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STUDY OF CONVERSION EFFICIENCY AND INTERNAL AND EXTERNAL QUANTUM EFFICIENCIES Of InGaAsSb 0.53 eV

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ABSTRACT

The work established on this article highlights the importance of the tandem SiC-InGaAsSb pair which according to the literature offers real hopes in the Thermophotovoltaic conversion (TPV). The parameters studied on this article are the absorption coefficient which gives us an assessment of the absorption quality of InGaAsSb. For an impeccable evaluation of the conversion of the thermophotovoltaic cell, we worked on the internal and external quantum efficiencies but also on the conversion efficiency. A comparative study has also been made on these efficiencies and absorption coefficient. These parameters are studied according to the (dimensionless) normalization quantity u=E/kT=hc/(λκT)=hω/kT.

Keywords: Thermophotovoltaic, InGaAsSb, SiC, power, electrique, InGaAsSb

1. INTRODUCTION

The SiC-InGaAsSb tandem is a very interesting transceiver pair. Indeed, the absorption spectrum of InGaAsSb and emission of SiC are compatible. We will now see some very important parameters to evaluate the good conversion of a thermophotovoltaic cell [1-5]. This is the absorption coefficient, the internal and external quantum efficiencies as well as the maximum and ideal yields. Both the internal quantum efficiency and the absorption coefficient are functions that depend on the wavelength of the photon. However, this approximation neglects much of the contribution from the depletion regions and the base and is valid only for the emitter a thickness greater than 5 mm.

1. THEORETICAL STUDY

A. InGaAsSb Absorption Coefficient

The absorption coefficient, $a(\lambda)$, applies when a photon of energy greater than that of the gap directly excites an electron from the valence band to the conduction band thus resulting in the production of an electron-hole pair.

In addition, photons with energies below that of the gap can also be absorbed by exciting electrons and holes to higher energy levels within the confines of the conduction and valence bands.

The expression of $a(\lambda)$ is the following [1,6]:

$$a(\lambda)=a_0\left(E-E_g\right)^{1/2}=a_0\sqrt{hc_0}\left(\frac{1}{\lambda}-\frac{1}{\lambda_g}\right)^{1/2} \qquad (1)$$

$$E_g \le E < \infty \; ; \; 0 \le \lambda \le \lambda_g$$

Where $a_0 = 2,6\mu m^{-1}\dfrac{1}{(eV)^{1/2}}$ [5] (2)

In our simulation, the gap of our cell is of the order of 0.53 eV to 300 K. We also have InGaAsSb cells with a gap of 0.53 eV with good properties [6].

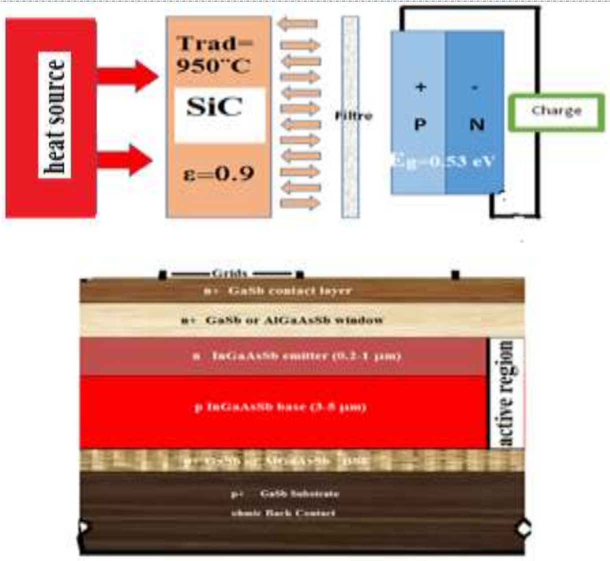

Figure 1. Schema of a 0.53 eV InGaAsSb diode

B. Internal quantum efficiency

The amount of electrons and holes collected by absorbed photon is called the quantum efficiency which can include reflection losses (external quantum efficiency) or to exclude the reflected radiation from the surface of the R (v) cell (internal quantum yield). In other words, the internal quantum efficiency corresponds to the collection of minority carriers, depends on the absorption of photons which lead to the creation of minority carriers and their diffusion at the junction interface, where minority carriers are transformed into majority carriers capable to produce electricity [1,2].

