2. Theory

2.1 Working Principle of Silicon Photocell

A photoelectric device works based on the so-called photoelectric effect of a matter. When a light illuminates on the surface of matters, such as gold, metal oxide or semiconductor, photons may be absorbed by electrons in the matters. If the photon energy is large enough, the electron that absorbed a photon can break the shackle of the atom and emits from the matter surface. The emitted electron is called as photoelectron. The phenomenon is known as photoelectric emission. Some substances illuminated by light, their internal atoms release electrons and the released electrons still remain inside the matter, so that the conductivity of the matter increased, this phenomenon is called as the internal photoelectric effect.

Photodiode detector is a typical photon detector that is based on photoelectric effect. When a PN junction is illuminated by an irradiation above a certain threshold frequency, carriers (i. e. electron - hole pairs) will be generated. The electrons of the electron - hole pairs will be pulled to N zone and the holes are pulled to the P zone by the electric field of the potential barrier, so as to generate photocurrent. At the same time, the optically induced carriers in an extended zone beside the potential barrier zone will be diffused to the potential barrier zone and involve in conducting under the effect of electric field. When the incident light intensity changes, the photo generated carrier concentration and the photo current will also change accordingly through the outer loop. This change maintains a good linear relationship within a large dynamic range of the incident light intensity.

2.2 Current-Voltage Characteristics of a Silicon Photocell

Silicon photocell is a large area photodiode. The basic structure is shown in Figure 1. When the PN junction is at zero bias or negative bias, there exists a built-in electric field in the depletion zone (between the P zone and the N zone). Without light illumination, it is an equivalent of an ordinary diode photodiode with the current-voltage (I-V) characteristic as

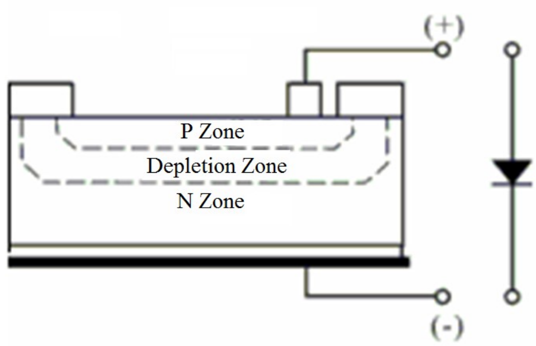

Figure 1 The basic structure of a Silicon photocell.

$$I = I_s\left(e^{\frac{eV}{kT}} - 1\right), \tag{1}$$

where I is the total current flowing through the diode, I_s is the reverse saturation current, e is the electron charge, k is the Boltzmann constant, T is the absolute temperature, V is the voltage applied to the diode.

If a forward voltage is applied, I will be exponentially increased with the increase of the V, called as the forward current; when the applied voltage is reversed (under the reverse breakdown threshold), the reverse saturation current is essentially constant. When there is a light illumination, the incident photon will excite the bound electron to the conduction band. The generated electron-hole pairs will respectively drift to N-Zone and P-Zone. When a load is connected to the two ends of the PN junction, there is a photo-current flowing through the load. The current flowing through the PN junction is written as

$$I = I_s\left(e^{\frac{eV}{kT}} - 1\right) - I_p. \tag{2}$$

Eq. (2) gives the I-V characteristics of a silicon photocell, where I is the total current flowing through the silicon photocell, I_s is the reverse saturation current, V is the voltage across the PN junction, T is the absolute temperature, I_p is the generated reverse photocurrent. It can be seen, when the photocell is at zero-bias, $V = 0$, the current flowing through the PN junction is $I = I_p$; when at negative bias, $I = I_p\text{-}I_s$. Therefore, when a photocell is used as a photoelectric converter, it must be at zero-bias or negative bias.

2.3 Load Characteristics of a Silicon Photocell

A circuit schematic of a silicon photocell used as a battery is shown in Figure 2. Under the effect of the built-in electric field, a photovoltaic voltage will be generated since the bound electrons will be excited to the conducting band by the incident photons. There will be a current flowing through the photocell battery if a load is connected to its two ends. When the resistance of the load is small, larger current and smaller voltage are generated, in contrary, smaller current and larger voltage. During the experiment, the load characteristics of a silicon photocell can be measured by changing the resistance R_L of the load.

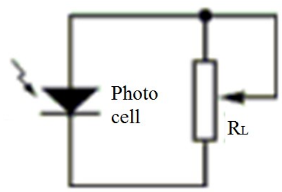

Figure 2. A circuit schematic of a silicon photocell.