Research on the electrical characteristics of the Pt/CdS Schottky diode

Jia-xin Ding, Xiang-feng Zhang, Guan-sheng Yao
Luoyang Optoelectro Technology Development Center, 471009 Luoyang, Henan, China

ABSTRACT

With the development of technology, the demand for semiconductor ultraviolet detector is increasing day by day. Compared with the traditional infrared detector in missile guidance, ultraviolet/infrared dual-color detection can significantly improve the anti-interference ability of the missile. According to the need of missile guidance and other areas of the application of ultraviolet detector, the paper introduces a manufacture of the CdS Schottky barrier ultraviolet detector. By using the radio frequency magnetron sputtering technology, a Pt thin film layer is sputtered on CdS basement to form a Schottky contact firstly. Then the indium ohmic contact electrode is fabricated by thermal evaporation method, and eventually a Pt/CdS/In Schottky diode is formed. The I-V characteristic of the device was tested at room temperature, its zero bias current and open circuit voltage is -0.578nA and 130mV, respectively. Test results show that the the Schottky contact has been formed between Pt and CdS. The device has good rectifying characteristics. According to the thermionic emission theory, the I-V curve fitting analysis of the device was studied under the condition of small voltage. The ideality factor and Schottky barrier height is 1.89 and 0.61eV, respectively. The normalized spectral responsivity at zero bias has been tested. The device has peak responsivity at 500nm, and it cutoff at 510nm.

Keywords: CdS, Schottky, ultraviolet, I-V characteristic.

1. INTRODUCTION

With the development of technology, the demand for semiconductor UV detector is growing. The wavelength of ultraviolet radiation is range between 0.01 and 0.4 microns. Among various kinds of UV light source, sun is the strongest ultraviolet radiation source. Different wavelengths of UV have different atmospheric transmittance. The UV light less than 280nm is almost non-existent in the atmosphere near the ground, so it`s known as solar-blind. The transmittance of 300-400nm band is high, it can reach the ground, and it is called atmospheric ultraviolet window. Military ultraviolet detection technique is mostly based on the solar-blind area and the atmospheric ultraviolet window of the atmosphere near the ground. According to the uniform and simple features of the atmospheric ultraviolet background, the target can be detected when dark spot on the uniform ultraviolet background is formed due to the plane or other aerial target close to the ground blocking the atmospheric scattering solar ultraviolet radiation [1-4].

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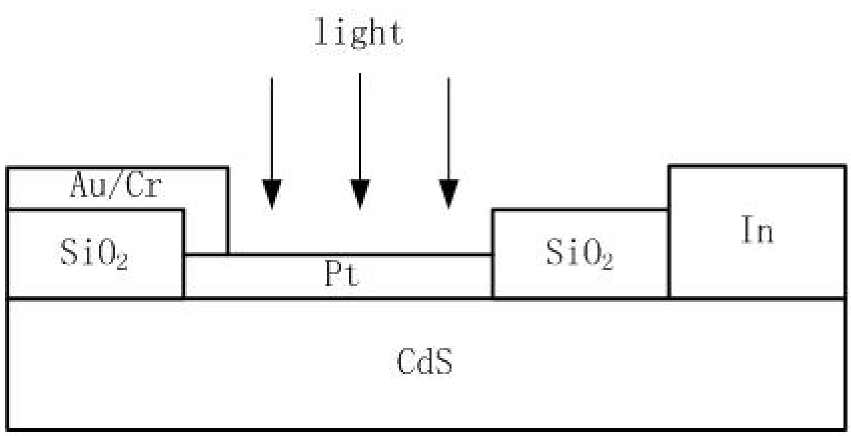
Compared with the traditional infrared detector, ultraviolet/infrared dual spectral detection can significantly improve the anti-interference ability of the missile. The working band of the CdS is range between 300 and 500nm, it covers nearly ultraviolet part and part of visible light, so it is applied earlier in the production of UV detector. Because the CdS has good infrared transmission, it has a special advantage in the applications of infrared/ultraviolet dual spectral detection. Data show that in the 1990s, American of missile -"stinger" has adopted the infrared/ultraviolet dual-color guidance technology, in which the InSb is used as the infrared detector materials, and the CdS is used as the UV detector materials [5-8].

