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Research Article

Modern Nanotechnology Application for Generation Highly Efficient Electricity in Save Mode and Much Less Polluting

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Abstract:

Most world country dependent on foreign oil to make things working, which means political disputes or any disputes between countries can result in energy crunches. The negative changes that occur in the global climate and environment due to the burning of fossil fuels, stimulate the search for modern and environmentally friendly sources of energy production. In addition, continued concern about the storage and processing of nuclear waste may limit nuclear energy options. New concepts use nanotechnology as a new application for production of the electricity. In the modern thin-film application technologies, a number of layers can be deposited to improve the cells' energy density, reduce operating temperatures, and lower manufacturing costs. Solid oxide fuel cells (SOFCs), which have the ability to convert chemical energy into electrical energy without combustion, are among the advantages of this cell; High efficiency and much less pollution. Fuel cells - zinc, air, proton exchange membranes, and solid oxide are recent and established energy applications. Several of these solid oxide fuel cells (SOFCs) have emerged as fuel cell technology that has additional positive advantages.

1. Introduction

According to many previous studies, it can be considered that 20 percent of the electric power in most countries of the world is through nuclear power plants, but the sources of electric power relying on nuclear energy still have many problems and accidents, although their number is less, their impact is long-term. After the Chernobyl and Fukushima experiments and the spread of radioactive pollutants for many world counties, concerns continued to be a constant concern [1, 2]. In the end and during the normal working operation the nuclear reactor, the radioactive waste and other kinds of side production disposal or storage to minimize the hazards of nuclear waste generated by nuclear reactors. In countries where electrical energy is produced from nuclear plants, very large amounts of radioactive spent fuel are temporarily stored from commercial nuclear plants. Most of the storage sites almost reach the total storage capacity. The establishment of permanent storage sites has many complex criteria for safety and environmental reasons. Radioactive Cesium (Cs-137) from the Chernobyl accident can still be detected in some soil models, in parts of central, eastern, and northern Europe, many animals, plants, and fungi near the accident site are still radioactive to the level that they may become unsafe for human consumption, Cesium has a half live about 30 years, it emits gamma radiation which it is harmful to live cells [3]. In figure 1 a picture from Chernobyl reactor after the explosion that happens in 1986 is displayed [4]. There are many studies that used nanotechnologies for the production of electricity, for example, an investigator team focus on Nanotechnology for catalysis and solar energy conversion focuses on the application of nanotechnology in addressing the current challenges of energy conversion [5]. Production the electricity by using crystalline silicon technologies for solar cell production [6]. Production electricity by using the chemical and thin-film deposition processes depending on some material to minimize radioactive waste and its long storage [7].

Figure 1. *Chernobyl reactor after the explosion that happens in 1986 [4]*

2. Thin-Film Technologies

There is a great demand for thin-film characterization techniques recently, due to the widespread proliferation of coating technology in many modern applications. The mechanical, functional, and engineering properties of thin films can vary greatly, making them difficult to characterize for general purposes. However, confocal microscopy and optical interferometry profiling can be considered among the few methods that can be used to characterize thin films [8]. It is possible to measure the thickness, residual pressure, adhesion, and roughness of different types of films using a thin-film application technique, this characterization technique can provide higher quality results than those of traditional characterization methods, such as indentation or scratch tests. For example, lenses in all modern optical systems, such as microscopes, binoculars, or eyeglasses, are covered with multilayer films that have different functions (optical, mechanical, or abrasion-resistant). The production of electric energy by burning fossil fuels changes the climate negatively due to the emission of greenhouse gases. These gases are emitted to the atmosphere and contribute negatively to global climate change.

3. Combine Nanotechnology and Radioactive Waste to Generate Electricity

Nowadays nanotechnology is getting more focuses attention and thus is building high expectations in

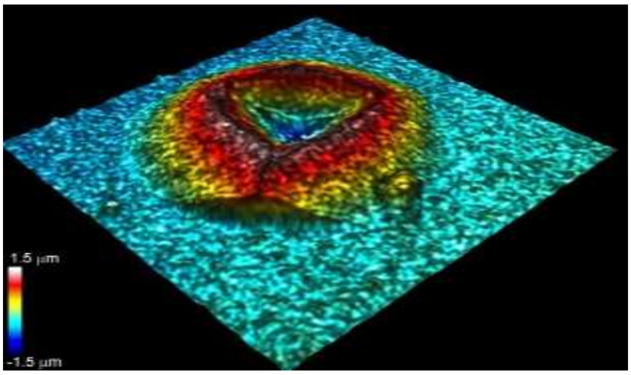

Figure 2. *Production of tools and molds for machining, anticorrosive materials, materials for functional and decorative coatings [9].*