$$\eta_{RQ,\mathrm{int}}(\lambda)=\frac{\alpha L_n}{\alpha^2 L_n^2-1}\left\{\frac{\left(\frac{SL_n}{D_n}+\alpha L_n\right)-e^{-\alpha y}\left[\frac{SL_n}{D_n}\cosh\left(\frac{y}{L_n}\right)+\sinh\left(\frac{y}{L_n}\right)\right]}{\frac{SL_n}{D_n}\sinh\left(\frac{y}{L_n}\right)+\cosh\left(\frac{y}{L_n}\right)}-\alpha L_n e^{-\alpha y}\right\} \quad (3)$$

y is the thickness transmitter ; S is the front surface recombination rate ; Dn is the diffusion coefficient of the minority carriers ; L_n is the length of the diffusion minority of the carriers ($L_n=\sqrt{D_n\tau_n}$)

τ_n is the life of minority bearers.

C. External quantum efficiency

External quantum efficiency is somehow the internal efficiency that can include reflection losses[2,6]:.

$$\eta_{RQ,ext}(\lambda)=(1-R)\eta_{RQ,\mathrm{int}}(\lambda)=(1-R)\frac{a_0\sqrt{hc_0}\left(\frac{1}{\lambda}-\frac{1}{\lambda_g}\right)^{1/2}L_n}{\left(a_0\sqrt{hc_0}\left(\frac{1}{\lambda}-\frac{1}{\lambda_g}\right)^{1/2}\right)^2 L_n^2-1}\times \quad (4)$$

$$\left\{\frac{\left(\frac{SL_n}{D_n}+a_0\sqrt{hc_0}\left(\frac{1}{\lambda}-\frac{1}{\lambda_g}\right)^{1/2}L_n\right)-e^{-a_0\sqrt{hc_0}\left(\frac{1}{\lambda}-\frac{1}{\lambda_g}\right)^{1/2}y}\left[\frac{SL_n}{D_n}\cosh\left(\frac{y}{L_n}\right)+\sinh\left(\frac{y}{L_n}\right)\right]}{\frac{SL_n}{D_n}\sinh\left(\frac{y}{L_n}\right)+\cosh\left(\frac{y}{L_n}\right)} \\ -a_0\sqrt{hc_0}\left(\frac{1}{\lambda}-\frac{1}{\lambda_g}\right)^{1/2}L_n e^{-a_0\sqrt{hc_0}\left(\frac{1}{\lambda}-\frac{1}{\lambda_g}\right)^{1/2}y}\right\}$$

$R_{(\upsilon)}$ Is the reflected radiation from the surface of the cell.

D. TPV conversion efficiency

Maximum conversion efficiency

In the expression of the maximum efficiencythat follows, we suppose that the dimensions of the emitter and the cell are identical so that we can obtain the following simplified expression [1,3]:

$$\eta_{\max} = \frac{e^{-a_1\frac{E}{T}}.\left[2+2.a_1.\frac{E}{T}+a_2.\left(\frac{E}{T}\right)^2\right]}{e^{-a_1\frac{E}{T}}\left[a_3\left(\frac{E}{T}\right)^3+3a_2\left(\frac{E}{T}\right)^2+6a_1\frac{E}{T}+6\right]+R\left[\frac{\pi^4}{15}-e^{-a_1\frac{E}{T}}\left[a_3\left(\frac{E}{T}\right)^3+3a_2\left(\frac{E}{T}\right)^2+6a_1\frac{E}{T}+6\right]\right]} \text{R (5)}$$

describes the performance of the transmitter and the filter,

R describes the performance of the emitter and the filter, R is the ratio of the emittance ε_{El},, for the region of low photon energy of the spectrum that can not be converted into electricity and the emittance ε_{Eb} for the useful photon energy ($E \geq E_g$) of the region of the spectrum.

