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Inexpensive Near-IR Photodetector

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Abstract

Fabrication and characterization of a CdS/Si heterojunction detector for 1.064 μm Nd:YAG laser detection has been carried out by pyrolytic spraying of CdS films onto single crystal n-type Si substrates. Response time has been determined in this study.

Key Words: CdS/Si heterojunction, spray pyrolysis, IR detector.

1. Introduction

Near-IR detectors, i.e., at 1.064 μm (Nd:YAG laser pulses), have been the subject of several investigations, which are necessary for the extended use of Nd:YAG laser in applications [1-3]. Despite that silicon p-n homojunction, in which its response ranged between 0.4 and 1.2 μm, is commonly used as a Nd:YAG photodetector, the disadvantages drawn from Si p-n homojunction devices prompted intensive studies on Si heterojunction [4,5]. The low junction formation temperature and reducing surface recombination effect of the heterojunction are some its advantages over diffused p-n homojunctions. In spite of the huge lattice mismatch of about 7%, CdS/Si heterojunction was considered one of the promising heterojunction devices [6-10]. This heterojunction is formed by several methods. The most commonly used are either evaporation or screen printing methods. Recently, the authors utilized an inexpensive technique to fabricate CdS/Si heterojunction covers for the spectral region of Si p-n homojunction. Preliminary aspects, in this regard, have been published earlier [11-16]. This paper introduces, for the first time, a CdS/Si heterojunction photon detector for Nd:YAG laser pulses. The foremost important feature of merit in photon detectors is the response time; this parameter was measured in this work.

2. Experimental Procedure

2.1. Samples Fabrication

Cadmium sulfide films have been deposited onto monocrystalline n-type silicon wafers of (111) orientation and 3-5 Ω.cm resistivity. The deposited film was made with a spray pyrolysis technique. In this technique, 0.4 M of $CdCl_2$and thiourea aqueous solution was atomized by a special glass nozzle sprayer directed at the heated silicon substrate fixed on a thermostatic-controlled hot plate heater. The substrate temperature (T_S) varied as 300, 350, 400, and 450 °C. The spraying period was 15 s, which was followed by a 2 min wait to avoid excessive cooling of the substrate. The deposition rate was about 2 nm/s. Ohmic contacts were achieved by vacuum evaporation of pure indium on both sides of the samples (sandwich mode).

2.2. Samples Measurement

Specific detectivity was calculated from spectral response measurements (with the aid of a monochromator, 400-1100 nm range) and dark current measurements at zero bias voltage (with the help of an electrometer with 12 digits of ampere accuracy). A GaAlAs laser diode was used to measure rise time. The detector response for Nd:YAG laser pulses of 176 mJ energy and 400 μs single pulse was measured across a load resistance of 5 kΩ connected in series with a non-polarized detector. The irradiation was performed with indirect exposure mode to avoid the induced damage, and the results were monitored with a storage oscilloscope.

3. Results and Discussion

Shown in Figure 1 is the specific detectivity (D*) variation with 400 to 1100 nm wavelengths for a selected CdS/Si heterojunction photodetector prepared at 400 °C. Over this span of wavelengths, there are two distinct peaks, the first one (at 500 nm) is related to the contribution of CdS absorption, while the second (at 800 nm) represents the absorption in the silicon side. The minimum at 600 nm is attributed to the absorption in the interface in which high density of states exist. Detectivity waveform depicted in this figure indicates that the spectral responsivity of this heterojunction photodetector is fairly consistent with that of an Si homojunction photodetector.

