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Suggestion for Modify of the School Educational Program at the Secondary Vocational School of Electrical Engineering

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Abstract

This article deals with the suggestion for modify the school education program at the Secondary Vocational School of Electrical Engineering, Pilsen, specifically by adding a chapter on thin film photovoltaic to the curriculum of the subject Use of Electric. The photovoltaic is increasingly considered to be one of the most important technologies of the 21st century. For this reason it is necessary to provide the students some information on this issue and to expand their competences.

Keywords: school educational program, curriculum, competences, targets, frontal form of teaching, excursion, vocational subject, photovoltaic, thin-films

Introduction

The Secondary Vocational School of Electrical Engineering, Pilsen is one the secondary vocational school in the Pilsen region, where about 850 teenagers study. In the Czech Republic the subjects at the secondary schools can be divided into two groups, namely general-educational subjects and vocational subjects. The general-educational subjects are designed to develop general knowledge, skills and abilities. The aim of the vocational subjects is to provide educators specific knowledge, skills and abilities needed for a particular profession of craft. The subject "Use of Electricity" is one of the vocational subjects at mentioned school. The students of course of "Mechanics of Electrical Engineering – Power Engineering" must graduate this subject. It is taught in the 3rd and 4th grade and is focused on power sources, electrical networks, electrical station, electrical light, electrical heating, etc. (Kalhous, Obst, 2009).

Concerns over increasing request for energies, resource energy scarcity, growing pollution and global climate changes make the photovoltaic (PV) one of the most important technology in the 21st century. It is therefore necessary to provide the students with more information on this issue. I think that the main information which the student should know are importance of the renewable energy sources, PV effect, principle of PV cells, reasons for research in issue of PV 2nd and 3rd generation, structure of thin-film PV cells, basic materials of these PV cells and electrical properties of cells. These information is mentioned in next part of this paper (Benešová, Škorpil, 2011b).

Basic information about Sun energy and PV effect

The energy obtained from fossil fuels is scarce energy that will soon be depleted and negative acts on our environment. Therefore, the people have found other energy resources – the renewable energy sources. The Sun is one of the most progressive and promising renewable energy sources. There are two possibilities to solar energy exploit. Solar technologies are characterized as either active or passive, depending on way how they capture, convert and distribute energy. The active solar technologies include PV and solar thermal collectors. The passive utilization includes orientation of building to the Sun or selecting suitable materials. In spite of, the people have derived benefit from solar energy since ancient times (the Sun has influenced the building design since starting of architectural); research in this sphere began as late as the 16th century, when first solar systems (for platinum melting and fruit maturation) were generated. The breakage in research work came but as late as the 19th century, when PV effect – headstone of the PV – was discovered by French physicist Becquerel. (Benešová, Škorpil, 2011a, 2011b).

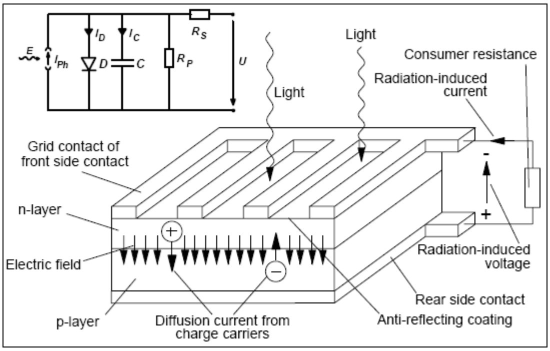

Fig. 1. Principe of PV cells

This effect can be defined by the physical effect, when the electrons are emitted from the semiconductor materials in consequence of their absorption of solar radiation of short wavelength. There are two types of this effect – external and internal photo effect, which is basis for PV. If the electromagnetic radiation hits surface of the solid body, electrons can absorb energy from the photons but they aren’t detached from solid body. They are lifted from the valence band up to the conduction band. For this reason, electron-hole pairs, which enhance the electric conductivity of solid body, are generated. Electrons and holes have the middle lifetime. To create the PV cell, the semiconductor junction must separate these elements – e.g. p-n junction, in which holes flow towards p-area and electron towards n-area, or p-i-n junction. Consequently, the electrical current is generated within this cell. At last, the carriers are collected at the contacts resulting in the electrical voltage (see Figure 1) (Benešová, Škorpil, 2011a, 2011c).