Conversion efficiency of an ideal system

To have an ideal system, it is necessary on the one hand a zero emittance (i.e. $\varepsilon_E = 0$) but also a reflectance equal to unity ($\rho_c = 1$) for the low energy region of the non-convertible spectrum in electricity $0 \leq E \leq E_g$ and, on the other hand, have an emittance equal to unity and a zero reflectance for the energy of useful photons $E_g \leq E$ [1,3,7].

Error!(6)

Error!(7)

2. RESULTS AND DISCUSSIONS

A. Influence of the temperature on absorption coefficient.

InGaAsSb has excellent absorption properties, which is why it is nowadays the most attractive material. When it is illuminated by the silicon carbide which constitutes its infrared emitter, the quantity of absorbed photons is characterized by the absorption coefficient.

It can be seen that the absorption depends very strongly on the temperature. The curve with the most important temperature gives us the most remarkable evolution.

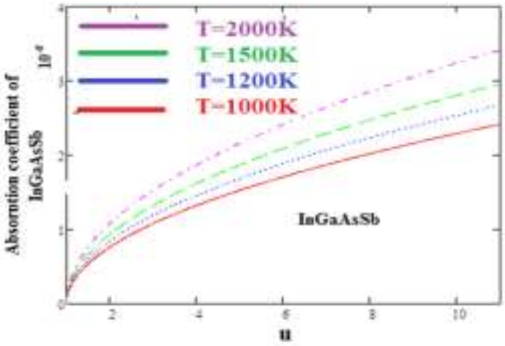

Figure 2: InGaAsSb absorption coefficient as a function of u

Indeed, more SiC is heated plus it generates thermal energy that illuminates the cell and absorbs it in turn. However, the large absorption of photons also requires a wide forbidden band, which explains why the coefficient increases at the same time as u.

However, the TPV conversion does not correspond to the high gap. What matters is not the fact that the gap is important or that the temperature is important. The essential thing is that the temperature of the transmitter corresponds to the energy of the gap of the cell.

B. Impact of the absorption coefficient and u on the internal and external quantum efficiencies

We will now see the influence of the absorption coefficient on the internal and external quantum efficiencies. We will also see the influence of gap energy on these. Thanks to MATHCAD we were able to realize the curves of figure 3 resulting from the functions obtained on the theoretical study of this chapter.