Figure 3. *The ill effects of fossil fuels for infrastructure through toxic emissions into the atmosphere*

many different community. Among them, great achievements are particularly needed in the energy sector which will allow us to maintain our growing appetite for energy. An example for thin-film technology is displayed in figure 2 [9]. For the case of fossil fuel effect, it is displayed in figure 3 to show the ill effects of fossil fuels for infrastructure through toxic emissions into the atmosphere. In figure 4, the world population, energy and electricity demands is displayed [10]. It requires a way that includes the environment in the wealth production equation as we gather more evidence about the human impact on climate, biodiversity, air, water, and soil quality [10]. Therefore we can use this new technology application to promote anew electricity source in some special location by using radioactive waste material. By this application we get more benefit such as:-

a- Find alternative sources of energy Efficiency Clean power is needed.

a- Degrease a large amount of radioactive waste material in the world.
b- Resolve one of important international human hazard.

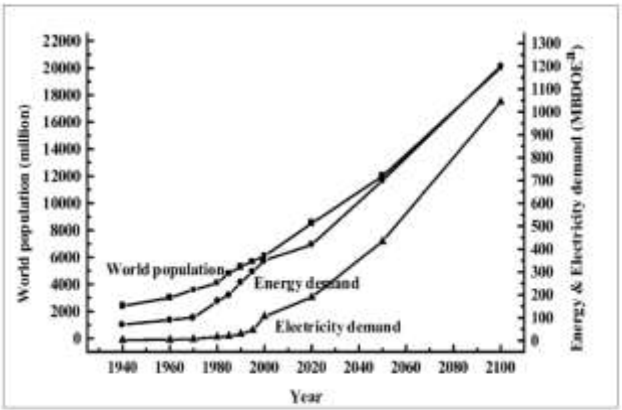

Figure 4. *The world population, energy and electricity demands [10].*

4. Find Alternative Sources of Energy

A fuel cell (Solid Oxide Fuel cell – SOFCs) is an energy conversion device that produces electricity by electrochemical combination of fuel and oxidizing materials through electrodes and an electrolyte that conducts ions. Quieter since there are no moving parts. A fuel cells are highly efficient and far less polluting. Typical Fuel Cell Configuration is displayed in figure 5 [11].

Production electricity by using the chemical and thin-film deposition processes depending on some material to minimize radioactive waste and its long storage.

4.1 Consists of Solid-oxide fuel cells (SOFCs)

A fuel cell consists of three electrochemical components:

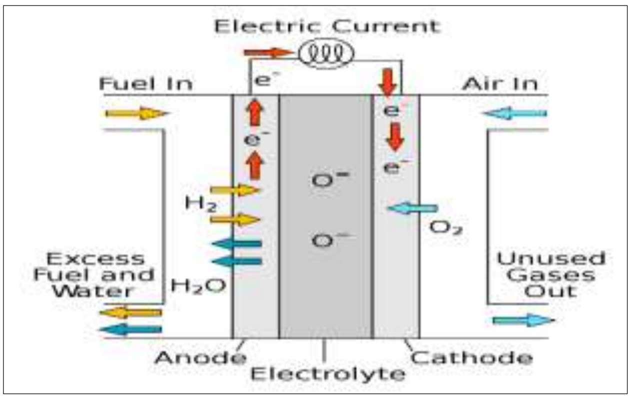

Figure 5. *Typical Fuel Cell Configuration [11].*

1- Cathode reduces oxygen from air.
2- An electrolyte that ensures the transport of oxygen ions.
3- Anode which oxidizes fuel (hydrogen or another combustible gas) by combining with the oxygen ions.

