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Five channel WDM communication using a single a:SiC-H double pin photo device

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ABSTRACT

Amorphous SiC heterostructures built as a double pin device has a non linear spectral gain which is a function of the signal wavelength that impinges on its front or back surface. Illuminating the device with several single wavelength data channels in the visible spectrum allows for Wavelength Division Multiplexing (WDM) digital communication. Using fixed ultra-violet illumination at the front or back surfaces enables the recovery of the multiplexed channels. Five channels, each using a single wavelength which is modulated by a Manchester coded signal at 12,000 bps, form a frame with 1024 bits with a preamble for signal intensity and synchronisation purposes. Results show that the clustering of the received signal enables the successful recovery of the five channel data using the front and back illumination of the surfaces of the double pin photo device.

1. Introduction

WDM (wavelength division multiplexing) communication consists in the transmission of a set of different wavelengths each with a different data signal, channel, as a single output signal. It is currently introduced worldwide into existing optical communication systems for capacity enhancement [1].

Modern optical networks use arrayed waveguide grating (AWG) as optical wavelength demultiplexers [2]. There has been much research on semiconductor optical amplifiers as elements for optical signal processing, wavelength conversion, clock recovery, signal demultiplexing and pattern recognition [3]. Here, a specific band or frequency needs to be filtered from a wide range of mixed signals. Active filter circuits can be designed to accomplish this task by combining the properties of high-pass and low-pass into a band-pass filter. Amorphous silicon carbon tandem structures, through an adequate engineering design of the multiple layers' thickness, absorption coefficient and dark conductivities can accomplish this function [4]. The use of a-Si:H/a-SiC:H heterojunctions without filters and with several layers allow for colour detection [2,3].

2. Material and methods

The structure used in this paper is a double pin amorphous silicon PECVD (plasma enhanced chemical vapour deposition) sensor (p(a-SiC:H)-i′(a-SiC:H)-n(a-SiC:H)-p(a-SiC:H)-i(a-Si:H)-n(a-SiC:H)) with optical transparent contacts at each end, presented in Fig. 1.

Shown in Fig. 1 are the layers of the sensor with arrows indicating the absorption of each wavelength ($\lambda_{V,B,G,R,O}$) used.

The thickness (200 nm) and the optical gap (2.1 eV) of the a-SiC:H intrinsic layer (i′-) is optimized for blue collection and red transmittance. The thickness (1000 nm) of the a-Si:H i-layer was adjusted to achieve full absorption in the green and high collection in the red spectral ranges. As a result, both front and back diodes act as optical filters confining, respectively, the blue and the red optical carriers, while the green optical carriers are absorbed across both. The deposition conditions of the i- and i′- intrinsic layers present good optoelectronic properties with conductivities between 10^{-11} and $10^{-9}\ \Omega^{-1}\,cm^{-1}$ and photosensitivity higher

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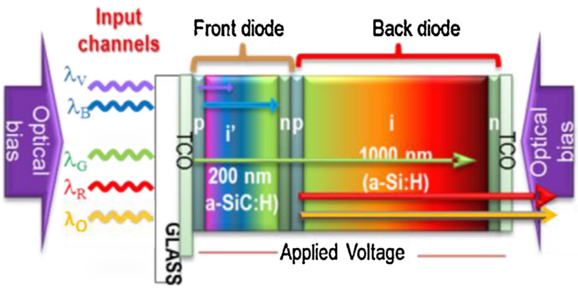

Fig. 1. Sensor description and operation.

than 10^4 under AM1.5 illumination ($100\,\mathrm{mW\,cm^{-2}}$). To decrease the lateral currents which are crucial for device operation, low doping levels were used and methane was added during the deposition process. The doped layers (20 nm thick) have high resistivity ($>10^7\,\Omega\,\mathrm{cm}$) and optical gaps around 2.1 eV. Transparent contacts have been deposited on front and back surfaces to allow the light to enter and leave from both sides. The back contact defines the active area of the sensor ($1\times1\,\mathrm{cm}^2$). The front and back contacts are based on ZnO:Al (ITO) and have an average transmission around 80% from 425 nm to 700 nm and a resistivity around $9\times10^{-4}\,\Omega\,\mathrm{cm}$.

The film layers were deposited using a parallel-plate PECVD reactor. Deposition conditions such as the RF power, partial pressure and gas flow rates are shown in Table 1. The substrate temperature was held at 260 °C [7].

This sensor has been tested as a two, three and four channel communication device [8], and its use as a logical operations and memory effect device [5,6]. Using a monochromator with 10 nm interval stepping from 400 to 700 nm the spectral response of the sensor was recorded. Then repeating the process with steady state front optical bias (390 nm) and steady state back optical bias (390 nm) the gain of each wavelength was calculated and plotted as Fig. 2.