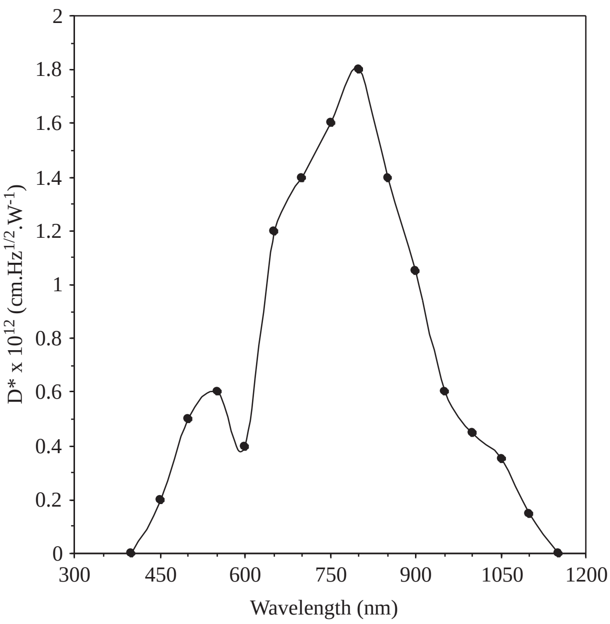

Figure 1. Specific Detectivity against Wavelength.

Rise times for CdS/Si heterojunction detectors fabricated at different preparation substrate temperatures are illustrated in the photographs of Figure 2. It is apparent from this figure that the signal tends to level off beyond its maximum, which refers to the long discharge from the high density of interfacial states. This is attributed mainly to the high lattice mismatch between CdS and Si. Rise time (the interval between 10% and 90% of the maximum signal) is tabulated in Table. This table demonstrates that rise time is lowest at 400 °C of preparation temperature of CdS (i.e., the faster detector). This result can be interpreted as follows: when Ts increases from 300 °C, the ratio between cubic and hexagonal phases becomes greater, as reported in literature [17], which in turn reduces the lattice mismatch and hence, decreases rise time. At 450 °C, oxidation of the wafer will have a negative effect, due to the formation of a considerably thick SiO_X layer [18].

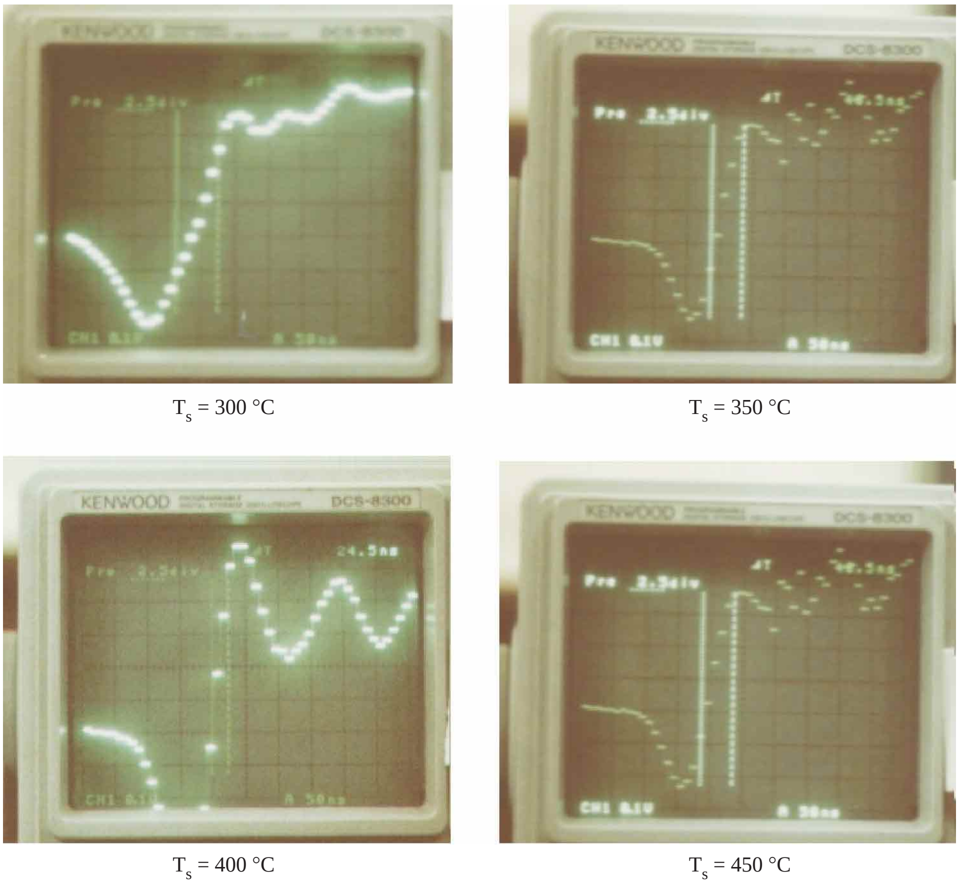

Figure 2. Output Signal of CdS/Si Photodetectors for Rise Time Evaluation.