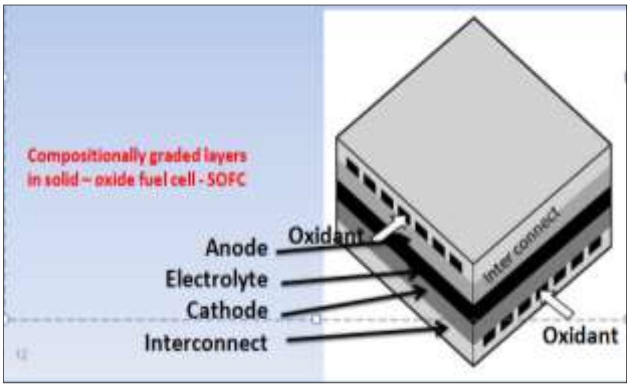

Figure 6. *The graded layers in a solid – Oxide fuel cell (SOFC) [12].*

A single fuel cell has the ability to generate a lower voltage (about 1 volt), the higher voltage being by connecting several fuel cells in series (a fuel cell stack). To further increase production efficiency and reduce resistance losses, it is necessary to reduce the thickness of its electrolyte layer. The development of fuel cells is carried out through the use of several methods, including the use of yttria-stable zirconia thin films to reduce the thickness of the electrolyte, in addition to making the operating temperatures of fuel cells at least 200 degrees Celsius. There are many studies and research to improve the thin-film technology used in SOFC fabrication and to increase the energy density, that the development of a new thin-film deposition technology that may pave the way for the commercialization of SOFCs. This technique is based on colloidal processing, in which the substrate is repeatedly dipped in a colloidal solution. This well-known process has been modified for a single coating ranging in thickness from 1 to 80 μm. The new technique can be applied to a variety of substrate geometries. Cross section of yttrium-stabilized zirconia electrolyte (photographed at various resolutions). Chemical deposition processes and improved thin films provide a strong coating for oxide materials. The coating of new complex and planar substrates should be in a variety of ways that will be particularly useful for applications requiring higher production efficiency. There are many manufacturing and laboratory in many countries work hardly to improve this new accept technologies, the result of these innovations, next-generation fuel cells are helping new and modern industries and special applications reduce manufacturing costs and thus accelerate commercialization of existing SOFC designs. The graded layers in a solid is displayed in figure 6 [12] and a SEM picture is shown in figure 7.

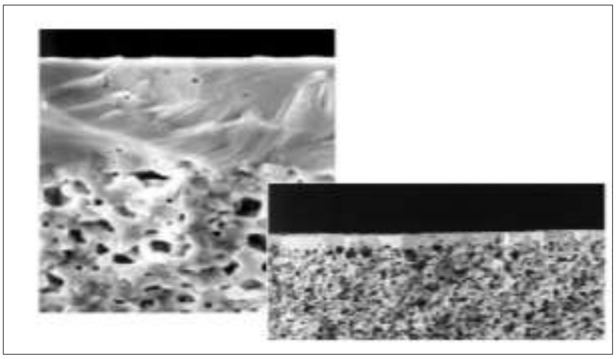

Figure 7. *Thin film for use in a solid – oxide fuel cell (SOFC)*

5. Conclusions

A wide spectrum of energy technologies will be needed to meet the long-term energy needs of the world. Therefore, it can use the new technology application in thin film characterization by using radioactive waste material to product energy. An electrical interconnect provides contact between cells by single coating in the ranges from 1 to 80 micrometers thickness. A fuel cell can be made more efficient when its electrolyte layer is made thinner, thus reducing its resistance losses. All these processing will increasing the carbon dioxide in the climate as it used to get and generate the energy to keep every things working. All these processing should be under controlling.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
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Research Article

Simulation of Neutrons Shielding Properties for Some Medical Materials

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Neutron shielding
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Radiation protection

Abstract:

Radiation is used different field and among others neutron is the one of the most hazardous particle as it is neutral and heavy. Its neutral characteristics make it more difficult particle to be shielded. In this study neutron shielding properties for some medical interested materials of water, fat and bone have been obtained using Phy-X/PSD software.

1. Introduction

The radiation is very important in space technology, nuclear engineering, radiation medicine, radiotherapy, and other fields. On the other hand the radiation requires extreme care due to its hazardous effect to human cell. Thus radiation dosimetry becomes important in science and new techniques, materials have been under study to develop as alternative to conventional materials [1-11].

The neutron with the proton is an important particle in nuclear physics and due to neutral character its shielding is more difficult than others. This is the results of weakly interaction with matter into which it can penetrate deeply. The neutron attenuation is related to the total microscopic neutron cross section (σ_t) and the interaction possibility with the material it is given as in equation 1 [12].

$$\sigma_t = \sigma_s + \sigma_a \qquad (1)$$

where σ_s is the cross section for both inelastic and elastic scattering.

While comprehensive calculations of radiation attenuation for different materials are available in the literature [13-22], the data for neutron are fairly scarce.

In this study, the fast neutron removal cross section (FNRCS) and related other parameters of mfp, HVL and TVL for water, fat and bone have been calculated.

2. Materials and Methods

The FNRCS (Σ cm^{-1}) and related other parameters have been obtained for four different types of medical interested materials. The chemical properties of

***Table 1.** Chemical contents of materials (w%) [23]*

	Water	Fat	Bone	Hydroxyapatite
H	0.1119	0.119	0.0344	0.002
C	-	0.772	0.714	-
N	-	-	0.1827	
O	0.8881	0.109	0.0689	0.414
P	-	-	-	0.185
Ca	-	-	-	0.399

materials is listed in table 1. The simulation was done using Phy-X/PSD online code which is a free online platform [24].

3. Results and Discussions

In this study the neutron shielding properties of four different types of materials of medical interested have been obtained. This is done obtaining FNRCS (Σ cm^{-1}) and some other parameters. The obtained fast neutron removal cross section (FNRCS, Σ cm^{-1}) results is shown as a function of density of materials in Fig. 1 where it is seen that the FNRCS decreased with the increasing materials' density. As it is well known that hydrogen is important for neutron shielding and this result may be the results of different rate of hydrogen on materials. This was obtained and displayed in Fig. 2. It can clearly be seen that the FNRCS increased with the increasing hydrogen rate in materials. Some other parameters such as mfp, HVL and TVL related to FNRCS are obtained.