About "thin-film PV cells"

Unfortunately, contemporaneous technology based on the crystalline silicon (c-Si) has some disadvantages, e.g. high power production intensity and considerable material consumption. As a result, the research in this sphere is progressing on finding of alternative material in effort to improve PV cells performances, reduce silicon consumption, decrease production intensity, etc. The thin-film (TF) offer promising alternative to c-Si technology, which have dominated the evolution of PV technologies since its origins (note: currently, c-Si cells rank 82% of market share). Configuration of TF cells (2^{nd} generation) is different compared to c-Si cell. Instead p-n junction, TF cells use p-i-n junction, which consist of p-, un- and n-doped layer. PV cells from TF materials have few advantages. Due to these advantages it can be supposed, that TF will become the very important material in the future. "Thin-film" is term used for material layer ranging of nanometers to several micrometers in thickness, which is applied on the substrates (e.g. glass, plastic foil). The act of applying thin-film is so called deposition. The deposition methods divide into two groups – chemical vapor deposition (CVD) or physical vapor deposition (PVD). In these ways prepared TF have special properties that destine these TF for various utilizations – e.g. power engineering, medicine or TF PV. The TF PV cells are cells produced by deposition one or more TF material on substrate (Benešová, Škorpil, 2011a).

Design of TF PV cells is completely different compared to PV cells 1^{st} generation. There are two configurations of TF cells – substrate and superstrate configuration (see Figure 2). These configurations differ in sequence of individual TF. TF of superstrate configuration are deposited on substrate in direction from light--exposed to shaded side; in the case of substrate configuration structure it is opposite. Instead of the p-n junction used in c-Si PV cells, thin-film cells use the p-i-n junction or the heterojunction. p-i-n junction consists of p-doped, un-doped and n-doped layers of semiconductor materials. Un-doped so called the intrinsic layer (i-layer) plays the most important role – this layer is single active layer (Benešová, Škorpil, 2011c).

It means that it is able to absorb incident solar radiation and to generate electron-hole pairs. Due to, such i-layer must meet few requirements: high optical absorption coefficient in useful spectral range of radiation, high carrier mobility and lifetime and high intensity and uniform electric field. This field occurring between PV passive p- and n-layer ensures electron-hole pairs separation. The PV cells 2^{nd} generation cannot use p-i junction as well as cell 1^{st} generation for few reasons – one of bigger is small diffusion length of the carrier. This length in cells 1^{st} generation is enough high (above 200 μm) to ensure carrier diffusion within p- and n-layer and ensure carrier collection at the contacts resulting in electrical voltage. Diffusion length in thin-film materials is extremely small (0,1 μm). That is way, it becomes impossible to base carrier collection on diffusion alone as in the case of p-n junction (Benešová, Škorpil, 2011a).

The materials applied for the cells can be divided into three basic groups: materials of semiconductor junction – so called absorbers, transparent conductive oxide and substrates. The absorbers are hydrogenated amorphous silicon (a-Si:H) and hydrogenated microcrystalline (μc-Si:H) silicon. The transparent conductive oxide using in this sphere is doped zinc oxide (ZnO) and substrate is formed by glass or plastic foils (Benešová, Škorpil, 2011a).

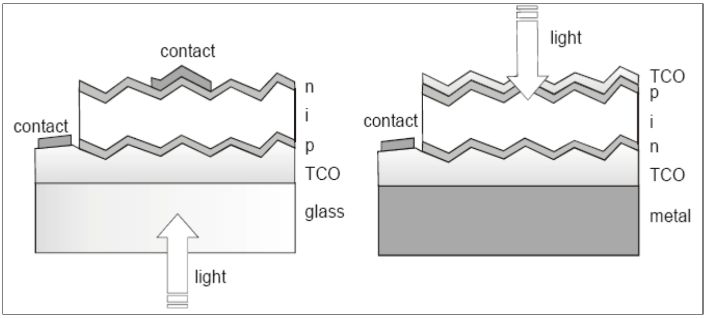

Fig. 2. Structure of PV cells 2^{nd} generation

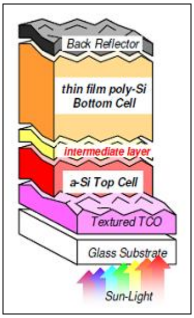

Fig. 3. Tandem cell

Short information about "tandem cells" – PV 3^{rd} generation

Figure 4 shows the optical absorption coefficient "alpha" as function of photon energy for three different materials. Vertical axis of this graph is calibrated in so called penetration depth (i.e. layer thickness, within which 63% of photons is absorbed). The graph pointes important crossover point between hydrogenated amorphous silicon (a-Si:H) and hydrogenated microcrystalline (μc-Si:H) silicon, which is around 1,75 eV. For energy above 1,75 eV, a-Si:H TF have higher value of absorption coefficient. For energy bellow 1,75 eV, μc-Si:H layer have higher coefficient. This fact indicates that it could be very advantageous to use above mentioned a-Si:H and μc-Si:H jointly within tandem configuration cell, i.e. tandem cell is PV cell used a-Si:H along with μc-Si:H (see Figure 3) (Benešová, Škorpil, 2011b).

