement of the photocurrent characteristics of top sensor.

Figure. 1 shows the schematic cross-sectional structure of monolithic integrated wavelength photo-sensor. The bottom sensor was formed by the thermal diffusion of B at 1000℃ in n-type (100) Si wafer with misorientation of 2° toward [011]. After the p-n junction formation, the Si wafer was etched and followed by heat treatment at 1000℃ in H_2 atmosphere to remove the oxide on it. On this Si wafer, n^+-GaAs buffer layer and the top sensor structure were grown by MOCVD using two-step growth technique.

The top sensor consists of n^+-GaAs layer, n^+-$Al_{0.4}Ga_{0.6}As$ layer, n^+-$Al_xGa_{1-x}As$ buffer layer, n-GaAs layer, p-GaAs layer, p^+-$Al_xGa_{1-x}As$ graded band gap layer, $Al_{0.85}Ga_{0.15}As$ window layer and p^+-GaAs contact layer.

The structure parameters are shown in Fig.1. During the buffer layer was grown, thermal cycle treatment from 300 to 850℃ was carried out three times in H_2 atmosphere. The EPD of GaAs revealed by molten KOH etching is $1.5\times10^7cm^{-2}$ and the hole diffusion length of GaAs on Si measured by EBIC was 0.9μm.

The Si_3N_4/SiO_2 layer was coated by evaporation for antireflection. Three electrodes of sensor were formed on p^+-GaAs, p^+-Si and n-Si, respectively.

$Al_{0.1}Ga_{0.9}As/Si$ and $Al_{0.22}Ga_{0.78}As/Si$ sensor were also fabricated.

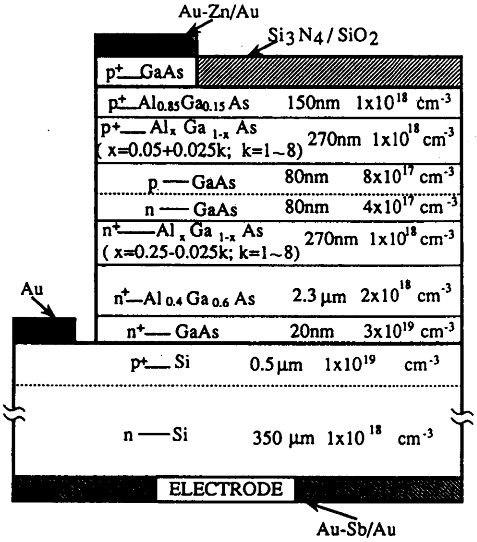

Fig.1 Cross-sectional structure of integrated wavelength division sensor using GaAs on Si.

3. Results and Discussion

The quantum efficiencies of the top GaAs sensor and the bottom Si sensor are shown in Fig.2. Both photocurrents of the bottom sensor Ib and of the top sensor It are the function of the wavelength of incident light. If we regard (Ib-It)/(Ib+It) as an output of the sensor, it has a good linear relationship with wavelength in the region from 620nm to 900nm as shown in Fig.3. This photoelectric current characteristics of the 3-terminal monolithic GaAs sensor is quite suitable for the measurement of the wavelength of monochromatic light.

The same measurement were also carried out on 3.0 μm-thick $Al_{0.1}Ga_{0.9}As/Si$ and 3.0 μm-thick $Al_{0.22}Ga_{0.78}As/Si$ sensors. The quantum efficiencies of the sensors are shown in Fig.4 and Fig.5, respectively.

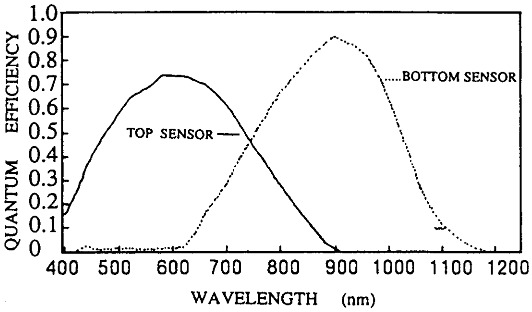

Fig.2 Spectral response of integrated wavelength division sensor using GaAs on Si.

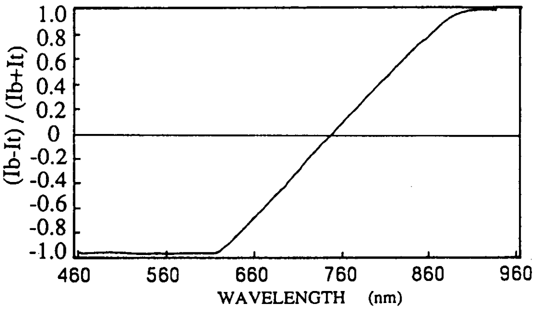

Fig.3 The output of integrated sensor using GaAs on Si versus wavelength.

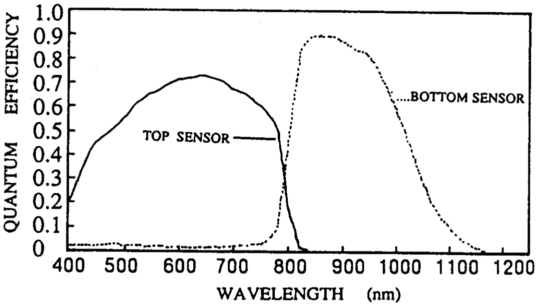

Fig.4 Spectral response of integrated wavelength division sensor using $Al_{0.1}Ga_{0.9}As$ on Si.

The output of the sensor (Ib-It)/(Ib+It) are shown in Fig.6. With increasing the Al content of AlGaAs of top sensor, the operating wavelength region shifts toward short wavelength because of the absorption edge shift of AlGaAs top sensor layer. The wavelength sensitivity becomes high but the operating wavelength band width becomes narrow.

This sensor can be used for the wavelength measurement of tunable laser such as Ti: sapphire laser.

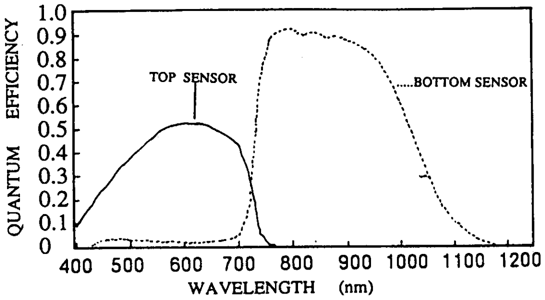

Fig.5 Spectral response of integrated wavelength division sensor using $Al_{0.22}Ga_{0.78}As$ on Si.

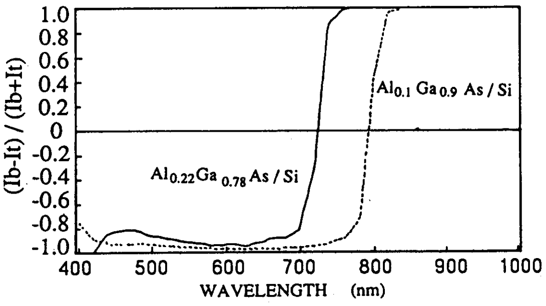

Fig.6 The outputs of integrated $Al_{0.1}Ga_{0.9}As/Si$ and $Al_{0.22}Ga_{0.78}As/Si$ sensors versus wavelength.

4. Conclusion

A new integrated wavelength division photosensor using GaAs/Si is proposed and fabricated by MOCVD. The output of this sensor is linearly dependent on the wavelength of the incident light. Signal processing circuits can be also integrated on the same Si wafer.

References

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