In this study, a CdS Schottky barrier uv detector has been fabricated. The I-V characteristic and the spectral response of the device has been tested.

2. EXPERIMENTAL DETAILS

The structure of the CdS Schottky UV detector is shown in figure 1. The material of the CdS used in this experiment is N type single crystal materials. In this device, Platinum has higher work function, it contacts with the CdS and forms the Schottky contact. Indium which has lower work function forms ohm contact with the CdS, and it is used as extraction electrode. SiO_2 is electrical isolation layer. Since the incident direction of the light is above the Platinum layer, the thickness of the metal must be made very thin to improve the quantum efficiency of the device, so we grows a layer of Au/Cr a thickening electrode for ease of test.

The process of the device is as follows: First, cleaning the CdS chip by the acetone and methanol respectively, then etching the surface of the CdS chip by the hydrochloric acid solution to get the fresh surface. Secondly, using the plasma enhanced chemical vapor deposition method to grows a layer of silicon dioxide on the CdS chip surface. And then the Schottky contact window is prepared by standard photolithography and etching process. Thirdly, high transmittance Schottky contact Pt Electrode is prepared by RF magnetron sputtering technique and lift-off technique. Finally, A Au/Cr thicken electrode is prepared by thermal evaporation and lift-off method for ease to test.



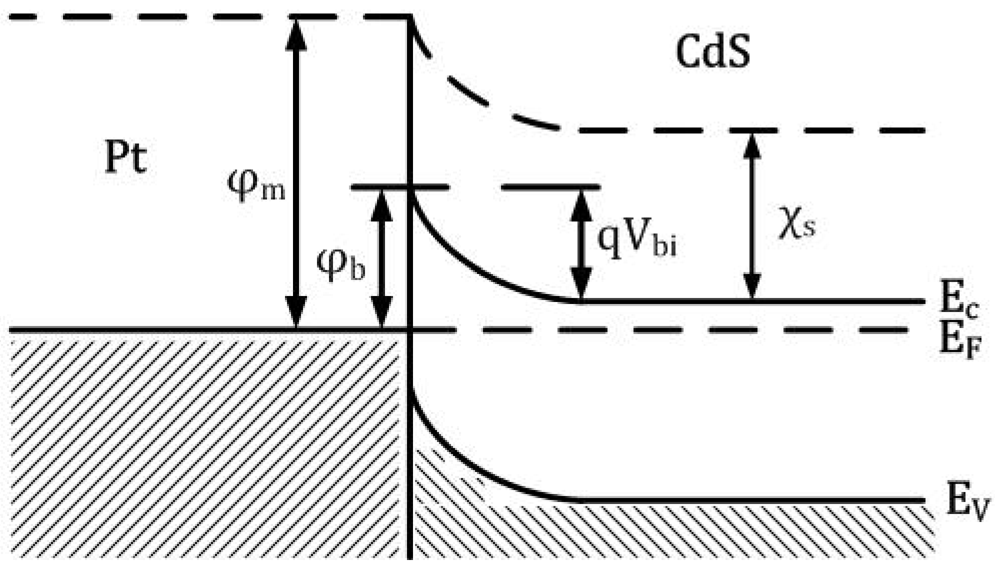


Fig. 1 structure and energy band diagram of Pt/CdS diode

3. RESULTS

The IV characteristics curve is tested at room temperature as shown in Fig.2. The background photocurrent and the open circuit voltage at zero bias is -0.578nA and 130mV, respectively. It shows that Pt and CdS form a Schottky contact, and the device has good rectifying characteristic.