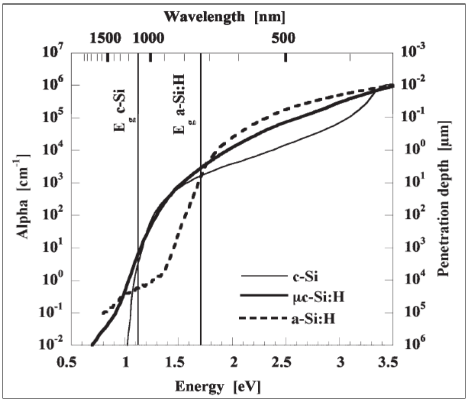

Fig. 4. Optical absorption coefficient as a-Si:H and tandem cell

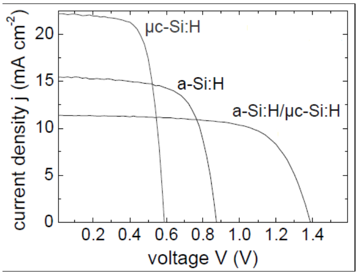

Fig. 5. I–V curves for µc-Si:H, function of photon energy

What about properties and performances of TF PV cells?

Thickness is one of the most important differences between the individual cells generations. Thickness of the PV cells 1st generation has drop to less 200 µm since 1990. Requirement thickness is intended with the material absorption capability. TF materials are characterized by high absorption coefficient compared to c-Si. That is why; mostly the TF cells thickness doesn't exceed 1 µm. The efficiency belongs to one of the performances, which is very important in light of power engineering. The efficiencies for single junction a-Si:H and µc-Si:H cells made by CVD are in the space of 8 and 10% and for the c-Si PV cells in the space of 14 to 17%. The use of a-Si:H absorber layer in combination with µc-Si:H in the tandem cell structure gives perspective of the considerable increase in the efficiency of the cells. These multijunction devices with one intrinsic layer a-Si:H and one intrinsic µc-Si:H layer allow for absorption of greater percentage of solar spectrum, then with each layer used individually – for this reason the tandem cell efficiency has higher value than the single cell efficiency. It is due to each sub-cell transforms part of the solar spectrum at the maximum efficiency. Consequently so called Shockley-Queisser limit (c. 33%) indicating the maximum theoretical efficiency of the PV cell using p-n junction can be exceed. Two sub-cells (one a-Si:H and one µc-Si:H) in series connection have maximum theoretical efficiency of 42% (Benešová, Škorpil, 2011a).

Table 1. Basic properties of PV cells

Type of PV cell	Thickness [µm]	Efficiency [%]	J_{SC} [mA/cm^2]	V_{OC} [mV]
c-Si	200	16,9	35	510
µc-Si:H	0,86	8,5	19,9	598
a-Si:H	0,38	8,0	12,8	883
a-Si:H/µc-Si:H	0,4/1,4	10,9	11,4	1391

Figure 5 illustrates I-V curves for three different types of the PV cells – for μc-Si:H, a-Si:H and tandem cell. The lowest value of voltage exceeds μc-Si:H, vice versa the tandem cell embodies the highest value, which is reaching 1,4 eV. In regard to current density, the situation is contrary – the lowest value has the tandem cell, the highest μc-Si:H cell (Benešová, Škorpil, 2011b).

Conclusion

This paper deals with adding of chapter about TF PV into curriculum. I suggest that the curriculum be supplemented by these target: students understand meaning of renewable energy sources, students can explain principle of PV cell, students can paint structure of TF PV cell, students can name basic materials for cells production, students know electrical properties of PV cells 2^{nd} and 3^{rd} generation and can compare their with the properties of c-Si cells. I think that in this case only frontal form of teaching is not suitable. In my opinion the excursion at New Technology – Research Center in Pilsen would be very beneficial for student. In the center they can see devices use for development and research of material for PV cells and devices for testing of PV cells.

Literature

Benešová, H., Škorpil, J. (2011a). Analysis of Similarities and Differences between Photovoltaic Cells 1^{st} and 2^{nd} Generation. In: *Proceedings of the 12^{th} International Scientific Conference – Electric Power Engineering 2011* (p. 343–346). Ostrava: Vysoká škola báňská – Technická univerzita Ostrava.

Benešová, H., Škorpil, J. (2011b). Analysis of Tandem Photovoltaic Cells. In: *Proceedings of the 6^{th} International Scientific Symposium on Electrical Power Engineering 2011* (p. 122–125). Košice: Technická univerzita v Košiciach.

Benešová, H., Škorpil, J. (2011c). Configuration of Thin-Film Photovoltaic. In: L. Noháčová, J. Mertlová, K. Noháč et. al., *Electric Power Engineering and Ecology – Selected Parts II* (p. 44–51). Praha: BEN – technická literatura.

Kalhous, Z., Obst, O. (2009). *Školní didaktika*. Praha: Portál.