The spectral response gain for wavelengths in the visible spectrum is shown in Fig. 2 for the double pin sensor. The gains change with the ultra-violet bias intensity; the outcome is an enhancing of wavelengths above 500 nm for front bias, and enhancing below 500 nm occurs with back bias. The non linear gain of the sensor allows the recognition of each input wavelength by the selection of the long or low pass filters shaped by the optical bias with the turning point around 500 nm [11]. Also shown as arrows in Fig. 2 are the relative positions of all the channel wavelengths used in this paper, five belonging to the long pass filter bandwidth and other five belonging to the low pass filter.

The aim of this document is to provide a useful five channels WDM communication application, using several encoding techniques, namely NRZ (No Return to Zero) and Manchester coding.

The sensor is electrically inversed biased with −8 V and setup as shown in Fig. 3. The sensor, deposited over transparent glass, has both end surfaces available for lighting.

The setup presented in Fig. 3 shows the LEDs relative position and the sensor. There are two LEDs used for optical bias, both ultraviolet (390 nm), and are called the front and the back LEDs. When

Table 1
Deposition conditions of the a-Si:H and a-SiC:H films.

Type	RF power (W)	Pressure (mTorr)	Gas flow(sccm)			
			SiH_4	1%TMB + 99%H_2	2%PH_3 + 98%H_2	CH_4
p (a-SiC:H)	4	600	10	25	–	15
i (a-Si:H)	4	500	10	–	–	15
n (a-SiC:H)	4	500	10	–	5	15
i′ (a-SiC:H)	2	400	20	–	–	–

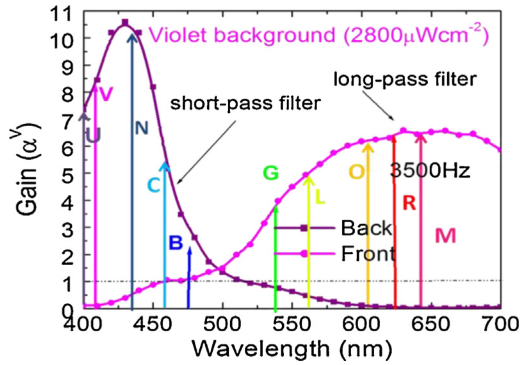

Fig. 2. Front and back gains.

an optical bias LED is lit it maintains a constant illumination. Both optical bias LEDs are not lit at the same time. Several data channel LEDs are used: Magenta (M: 640 nm), Red (R: 626 nm), Orange (O: 605 nm), Lime (L: 565 nm), Green (G: 524 nm), Cyan (C: 460 nm), Blue (B: 470 nm), Navy (N: 430 nm), Violet (V: 400 nm) and Ultraviolet (U: 390 nm). Each channel, unless stated otherwise, carries different Data patterns but they are all time synchronized.

Data values are supplied by a computer program that can shape it into configurable frames and data encoding. The frame can be raw, with the data bits presented to the channel LEDs just as they are, or in a frame with a preamble, start of frame, data values and end of frame. The preamble, a sequence of several [010101] on all channels, that is used for the reception to determine the maximum intensity value of the whole frame for normalisation and synchronisation purposes. The start of frame is set by a difference in the preamble [0110] and is followed by the data as is the case of the raw transmission. The end of frame is a sequence of [010100] and all channels are switched off.

Each bit has two types of encoding: NRZ or Manchester. The NRZ encoding is a direct translation of the data value, a 0 value corresponds to no current and a 1 value is a fixed determined current sent to the LED (0.25–5 mA, depending on the wavelength used). The Manchester coding assures that there is a transition in the middle of each bit: a 1–0 transition if a 0 data value is transmitted, and if the data value is 1 the encoding is a 0–1 transition. A random sequence is shown in Fig. 4 with both types of data encoding.

When there is a large number of equal data bits to be transmitted the result using NRZ is a continuous state illumination, if data value is 1 or no illumination at all if the data value is 0, as shown in Fig. 4. On the other hand, using Manchester there is always a pulsed pattern, which has either the same or double frequency of the data bit. The NRZ pattern when of several data bits set to 1 is inconvenient for the reception because it is almost an optical bias.

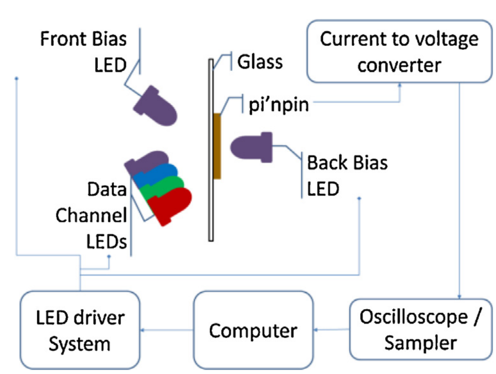

Fig. 3. Sensor and LED relative positions.