The *mfp* of any material is the neutron penetration length is obtained using equation 2

$$mfp = \frac{1}{\Sigma} \quad (2)$$

The HVL and TVL are expressed as the thickness of materials to stop half (%50) and 10% of neutrons and they are obtained using by equation 3 and 4 respectively:

$$HVL = \frac{Ln(2)}{\Sigma} \quad (3)$$

$$TVL = \frac{Ln(10)}{\Sigma} \quad (4)$$

The obtained results of *mfp*, *HVL* and *TVL* as a function of materials' density is shown in figure 3. It can be seen from this figure that the all quantity have inverse distribution with the FNRCS.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
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- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

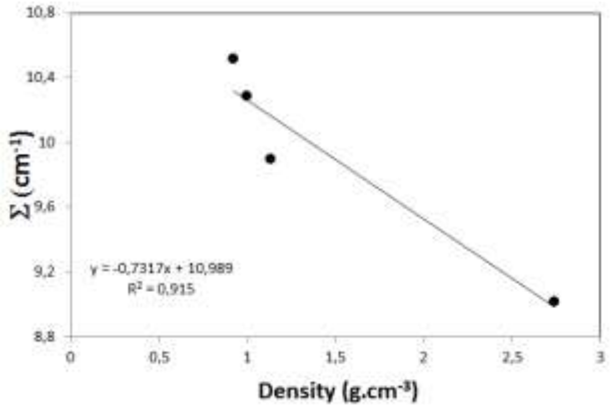

Figure 1. FNRCS *as a function of densities of material*

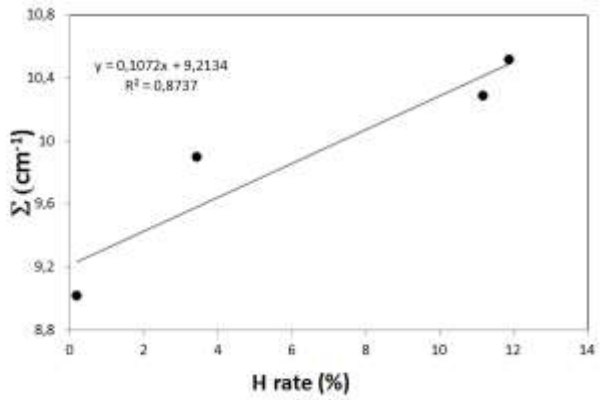

Figure 2. FNRCS *as a function of H rate in materials*

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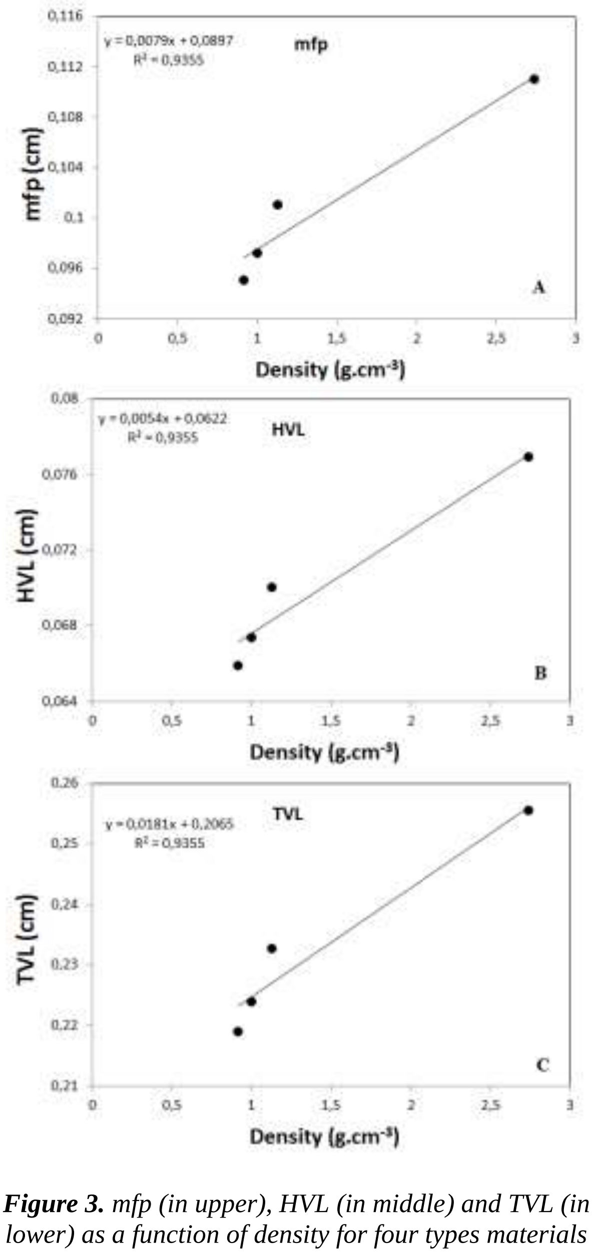

