Investigation on ZnSe for ZnSe/GaAs/Ge High Efficiency Solar Cells

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1. Introduction

For any one kind of semiconductor materials, such as Si, GaAs, CdS etc., its photo-response range is narrow compared with solar spectrum, and it is not possible to cover the solar spectrum well. So the efficiency of energy conversion of solar cells made from these materials is low in contrast with objective needs and possibility.

In order to increase the efficiency of solar cells by a big margin, to use composite semiconductor materials is necessary. After comparing and selecting the ZnSe/GaAs/Ge composition is a hopeful group of matching materials for good coverage of the solar spectrum. Their lattice constant is near the same; their energy gaps (Eg) equal to 2.61, 1.43, and 0.67 eV respectively, and are well distributed in the range of solar spectrum.

The solar cells made from ZnSe/GaAs/Ge can cover 94% of the total solar energy according to the data of solar spectral irradiance under AM 1.5, their theoretical efficiency is 56%, and their actual efficiency can be over 30%.

One possible structure of ZnSe/GaAs/Ge tandem solar cell is shown in Fig.1.

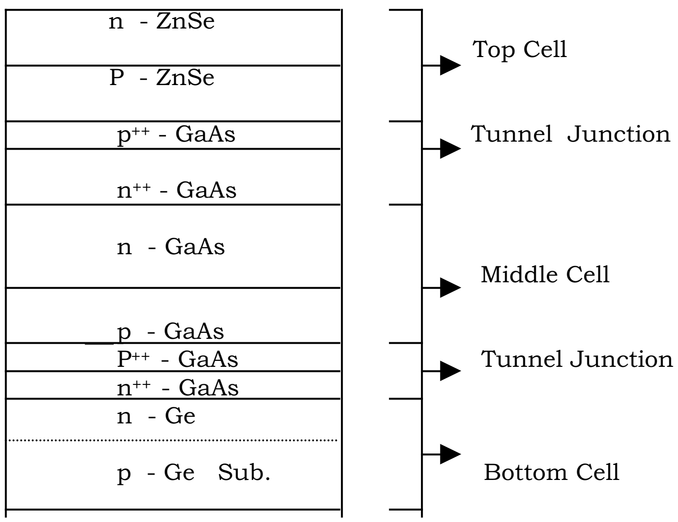

Fig.1. Cross-section of a ZnSe/GaAs/Ge tandem solar cell.

2. Experiment

The bottom cell (p- Ge/n-Ge) and the middle cell (p- GaAs/n-GaAs) have been developed very well, but the top cell (p-ZnSe/n-ZnSe) has been investigated very little. Our research has been focused on the ZnSe p-n junction.

It is a difficult work to highly dope P type of ZnSe for many years. But under the direction of Prof. G.F. Neumark at the Columbia University and Prof. M.C.Tamargo at the City University of New York, we have obtained a progress to raise the P type doping concentration up to 1_10^{18} cm^{-3} through adding a little bit of Tellurium (Te), so that to make the p-n junction of ZnSe becomes possible and interesting.

We prepared the ZnSe p-n junction sample by MBE in the Columbia University and in the City University of New York, U.S.A.. Its structure is shown in Fig.2.

Its external quantum efficiency (QE) has been measured in the Institute of Energy Conversion, University of Delaware, USA. The QE of sample A1340 is shown in Fig.3.

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ZnO		200 nm
N – ZnSe	1_10^{19}	2.5 _m
P – ZnSe	5_10^{17}	0.4_m
P- GaAs buffer	3_10^{18}	0.1_m
P – GaAs sub.	4_10^{18}	

Fig.2. Cross-section of a ZnSe solar cell (sample A1340).

3. Discuss

The QE has a reasonable shape, the energy gap of ZnSe is 2.61 eV (absorption starting from 475 nm) , and the half-high-wide response range of ZnSe is 365 – 450 nm, the peak value is located at 400 nm.

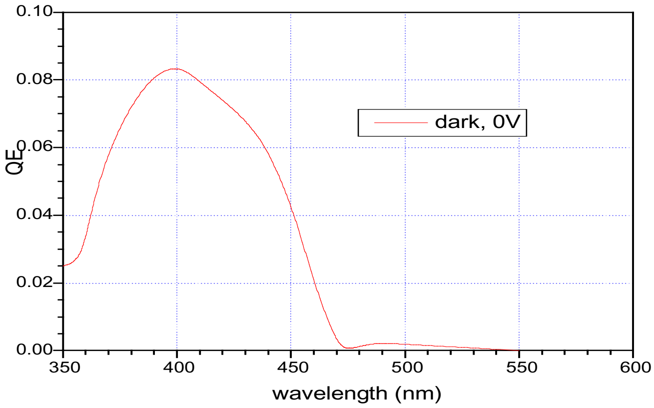

Fig. 3. The quantum efficiency of the sample A1340.

