Dependence of Cd Compositione on Transient Photovoltage Characteristics in $Hg_{1-x}Cd_xTe$ Photodiode

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***Abstract*—This paper presents an experimental study of transient photovoltage induced by the pulsed laser excitation in the HgCdTe pn junction photodiode. The excitation light source is a wavelength-tunable pulsed infrared laser. The photo-response shows an apparent negative valley during the first then evolves into a positive peak. An obviously magnitude decreasing of the negative valley can be observed as the Cd composition decrease. When the experiment temperature increase from liquid nitrogen to room temperature, only the positive peak can be observed even the photodiode illuminated by the strong laser intensity. This shows that the negative valley of the transient photovoltage can be attributed to the Schottky barrier at metal-semiconductor (M/S) interface, and the M/S interface photovoltaic effect influenced by the Cd composition and the temperature.**

Keywords- HgCdTe photodiode, transient photovoltage, Cd composiotion, temperature

I. INTRODUCTION

Currently, typical HgCdTe (MCT) photovoltaic infrared focal plane array (IRFPA) photodetectors is still the most important detector in the infrared detestation field, and have been widely applied in aerospace infrared optical remote sensors, scientific satellites, military defense and meteorological observation [1]. It is believed that *n*-type HgCdTe/ Metal electrode interface is a good Ohmic contact in this type photodetector, while due to the large work function differences between the HgCdTe and electrode metal, the *p*-type HgCdTe/Metal interface will form Schottky contact on the electrode interface, which the direction of the built-in electric field is opposite to the *pn* junction. In this way, a back-to-back junction structure *np*-on-*pn* is formed in the photodetector.

Since the electric characteristics of the Schottky contact will overlap with the *pn* junction in the traditional quantitative evaluation methods, such as *I-V* measurements and *C-V* measurements, the electric measurement method are often ineffective in such complex device structure. Given this backdrop, a transient photovoltaic technique (TPV) has been developed to overcome the shortcomings of traditional technology. With the ultrafast-pulsed laser excitation, HgCdTe potodiodes will generate many photo-generated carriers, which is very sensitive to the internal electric field of the semiconductor. Additionally, the electric field of HgCdTe/Metal electrode interface is opposite to the *pn* junction, thus the transient photovoltaic properties will provide the information of HgCdTe/Metal electrode interface. Despite the Cd composition is the important issue in the HgCdTe photodiode M/S interface contact preparation, the related study about the dependence of Cd composition and temperature on the M/S interface contact of the in HgCdTe photodiodes is still scare. In this paper, we present the study of dependence of the Cd composition on the M/S contact using transient photovoltage measurement method.

II. EXPERIMENTAL

The HgCdTe photodiode was grown by MBE on GaAs substrate with a buffer layer of CdTe [2, 3]. Then, n^+-on-*p* photodiode with an ion implantation size of W≈1 μm were fabricated on the *p*-type HgCdTe layer through B^+ ion implantation. The metal contacts were deposited with Sn/Au on either side of the *n*-on-*p* junctions in preparation for photovoltaic measurements. In order to show the dependence of the Cd composition on the M/S interface contact, four Cd composition photodiodes had been prepared. The composition of $Hg_{1-x}Cd_xTe$ in our experiments are x = 0.3035, x = 0.298, x = 0.233 and x = 0.2234. The detectors were processed into 50×50 μm^2 area of planar structures. The active area of photodiode is 50×50 μm^2 or 28×28 μm^2. The sample was mounted in a liquid nitrogen-cooled Dewar for measurement and the temperature is close to 77 K.

The incident laser pulse was provided by a picosecond Nd:YAG laser (30 ps pulse duration, 10 Hz repetition rate). The Laser beam was reflected by a beam splitter and measured using an energy detector (COHERENT J4-09) in order to monitor the exciting energy. The HgCdTe photodiodes were excited by using backside illumination. The pulsed photo-response of the MCT photodiode was measured from the voltage drop across a 50 Ω load-resistor. Both signals from the energy detector and the MCT photodiode were input into an Agilent Infiniium 54832B oscilloscope to monitor and record the pulse profiles. An average of 100 pulsed profiles was recorded to eliminate the pulse-to-pulse fluctuation and to improve the signal-to-noise ratio. A tunable dc power supply was used for adjusting the bias on the *pn* junction.

