Performance evaluation of a thermoelectrically-cooled SiC single photon avalanche photodiode

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In this paper, we report on the characteristics of a lab-assembled UV single photon avalanche photodiode (SPAD) based on a thermoelectrically cooled silicon carbide (4H-SiC) avalanche photodiode (APD). A SiC avalanche photodiode (APD) fabricated with bevelled mesa structure was integrated into a lab-assembled SiC SPAD working in a passive Geiger-mode. A 4-stage thermoelectric cooler (TEC) was used for adjusting the APD temperature. Changing bias voltage and comparator level, we evaluated after-pulse characteristics and dark count rates at different APD temperatures.

MOTIVATION

The development of sensitive detectors for UV light has attracted great attention in solar-blind applications such as flame detection, aerosol measurement and missile tracking [1]. In particular, avalanche photodiodes (APDs) based on a silicon carbide (SiC) are known as suitable candidates for sensitive UV detectors because they have excellent spectral responsibility only in the UV region [2]. Further work is underway to develop SiC-based single photon avalanche photodiodes (SPADs) that are sensitive enough to measure UV photons in an extremely low light level [3]. Therefore, in order to guarantee the successful studies on the development of such SPADs, the characteristics of single photon detectors such as dark count rate, afterpulsing probability and detection efficiency must be evaluated in the UV region [4].

In this paper, we report on the performance evaluation of lab-assembled SiC-SPAD working in passive Geiger-mode. 4H SiC-APDs are demonstrated through eUPBAS (enhanced Ultraviolet Photodiode for Biological Aerosol Sensors) program lead by ADD, CCDC-CBC and CCDC-ARL. The APD fabricated with bevelled mesa structure was integrated into the SPAD and the passive quenching circuit enables the Geiger-mode operation of the APD. We measured photon counting rates as a function of incident UV LED power. Dark count rate (DCR) and afterpulsing probability are also measured at different APD temperatures.

EXPERIMENTAL SETUP

Figure 1 shows an experimental setup to evaluate DCR and afterpulsing probability of our SPAD module. We used two source meters to apply stable voltage to the APD and comparator level, respectively. The SiC-APD was attached on a TEC element to control its temperature. The metal housing and cooling fan were used as a heat sink which consumes heat from the TEC element. To test the response of the SPAD on input photons, we used a deep UV LED of 285 nm. This system to measure dark count rates and afterpulsing probability consists of a level translator (Phillips Scientific, 726), a time-to-

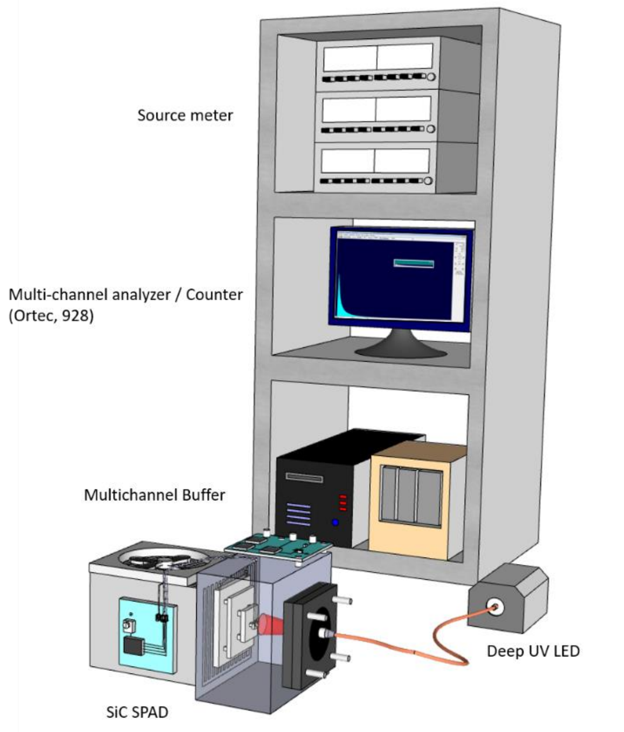

Figure 1. Experimental schematics for the performance evaluation of the SiC-based SPAD.