The Fig. 4. is the QE of GaInP/GaAs tandem solar cell and corresponding single junction GaAs and GaInP solar cell, reported by the Fraunhofer Institut Solare Energiesysteme.

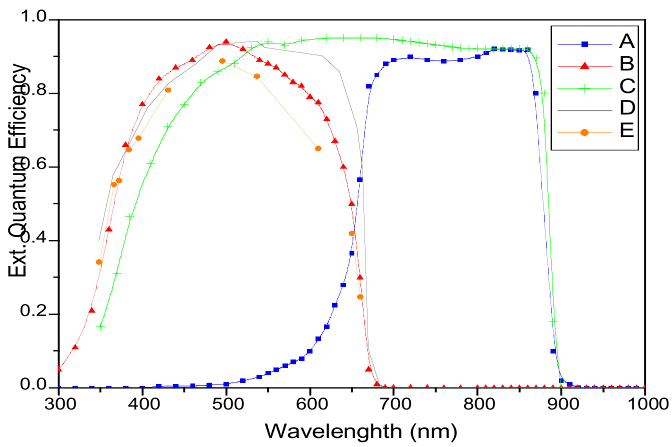

Fig.4. External QE of a GaInP/GaAs junctions solar Cell and corresponding single junction GaAs and GaInP solar cells.
A: the QE of GaAs bottom cell
B: the QE of InGaP top cell
C: the QE of GaAs single junction cell
D: the QE of InGaP single junction cell (2.1_m thickness)
E: the QE of InGaP single junction cell (0.6_m thickness)

From the Fig.4 we can know that the band gap of InGaP is 1.93 eV (i.e. 640 nm), its half-high-wide response range is 370-650 nm, the peak value is located at 500 nm; the half-high-wide response range of GaAs single junction cell is 410-880 nm. Obviously, the response range of the InGaP cell has near completely droped into the response range of single junction GaAs cell. In fact, the GaInP blocks the GaAs to absorb photons, because GaInP will absorb some photons which should be absorbed by GaAs, so the half-high-wide response range of GaAs has been decreased into 660-880 nm. In other words, the GaInP top cell is not necessary, we can get the efficiency of GaInP/GaAs/Ge cell with the GaAs/Ge cell; though using GaInP can raise the open circuit voltage for the bigger Eg of GaInP, the short circuit current will be definitely decreased.

So that, InGaP is not optimum selection for high frequency band of solar spectrum. If substituting GaInP with ZnSe, 4.5 points of percent can be added into the efficiency; because the Eg of ZnSe is 2.61eV, it can cover about 18% of total solar energy, and we suppose the energy conversion efficiency is 25%.

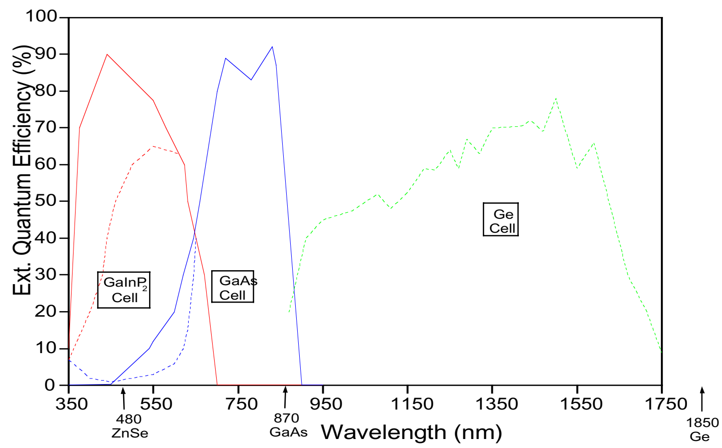

Fig.5. External QE of a GaInP/GaAs/Ge tandem solar Cell.
The dotted line: 1995 results,
The real line: 1996 results.

The Fig. 5. is the external QE of GaInP/GaAs/Ge tandem solar cell, reported by the laboratory of the Renewable Energy Sources of USA. From it we can get the same conclusion as the above.

4. Conclusions

To sum up, it is benefit to develop the ZnSe/GaAs/Ge tandem solar cells.

REFERENCES

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