Figure 3. *mfp (in upper), HVL (in middle) and TVL (in lower) as a function of density for four types materials*

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Research Article

The Effect of Circadian Blood Pressure in The Development of Lacunar Infarcts, Together with Other Possible Factors

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Blood pressure
Lacunar Infarct
Circadian

Abstract:

This study was carried out in Amasya University S.S.R.E. Hospital Department of Neurology and Cardiology between 2021 and 2022. Total number of 58 patients (29 lacunar infarct patients and 29 control subjects, 42 females and 16 males) over the age of 45 (mean age 57.1+-6.8) were recruited to the study. All patients underwent 24-hour blood pressure monitoring. The patients with a history of stroke, malignancy, renal or endocrinal disease were excluded from the study. According to the systolic blood pressure measurements, twenty-seven patients were 'non-Dipper' and thirty-one patients were 'Dipper'. Diastolic blood pressure measurements revealed that twenty-one patients were 'non-Dipper' and thirty-seven patients were 'Dipper'.Mean daytime and night-time systolic blood pressure values were higher in patients with lacunar infarction (p:0.02). There was no difference in the diastolic BP and variability (p > 0,05). The clinical importance of the alteration in the reduction of blood pressure is still controversial. Understanding the alterations in blood pressure rhythmicity will be helpful to prevent and treat the lacunar infarctions.

1. Introduction

Lacunar infarcts are defined as small subcortical infarcts normally located in the basal ganglia brainstem etc. that result from occlusion of a single penetrating artery of the brain [1,2] and they account for about a quarter of all ischemic strokes [3]. With development using of magnetic resonance (MR) and computed tomographic (CT), silent lacunar infarction shown to occur among the elderly and patients with stroke [4,5]. Besides of age and other cardiovascular risks, lacunar infarction is related to arterial hypertension [6]. The major risk factor of the development of lacunar infarct is hypertension. Dipper is someone who shows a reduction in BP of 15% mm Hg; those who have less than a 15% reduction in BP during sleep are defined as non-dippers [7]. In patients with lacunar infarction, a reduced night-time blood pressure decreased as seen before [8]. On the other hand limited knowledge regarding the possible pathogenic role of circadian blood pressure changes for the occurrence of lacunar infarction is possible [9]. In this study we evaluated the association of the CBP alterations.

2. Materials and Methods

The study was carried out in Amasya University S.Ş.R.E. Hospital Department of Cardiology/Neurology between 2021 and 2022. Total number of 58 patients (29 lacunar infarct patients and 29 control subjects, 42 females and 16 males) over the age of 45 (mean age 57.1+-6.8) were enrolled to the study. Patients with a history of stroke, malignancy, renal or endocrinal disease were excluded from the study. Patients' clinical risk factors were determined and the occurrence of lacunar ınfarction was analysed. All patients underwent detailed physical examination after enrolment to the study. Presence of lacunar infarction risk factors, together with the presence of diabetes mellitus, hypertension, coronary artery disease and smoking was determined. Blood chemistries and complete blood count were analysed in the whole study population. Carotid and vertebral artery Doppler ultrasonography, electrocardiography (EKG), computerized tomography of brain and magnetic resonance imaging were evaluated in patients with lacunar infarction (n=29) and in control subjects (n=29).

2.1 Blood Pressure Measurements

Non-invasive ambulatory blood pressure (ABP) monitoring and CBP monitoring were carried out with MAPASYS4 by using SYS-SAVE-33 software program. According to some population-based studies, for average daytime values, recordings between 6 AM and 10 PM and for average night-time values, recordings between 10 PM and 6 AM were used [8].

Holter recordings were accepted as successful if 80% or above of the measurements were valid. Successful Holter recordings were taken into consideration.

Blood pressure was obtained in daytime and in deep sleep with 15-minute intervals. Total, nocturnal and daytime systolic, diastolic, and mean BP and heart rate values were determined. MBP was calculated using SBP-DBP/3+DBP formula. Circadian blood pressure difference was determined as the difference between daytime and nocturnal measurements.

If the difference between the diurnal BP and nocturnal BP was equal to or greater than 10 mmHg, then the patient was accepted to be a dipper, whereas those who had less than a 10% reduction in BP during sleep were defined as non-dippers [10]. At least two measurements were performed for both systolic and diastolic BP.

2.2 Lacunar Infarct Classification

Evaluation of lacunar infarction was performed using MRI or CT imaging. Lacunar infarct is expressed as low-signal intensity areas on CT and/or T1-weighted MR images.