Figure 3 reveals the voltage response of the CdS/Si detectors. Values of maximal output voltage signals are also listed in Table. These results confirm the previous interpretation of the rise time and demonstrate the best value at 400 °C. The decay region exhibits a long lifetime in all preparation conditions.

Table. Influence of Ts on some Detector Parameters.

T_S (°C)	Rise Time (ns)	Output Voltage Signal (mV)
300	60	145
350	45	160
400	24	182
450	46	105

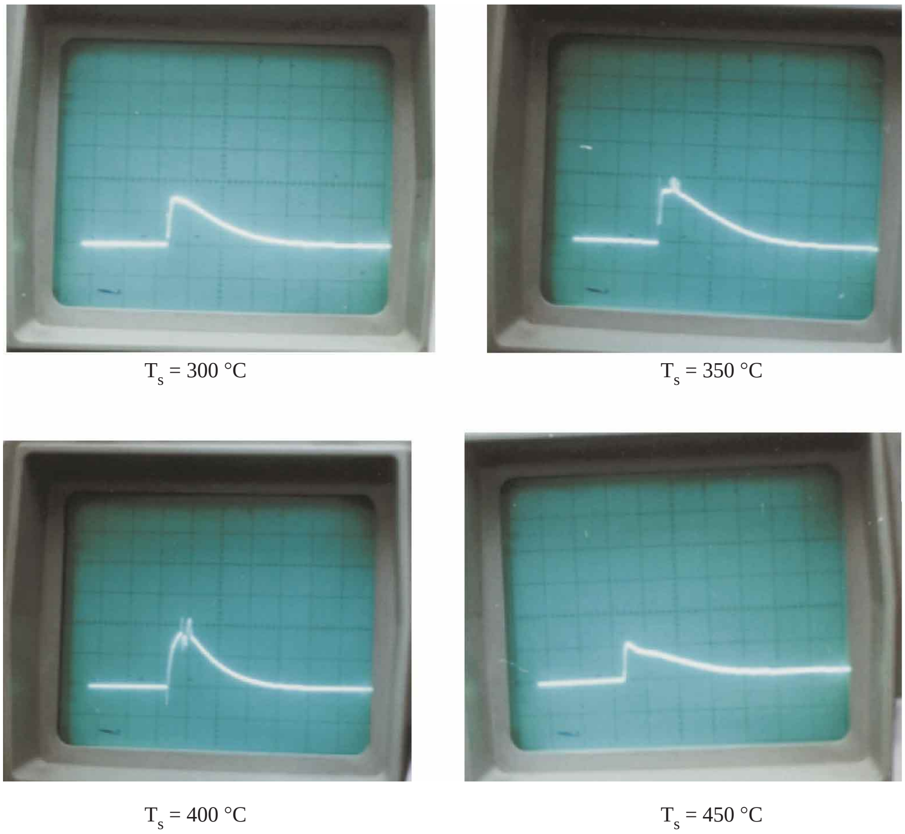

Figure 3. Output Signal of CdS/Si Photodetectors by Indirect Exposure to Nd:YAG Laser Pulses (Vertical Division=0.1 mV).

4. Conclusions

An inexpensive near-IR CdS-(n)Si isotype photodetector of 0.4 mV/W responsivity at 1.064 μm wavelength with an appreciable speed response can be fabricated with the low-cost chemical spray pyrolysis technique. These detectors have a substantial amount of D* reaches to 0.23 x 10^{12} cm.Hz$^{1/2}$.W^{-1} at 1.064 μm wavelength at a fabrication condition of 400 °C substrate temperature. The presented results are comparable with those of the Si p-n homojunction.

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