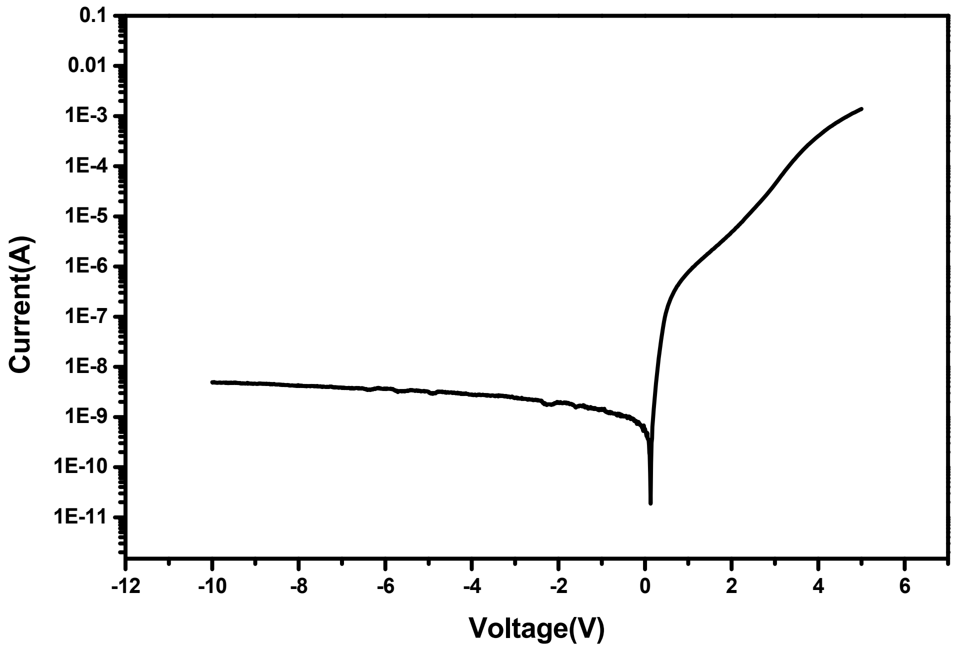


Fig. 2 The I-V characteristics of the Pt/CdS Schokkty diode at 300K

For thermionic emission theory and V＞3kT/q, the diode equation is

$$I = SA^{*}T^{2}\exp\left(-\frac{q\varphi_b}{kT}\right)\exp\ [q(V-IRs)/nKT]\ ) \tag{1}$$

$$A^{*} = (\frac{m_n^{*}}{m_0})A \tag{2}$$

$$A = \frac{4\pi q m_0 k^2}{h^3} = 120\text{amps}/(\text{cm}^2\text{K}^2) \tag{3}$$

Where S is the Schottky contact area, q is the elementary charge, V is the applied voltage, Rs is the series resistance of the diode, n is the deality factor, T is the absolute temperature, k is Boltzmann's constant, φ_b is the barrier height, A* is the effective Richardson constant. In this work, A*=25.2,where $\frac{m_n^{*}}{m_0}$=0.21 [9].

The Eq. (1) can be written as

$$\frac{dV}{d(\ln J)} = JSR + \frac{n}{\beta} \tag{4}$$

Where S is the Schottky contact area, and $\beta = q/kT$.

Seen from the Eq.(4) that when fitting curves about dV/d(lnJ) ~J between 0.24V and 0.48V, we can get a linear line. The intersection of the straight line and the y-axis is the intercept which is equal to n/β. This yields an ideality factor of n=1.89 at 300K for this diodes as shown in Fig.3. Device conduction mechanisms can be reflected by the ideality factor. For Schottky devices, the ideality factor is generally between 1 to 2. If n is closer to 1, then diffusion current dominates the device, while if n is closer to 2, recombination current dominates the device. Our value of n=1.89 at 300K is closer to 2, suggesting that the Schottky contact`s IV curve is imperfect. This may be caused by defects in the CdS crystal lattice exists.