III. RESULTS AND DISCUSSION

Fig.1 and Fig 2 shows the pulsed photoresponse profiles from MCT photodiode illuminated with laser pulses for the Cd composition are

0.3035 and 0.298. They show apparent negative valley during the first 15 ns, and then evolve a positive peak. By changing the excitation laser intensity, the transient photo-response of the detector show the similar time evolution profiles, no matter for the case of one-photon absorption (OPA) transition that the photon energy is larger than the bandgap. The signals measured from the photodiode have been attributed to the summation of the positive polarity photovoltage of the *pn* junction and the negative polarity photovoltage of the Schottky contact.

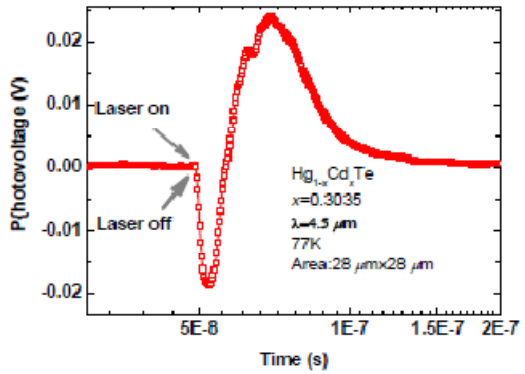

Fig.1 Photoresponse profiles from MCT photodiode illuminated with the Cd composition is 0.3035.

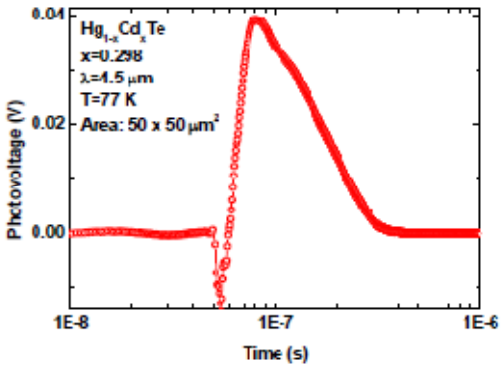

Fig.2 Photoresponse profiles from MCT photodiode illuminated with the Cd composition is 0.298.

Fig.1 and Fig 2 shows the pulsed photoresponse profiles from MCT photodiode illuminated with laser pulses for the Cd composition are 0.233 and 0.2234. By comparing the photovoltaic profiles for the four different Cd composition HgCdTe photodiodes, we can see that the negative photovoltaic valley are not easy to be observed in the low Cd composition photodiode even if the incident intensity increase, such as x=0.233 and x=0.2234 which is shown in Fig.3 and Fig.4. This shows that there are obviously Schottky barrier electric field exist in the p-type HgCdTe/ Metal electrode interface of the mid-wave (x=0.3035 and x=0.298) MCT photodiode, however, the Schottky photovoltaic effect is not obvious in the long-wave (x=0.233 and x=0.2234) MCT photodiode, therefore, the Schottky contact can not be characterized by the TPV measurement. The above results suggest that the Schottky barrier is closely related to the Cd composition for the MCT infrared photodiode. This is in consistent with the conclusion that the Schottky barrier height increase with the Cd composition in the HgCdTe Schottky barrier photodiode using traditional electric measurement methods [4], and the reason can be interpreted by the work function differences between the HgCdTe and electrode metal increasing with the Cd composition.

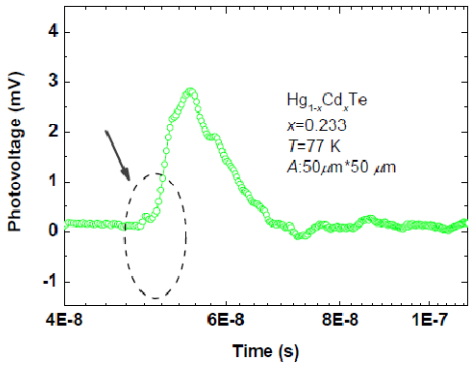

Fig 3 Photoresponse profiles from MCT photodiode with the Cd composition is 0.233.

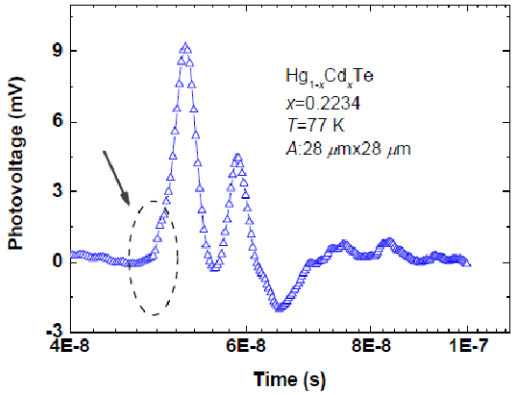

Fig 4 Photoresponse profiles from MCT photodiode with the Cd composition is 0.2234.

ACKNOWLEDGEMENT

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