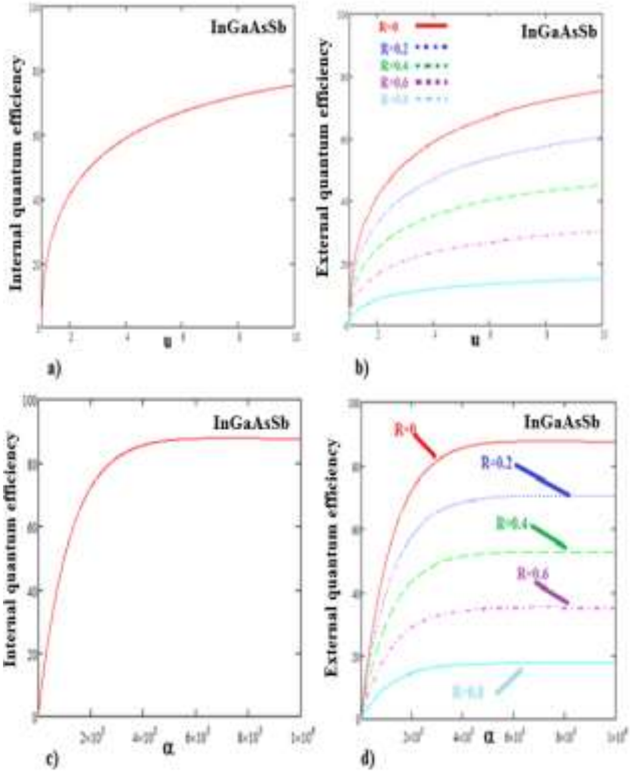

Figure 3 Internal and External Quantum Yields as a Function of u and Trad

For the figure (a) we see that the internal quantum efficiency can be around 80% for a high gap of the material. Depending on the absorption coefficient (figure (c)) it is clear that we can surpass the 80%. This is related to the conditions of this simulation. In fact, when photons released from the SiC are absorbed into the cell, electrons and holes are collected through the cell by diffusing them at the interface of the PN junction, for electricity production. Given this, it seems normal that the increase in quantum efficiency goes with the increase of the absorption coefficient. When this absorption is important it seems obvious that u also increases.

External quantum efficiency excluded from internal efficiency, reflected photons. These are taken into account in R. Figures (b) and (d) show the dependencies of the external quantum efficiency as a function of u and the absorption coefficient respectively. We see the impact of R on the latter. Each time R increases, the external efficiency decreases. Indeed, the increase of R simply means the reduction of incident photons, by reflection. These incident photons are likely to be absorbed. As they decrease, the number of absorbed photons also decreases.

C. Maximum efficiency vs internal quantum efficiency

In this section, we will study the evolution of the internal quantum efficiency and the maximum TPV conversion efficiency in the far field.

Figure 4 contains two curves: the red curve relates to the internal quantum efficiency and the red curve gives the maximum conversion efficiency.

Recall maximum conversion efficiency takes into account only the gaps corresponding to infrared radiation. That is why, by approaching values of u superior to these, the efficiency decreases considerably. What the internal quantum efficiency does not take into account is the reason why it is always increasing whatever the value of u.

Indeed, the internal quantum efficiency, taking into account the electrons and holes collected on the quantity of photons absorbed must be favorable to the large values of u when it increases because each time u increases, it insinuates that the corresponding photons are absorbed. by the cell.

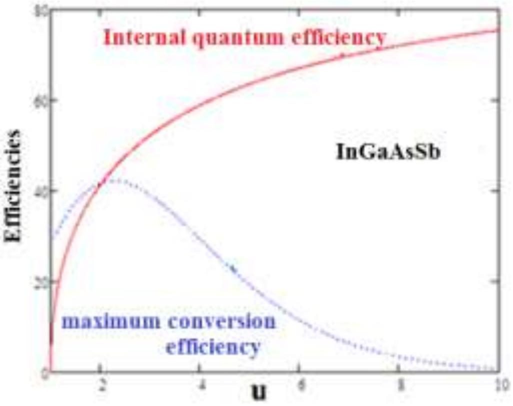

Figure 4: Comparison between the internal quantum efficiency and the maximum yield of InGaAsSb

Note that the intersection of the two curves in Figure 4.33 occurs when the conversion efficiency becomes maximal. This simply means that the corresponding value of the quantum yield corresponds to the amount of net minority carriers collected by photon absorption by the cell. This value is actually that of the external quantum efficiency because the missing value can only be that of the reflected radiation. The material most suitable for obtaining these two yields must have a band gap energy corresponding to that of u.

3. CONCLUSION

As a result of the discussions on this part we learned the dependence of each of the parameters quoted below with respect to the temperature of the emitter and the energy of the gap. We have seen that the importance does not lie in the fact that the gap is important or that the temperature is too important. The importance lies in the match between the temperature of the emitter and the energy of the forbidden band of the emitter. The absorption coefficient is a very important parameter. We have seen the dependence of the infrared light delivered by the emitter. We have finished on the comparison between the maximum TPV conversion efficiency and the internal quantum efficiencies of the photocell. We have seen that the intersection of these two emitter reflected by the two curves is the value of the external quantum efficiency obtained in the case of the maximum conversion efficiency.

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