3. Results

3.1 Demographic Features

The number of patients with lacunar infarct and control patients are 29 and the results were evaluated in 3 stages:

1- evaluating patients with lacunar infarct and healthy controls

2-Comparison of 'dipper' and 'non-dipper' patients

3-Determination of the factors that can cause the occurrence of lacunar infarct

According to the SBP measurements, there were 27 non-dipper patients and 31 dipper patients. DBP measurements showed that there were 21 non-dippers and 37 dippers. Mean daytime and nocturnal SBP values were higher in patients with lacunar infarct (p:0,02). Reduced SBP variability was demonstrated. There was no difference in the variability of DBP measurements (p> 0.05).

History of hypertension (p: 0.001 OR, 4.84; 95% Cl, 1.47-15.97), night-time SBP values (p<0.001 OR, 1.11, 95% Cl, 1.05- 1.17) and reduced circadian SBP variability (p<0.001, OR: 15.1 95% Cl, 4.2-54.5) were significant factors in the development of lacunar infarct.

4. Discussions

Hypertension stands out as a very relevant risk factor for lacunar infarction [11,12]. The underlying pathophysiological mechanism of circadian BP variability causing lacunar infarct is unclear. In our study, presence of hypertension was found to be higher in the patients with lacunar infarct. Mean daytime and night-time systolic blood pressure values were higher and reduction in the alteration of systolic BP values was detected in patients with lacunar infarction. There was no difference in the Diastolic BP and its alterations. Hypertension, night-time systolic BP values and the reduction of the circadian systolic BD variability were effective factors in the development of lacunar infarction. A risk factors besides age, hypertension, and pathologic changes of circadian rhythmicity may cause multiple lacunar infarctions [8]. rolonged hypertension can produce hypertensive, atherosclerotic, and arteriosclerotic cerebrovascular changes (Figure 1) [13].

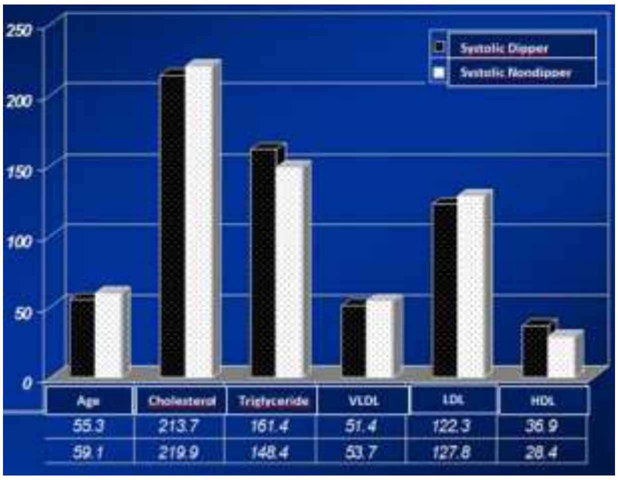

Figure 1. *Hypertensive, atherosclerotic, and arteriosclerotic cerebrovascular changes in long-term hypertension*

Circadian blood pressure patterns are the major impact factor on the development of early carotid atherosclerosis [14].

Systolic daytime blood pressure variability is most closely related to the extent of intima media thickness [15], which is generally considered as an early marker of atherosclerosis (Figure 2) [16]. The lacunar infarction was due to the changes of systolic circadian blood pressure patterns. The diastolic component of blood pressure is the major determinant of cardiovascular risk, systolic hypertension (Figure 3) [8].