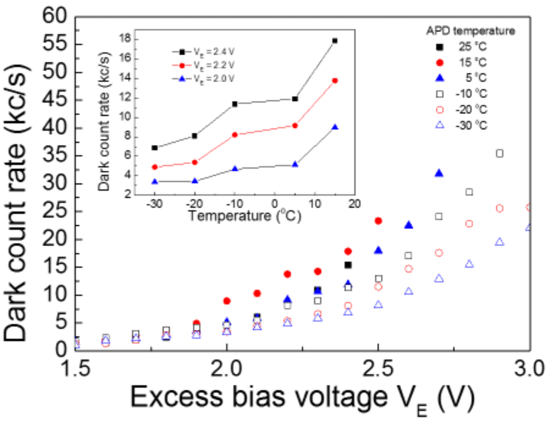

Figure 2. Dark count rates at various temperatures as a function of bias voltage.

amplitude converter (Ortec, 567) and a multi-channel analyser (Ortec, 928).

EXPERIMENTAL RESULTS

As shown in Fig. 2, measurement of DCRs at six different APD temperatures were performed in steps of excess bias voltage applied to the SPAD; the filled squares, circles, and triangles represent the DCRs measured at 25 °C, 15 °C and 5 °C, respectively, while the hollowed squares, circles, and triangles represent DCRs at –10 °C, –20 °C and –30 °C, respectively. Inset figure shows the DCRs at different excess bias voltages of 2.0 V, 2.2V and 2.4 V. From the results we observed that DCRs are reduced with decreasing the APD temperature. The reason for this reduction is resulted from decrease of the thermally generated carriers in the APD junction.

Finally, we measured afterpulse characteristics at APD temperatures as shown in Fig. 3.When the APD temperature reached 0 °C we observed appearance of afterpulse events. At the APD temperature of -30 °C, we clearly confirmed the afterpulse characteristics. With a simple equation in Ref. [4], we can assume that the afterpulsing probability was less than 0.01% at the APD temperature of -30 °C.

CONCLUSION

In this paper, we introduce lab-assembled SPAD based on temperature-controlled SiC-APD. The dark count rates were measured as a function of APD temperature. By using the time-correlated photon counting method, we evaluated afterpulsing probability of our lab-assembled SiC-SPAD.

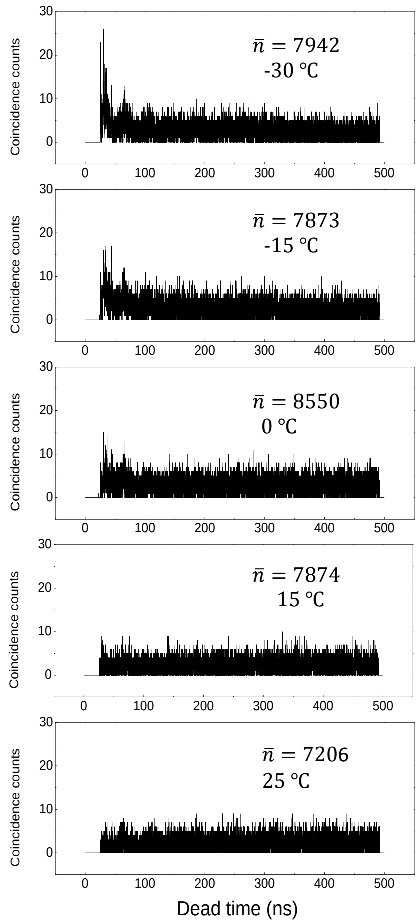

Figure 3. Afterpulse characteristics of the SiC-SPAD as a function of APD temperature. Coincidence count and photon count rates were recorded by a start-stop correlator and photon counting module, respectively.

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