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A COMPARATIVE ANALYSIS OF SILICON AND CADMIUM TELLURIDE BASED SOLAR CELLS

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A compartive analzsis of silicon solar cells and of those containing a CdTe thin film which are widely used in solar energetics, particullarilly, in photovoltaic modules fabrication, is brought in this paper. The silicon is largely used in solar cells fabrication due to the low cost of solar cells production related to the low cost of the semiconductor fabrication and to the advanced material processing technology, when at the same time cadmium telluride has the wide use due to the fact that its fundamental parameters can provide theoretically a high value of efficiency of solar energy conversion into electrical one of 30%. The structure and photoelectrical parameters of silicon solar cells and of those cotaining a thin cadmium telluride layer are considered.
***Keywords**: Silicon, Cadmium Telluride, solar cell, PN junction, doping process.*

ANALIZA COMPARATIVĂ A CELULELOR SOLARE DIN SILICIU ŞI TELURURA DE CADMIU
În lucrarea de faţă este prezentată analiza comparativă a celulelor solare fabricate din siliciu şi a celor cu strat subțire de CdTe, care sunt pe larg utilizate în energetica solară, în particular la producerea modulelor fotovoltaice. Siliciul este intens folosit în fabricarea celulelor solare datorită costului redus al materialului semiconductor şi tehnologiei avansate de procesare, pe când telurura de cadmiu are o utilizare tot mai largă care, datorită parametrilor fundamentali, poate asigura teoretic o valoare înaltă a eficienței conversiei energiei solare în cea electrică de (30%). Sunt considerate structura şi parametrii fotoelectrici ai celulelor solare din siliciu şi ai celor cu strat subțire de telurură de cadmiu.
***Cuvinte-cheie:** siliciu, telurura de cadmiu, celule solare, joncțiunea PN, proces de dopare.*

Introduction

Using the fossil energy resources on the Earth has contributed to the global warming due to the increase of carbon dioxide rate increase. The impact of global warming leads to a very negative consequences on the world economy and life on the Earth. Therefore the civilazation is seeking for alternative, available, renewable sources ofenergy, such as solar energy which can be converted into other types of energy. Solar energy conversion into electrical one can be realized by using solar cells and photovoltaic modules based on them. Crystalline and amorphous Silicon (Si), Cadmium Telluride (CdTe), and Gallium Arsenide (GaAs) are the most popular semiconductor materials used forfabrication of the solar cells. Recenly a wide spread using have silicon solar cells [1] and a rather intense studies are carried out in the possibilities of using of solar cells with a thin cadmium telluride layer [2].

Silicon Solar Cell Structure

A typical structure of silicon solar cell is given in Figure 1.

Solar cell consists of two layers made of semiconductor material (Si) having different type of electrical conductivity and thus forming a p-n junction. These two layers are provided by front and rear metal Ohmic contacts. At the top, the cell is covered by a transparent glass which allows the light radiation to pass through it and protects its components from dust.

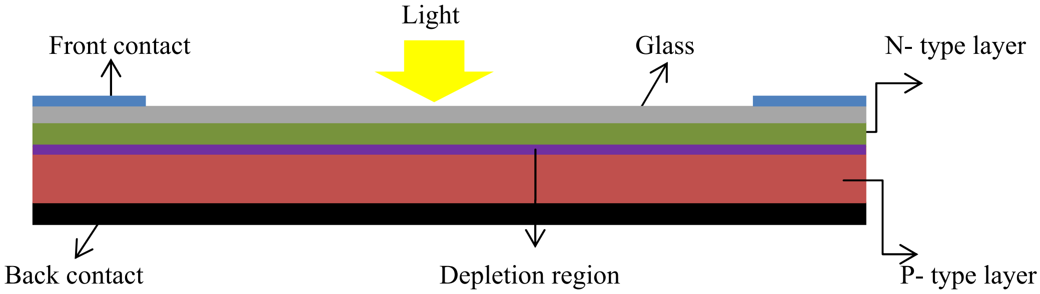

Fig.1. The structure of p-n junction Solar Cell.