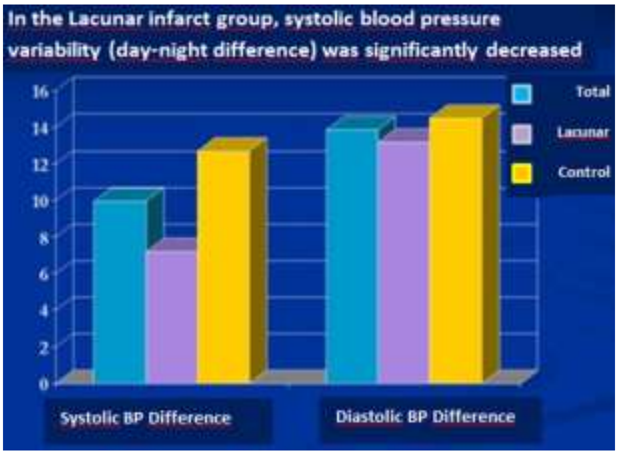

Figure 2. *Lacunar infarct group, systolic blood pressure*

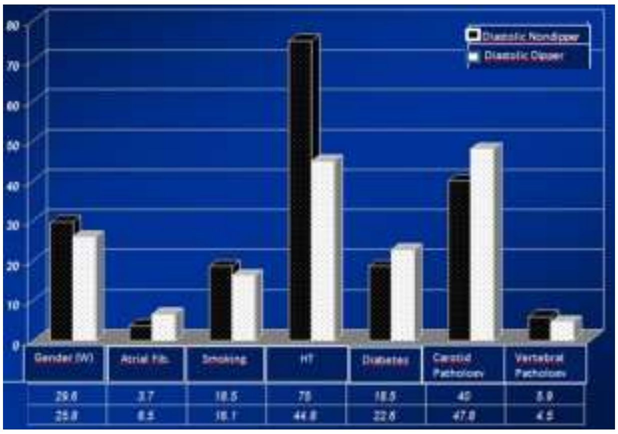

Figure 3. *Lacunar infarct group, diastolic blood pressure*

In recent studies it has been shown that daytime BP variability is more strongly related to organ damage than sudden BP changes (Figure 4) [17]. We used MAPASYS4 in our study to monitor ambulatory BP. The studies with lacunar infarct patients showed that reduced nocturnal BP dipping were associated with the development of lacunar infarct [18]. Most authors have reported that non-dippers, tended to have more severe target organ damage, including cerebrovascular and cardiovascular disease (Figure 5) [19,29]. Nocturnal pressure dip is frequently encountered in patients with hypertension and vascular disease and could be a risk factor for stroke [20]. An absent or lower

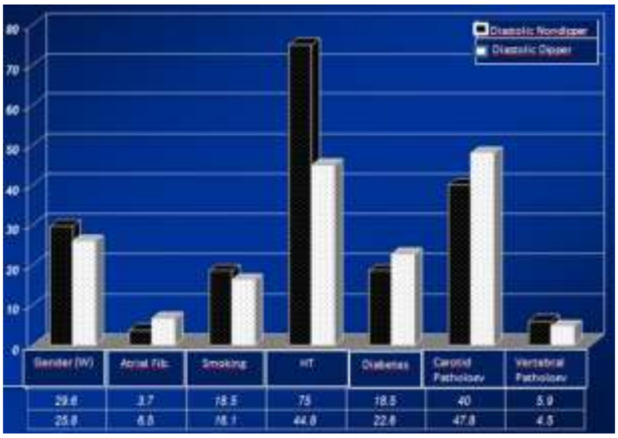

Figure 4. *Lacunar infarct group, diastolic blood pressure*

nocturnal blood pressure fall in elderly hypertensive patient is associated with silent cerebrovascular damage. In contrast, the presence of a nocturnal blood pressure fall could prevent progression of hypertensive vascular damage (Figure 6) [21]. The incidence in symptomatic (recurrent) and/or asymptomatic (silent) brain lesions was higher in non-dippers than in nocturnal dippers [20]. In dipper patients being treated with antihypertensive medications, who had additional new silent ischemic lesions, stenosed arterial lesions were demonstrated (Figure 7) [20]. Controlling high blood pressure is effective in preventing stroke recurrence [22] and preserving cerebral blood flow [23]. The diurnal change of autonomic nervous system activity is closely involved in the diurnal BP variation pattern [24]. A diurnal pattern of BP change, with morning values being higher than those recorded in the evening is well known and it decreases during night-time [20]. Diurnal SBP change was significantly reduced in patients with cortical infarcts and primary intracerebral haemorrhage, but the change in SBP was not prominent in those with subcortical infarcts compared with control subjects [20].

