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Active Layer Thickness Dependence of the Bandwidth of Amorphous Silicon Photoconductors

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1. Introduction

Amorphous silicon (a-Si) photodetectors have been developed for a fluorescence based on a detection of DNA and a two-dimensional image sensor [1]-[4]. The typical fluorescence spectrum of biomolecule is found at from 500nm to 700nm wavelength. The a-Si has high absorption coefficient at visible wavelength. The relative response of a-Si is match as that of biomolecule. In addition, the a-Si is able to deposit on amorphous materials such a glass substrate. The a-Si film can be deposited on large area substrate.

The electron mobility of a-Si is lower than that of the crystalline and the polycrystalline silicon. The a-Si photodetectors are used in a low response speed devices such as a two-dimensional (2D) image sensor and thin-film transistor. The a-Si photodetector have been achieved by the pin type [1] and the metal-semiconductor-metal (MSM) type [5], [6]. The static characteristics have been reported in above reports. The dynamic characteristics of a-Si photodetector are not understood.

In this study, a-Si planer type photoconductors were fabricated by photolithography and lift-off process. The optical sensitivity and frequency response of the devices with the two types of the a-Si layer thickness were measured at wavelength of 650 nm.

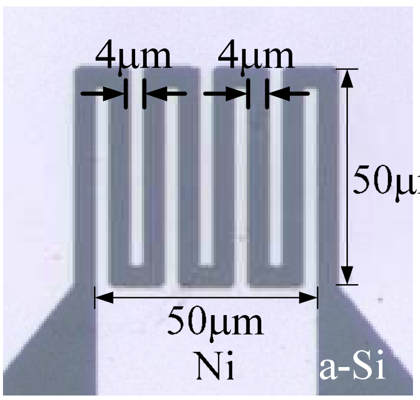

Fig. 1 Optical microscopic image of the a-Si photoconductor.

2. Fabrication process of a-Si photoconductor

A-Si photoconductors were fabricated on a SiO_2 (1 μm-thick)/Si substrate. An a-Si film thickness of 1.0 μm-thick and 0.12 μm-thick were deposited by a plasma-enhanced chemical vapor deposition (PE-CVD). The comb type electrodes were patterned using the standard photolithography and the liftoff process. Ni was used as the metal electrodes due to good adhesion and low dark current on a-Si surface. Figure 1 shows the top view of the fabricated a-Si photoconductor. The electrodes pattern is formed with 2 μm finger width, 2 μm spacing and optical receiving area is 50 μm × 50 μm.

3. Results and discussion

A laser beam of 650 nm wavelength is incident normally on the a-Si photoconductor via an optical fiber. Figure 2 shows the bias voltage dependence of a device photocurrent at wavelength of 650 nm. The photocurrent is evaluated by subtraction a dark current from a measured current. The nonlinearity of photocurrent at low bias voltage is attributed to the Schottky contact of Ni/a-Si.

The incident laser power dependence of the photocurrent at bias voltage of 10 V is shown in Fig. 3. The sensitivities of 5.7 mA/W and 0.9 mA/W were obtained from the 1.0

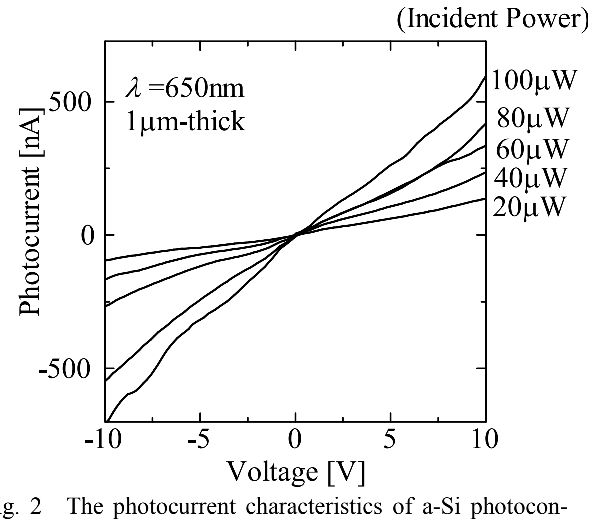

Fig. 2 The photocurrent characteristics of a-Si photoconductor at 650 nm wavelength.

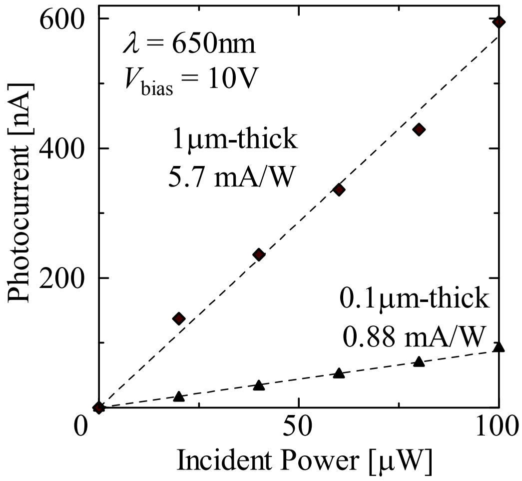

Fig. 3 The incident light power dependence of the photocurrent of the a-Si photoconductor.

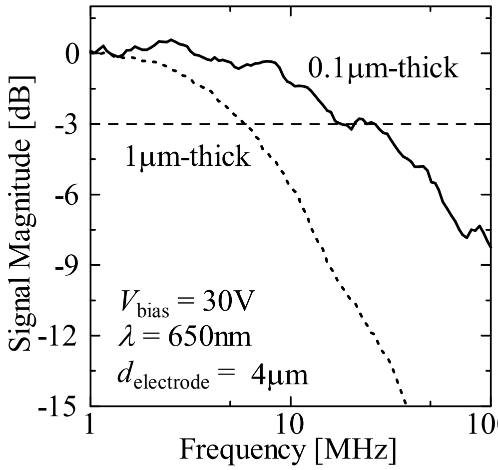

Fig. 4 The frequency response of the normalized photocurrent at 30 V.

μm-thick and the 0.12 μm-thick devices and the external quantum efficiencies (EQEs) of 1.0 % and 0.17 % were estimated at wavelength of 650 nm, respectively. These EQEs are lower than an ideal EQE. The ideal EQE of 1.0 μm-thick device is expected to be 33 % considering a shadow by contact electrodes, a reflection at the a-Si surface, and an absorption in a-Si layer, respectively. The reason for the low EQE at these devices is that the carrier lifetime of a-Si is around 100 times shorter than that of crystalline Si [7].

The frequency responses were measured by a network analyzer with a 1-1000 MHz frequency range at the bias voltage of 30 V. The photocurrent was normalized at low frequency range. The frequency response of signal magnitude is shown in Fig. 4. The 3-dB bandwidth of 8 MHz and 25 MHz were measured from 1.0 μm-thick device and 0.12 μm-thick device, respectively. The bandwidth improvement with thin active layer is because that the photocurrent from the deep a-Si layer is removed. The bandwidths are triple-digits low compared with the crystalline Si photodiode [8]. The reason for low bandwidth of a-Si photoconductor is that the carrier mobility of a-Si has triple-digit lower than that of crystalline silicon.

4. Conclusions

We fabricated two types of a-Si photoconductors and measured the sensitivity and the frequency response at a wavelength of 650 nm. The maximum bandwidth of 23 MHz was obtained from the thin active layer (0.12 μm) device at the bias voltage of 30 V. This bandwidth is sufficient for using the biomolecular imaging applications.

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