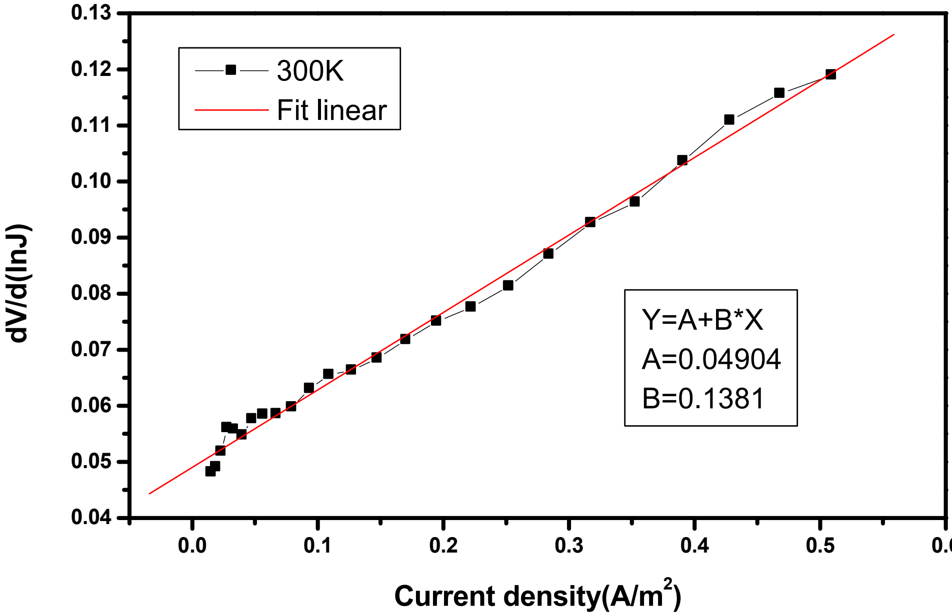


Fig. 3. J versus dV/d(lnJ) for Pt/CdS Schokkty diode at 300K

To calculate the Schottky barrier height, we define a function H(J) from Eq.(1):

$$H(J) = JSR + n\varphi_b \tag{5}$$

Where,

$$H(J) = V - \frac{n}{\beta}\ln\left(\frac{J}{A^{*}T^{2}}\right) \tag{6}$$

When made a H(J) versus J curve, it should be a linear line. The intersection of the straight line and the y-axis is the intercept which is equal to $n\varphi_b$. n=1.89 for foregoing calculation. This yields a Schottky barrier height of φ_b=0.61 at 300K for this diodes as shown in Fig.4. The larger the Schottky barrier height is, the smaller the background photocurrent is. Our value of φ_b=0.61 is smaller than the theoretical value. This because the Schottky barrier height is dominated not only by the metal`s work function, but also by the surface state of the device. This suggests that we should improve the surface state of the device.