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The light incident on the front Silayer of n-type conductivity is absorbed in the depletion region of p-n junction by generating in it the „electron –hole" pairs. The p-n junction electric field separates the generated by the light „electron-hole" pairs and creates a potential difference (voltage) on a solar cell contacts. The value of the open circuit voltage (in Volts) appearing on solar cell contacts under illumination does not exceed the value of the semiconductor band gap E_g (in eV). The diagram illustrated in Figure 2 outlines the relationship between the theoretical value of solar cell efficiency and the band gap of semiconductor [3]. In addition, it indicates that semiconductors whose band gab ranges between 1-1.5 eV has a higher possibility of constructing high efficient solar cells.

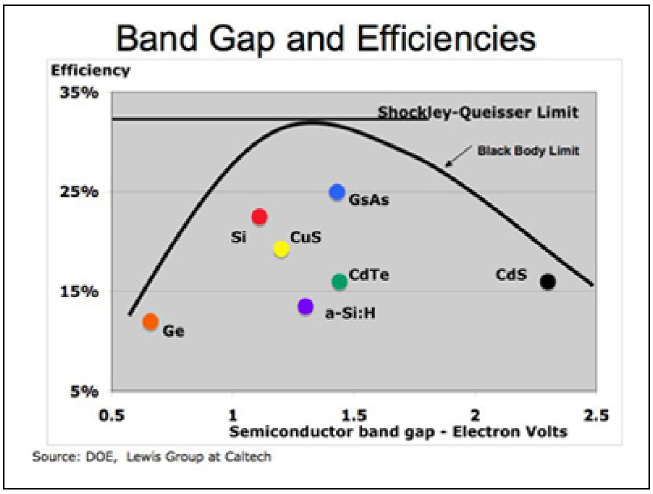


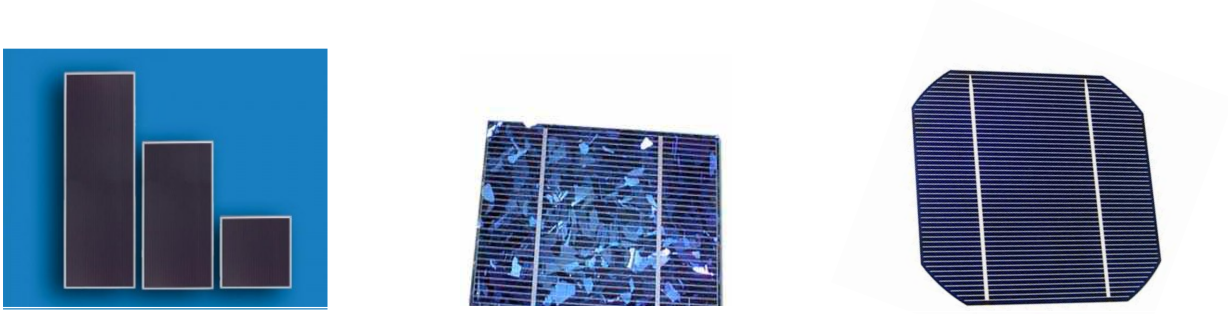
Fig.2. The relationship between the ultimate efficiency of solar cells and band gap of semiconductor [4].

At the market, there are various types of solar cells which are different from each other in the way, the cost of their fabrication, components,efficiency and life expectancy.

There are three types of silicon solar cells:

1. Monocrystalline solar cells
2. Polycrystalline solar cells
3. Amorphous solar cells

Monocrystalline solar cell also known as single – crystal silicon with abbreviation Mono-Si is produced from single silicon crystals [2]; it is, therefore, featured by one uniform color and regular crystal structure [4]. Polycrystalline solar cell, also called multicrystalline with abbreviation Multi-Si, is micro layers of silicon composed of a very huge number of heterogeneous silicon crystals [4]. Polycrystalline solar cells are, therefore, featured by heterogeneity of color and structure; these crystals do not contain a large amount of impurities. Amorphous solar cell, also known as thin film solar cell with abbreviation a-Si [5] is produced from silicon deposition in the form of micro layers placed on glass or plastic surfaces [5].



Amorphous cell **Polycrystalline cell** **Monocrystalline cell**

Fig.3. Different types of Silicon solar cells [2].

Solar Cells based on Cadmium Telluride

Cadmium Telluride (CdTe) has various features enable it to potentially compete with silicon. The most important features are as follows: a very optimal value of band gap **(E_g~ 1.5 eV)** [6] which contributes to the absorption of almost total solar radiation that reaches it, and a high value of light absorption coefficient (**α**= 10^4 - 10^5 cm^{-1}) which enables to use layers with the thickness of few microns. Here, over 90% of fallen radiation is absorbed. On the contrary, the level of fallen radiation absorbed by silicon coefficient is low. Cells with a thickness of 100 – 300 microns are, therefore, required in such a case. As stated, solar cells are composed of a pair of materials that are different in electrical conduction. Recently the studies had shown that solar cells containing a thin CdTe layer such as CdS-CdTe hetrostructure (Fig.4) are relatively cost effective and have high quality [6], and the efficiency of these cells is enhancing.

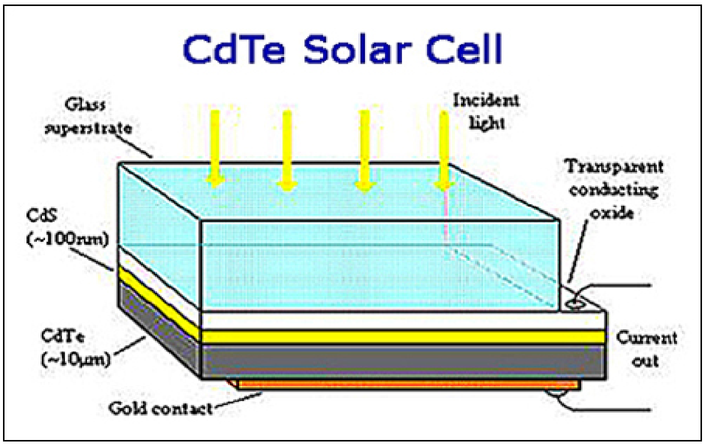


Fig.4. The structure of Solar Cell based on CdTe/CdS hetrojunction [6].

Table shows the values of main parameters of Silicon solar cells and solar cells based on CdTe: Short circuit current I_{sc}, opened circuit voltageV_{oc}, fill factor FF and efficiency η.

Table

Type	Efficiency **(%)η**	Opened circuit Voltage V_{OC} (V)	Short circuit current I_{SC}(mA/cm^2)	Fill factor FF %	Research center and date	Resource
Mono – Si	**25.6 ± 0.5**	**0.740**	**41.8**	**82.7**	**AIST** (2014)	[7]
Multi - Si	**20.8 ± 0.5**	**0.6626**	**39.03**	**80.3**	**FhG-ISE (2014)**	[3]
a – Si	**10.2 ± 0.3**	**0.896**	**16.36**	**69.8**	**AIST** (2014)	[8]
CdTe	**21.0 ± 0.4**	**0.8759**	**30.25**	**79.4**	**Newport (2014)**	[9]

As one can see from Table the efficiency of CdS-CdTe solar cells is below the theoretical value, which is related to the recombination processes involving interface states. As it was shown [10] a way of CdS-CdTe solar cells efficiency enhancement is formation of very thin layer of CdO between CdS and CdTe materials (see Fig.5).

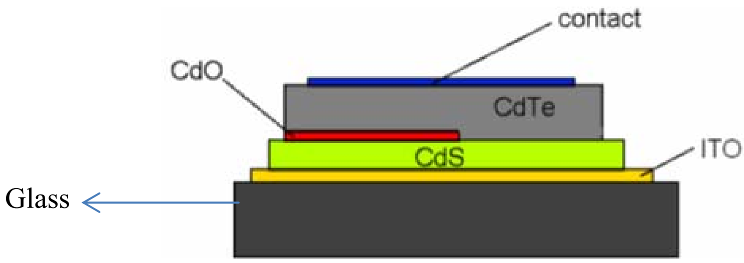


Fig.5. Structure of CdTe-CdS solar cell containing an intermediate CdO layer [10].

Conclusion

A comparative analysys of photoelectrical parameters of silicon solar cells and of those containing a thin cadmium telluride layer had shown, that the efficiency of silicon solar cells is close to its theoretical value. The efficiency of solar cells containing a thin CdTe layer recently is close to the same for silicon cells but there is a possibility to enhance it to the theoretical one which is expected to be higher (30%) than for silicon solar cells.

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