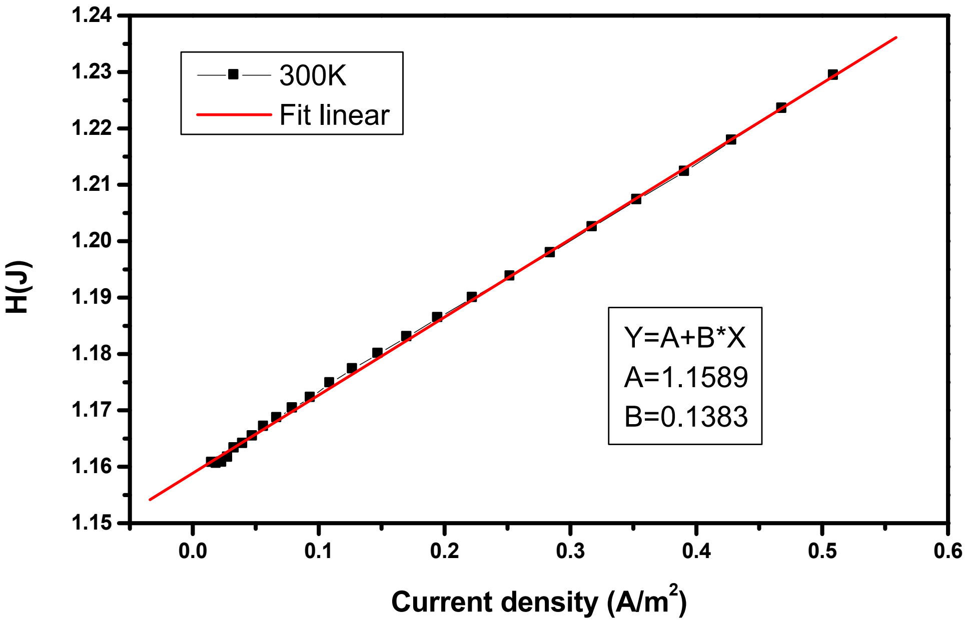


Fig. 4. J versus H(J) for Pt/CdS Schokkty diode at 300K

Fig.5. shows the normalized spectral responsivity as a function of wavelength for Pt/CdS Schokkty diode at 300K. The figure shows that the device has peak value responsivity at 500nm wavelength, the responsivity decreases rapidly in the longer wavelength. A sharp cutoff is observed at 510nm wavelength.

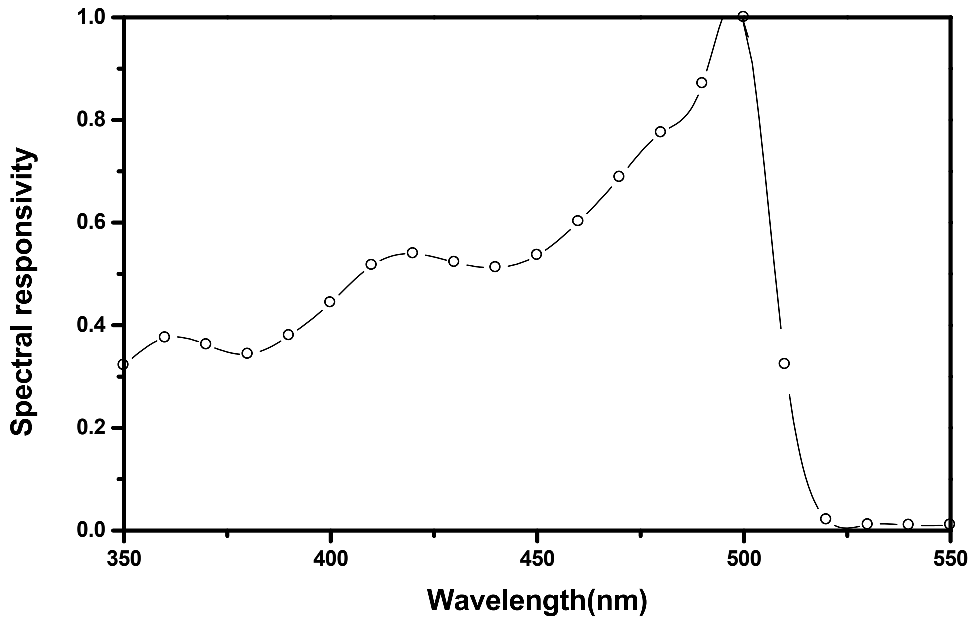


Fig. 5. Normalized spectral responsivity for Pt/CdS Schottky diode at 300K

4. CONCLUSIONS

A Pt/CdS Schottky barrier diode has been fabricated by RF magnetron sputtering technology. By testing device IV curve, it shows that Pt and CdS form a Schottky contact, and the device has good rectifying characteristic. The background photocurrent and the open circuit voltage at zero bias is -0.578nA and 130mV, respectively. The IV curve at room temperature has been analysised on the basis of the thermal emission theory, it shows that the ideality factor and the Schottky barrier height is 1.89 and 0.61eV, respectively. The calculated value of the ideality factor and the Schottky barrier height is imperfect to the theoretical value, the reason is mainly because of the CdS crystal lattice defect and the surface state of the device, etc. The normality spectral responsivity at zero bias has been tested, the device have peak value responsivity at 500nm wavelength, and it cutoff at 510nm wavelength.

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