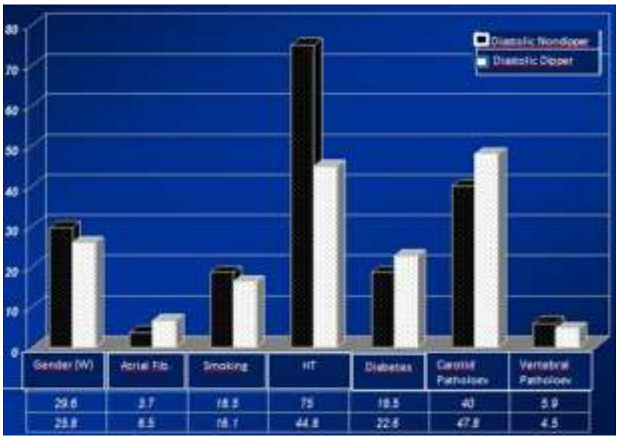

Figure 5. *Lacunar infarct group, diastolic blood pressure*

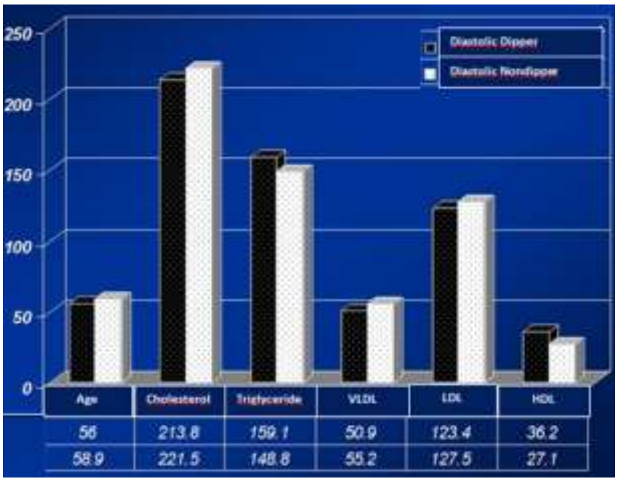

Figure 6. *Lacunar infarct group, diastolic blood pressure*

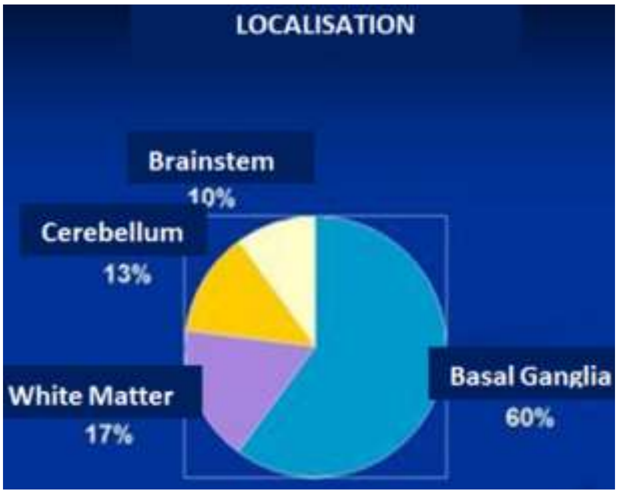

Figure 7. *Lacunar infarct localisation*

The clinical importance of reduced blood pressure variability is still controversial. Further studies with long term follow up are needed to understand/reveal/disclose the importance of circadian blood pressure alterations.

Author Statements:

- **Ethical approval:** As this work related to human issue required processes for permission has been done. (ethical report info: dated on 27.12 2021 Amasya University, E-76988455-044-49467).
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
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- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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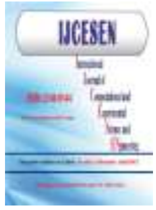

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Research Article

Modeling of a Tandem Solar Cell Structure Based on CZTS and CZTSe Absorber Materials

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Kestrite
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Abstract:

In this paper, we simulated a double junction cell based on top CdS/Cu_2ZnSnS_4 cell, stacked on a bottom CdS/$Cu_2ZnSnSe_4$ cell. We started by studying the perfomance of the bottom solar cell, based on the copper zinc tin selenide $Cu_2ZnSnSe_4$ (CZTSe) absorber. Then, we evaluated the photovoltaic parameters of the tandem cell at the optimized thickness of the copper zinc tin sulfide Cu_2ZnSnS_4 (CZTS) absorber of the top cell, where the top and bottom cells deliver the same photocurrent density. We achieved A maximum efficiency of 24.68% with an open circuit voltage of 1.33 V and a photocurrent density of 16.54 mA/cm² for the thicknesses 413.8 nm and 2 µm of CZTS and CZTSe absorbers, respectively. İn order to improve power conversion efficiency, light trapping effects was studied. The use of randomly textured top cell absorber allows the reduction of its thickness to 270 nm. An efficiency of 24.71% was then obtained. Finally, the effect of replacing the toxic CdS buffer absorber with the ZnS material was investigated.

1. Introduction

It is difficult to predict the world economic and technological development without using renewable energy sources [1]. Photovoltaic technology has experienced considerable development since its emergence. Silicon technology remains dominant and currently shares about 85% of the total photovoltaic market [2]. The other sectors based on thin films such as $CuInGaSe_2$ (CIGS) have experienced a remarkable progress, and have reached efficiency records exceeding 22% [3]. However, due to the use of rare and expensive metals [4], Kestrite materials have emerged as one of the best candidates for replacing the CIGS absorber material [5]. Kestrite semiconductors, such as Cu_2ZnSnS_4 (CZTS), $Cu_2ZnSnSe_4$ (CZTSe), and $Cu_2ZnSn(S,Se)_4$ (CZTSSe) have very attractive properties as they are eco-friendly, with high absorption coefficient [6],in addition to direct and tunable band gap energy between 1 eV and 1.5 eV [7]. Nevertheless, solar cells based on these materials suffer from poor efficiency in addition to large V_{oc} deficit [8]. Thus, using an improved device is required. In order to achieve higher efficiency and to increase the open circuit voltage V_{oc}. Multi-junction tandem structures offer this possibility. A tandem solar cell is a stack of two or more p-n junctions with band gap energies, which decreases in the depth direction from the top surface [9]. The tandem concept has been well established with thin film solar cells based on III-V compound semiconductors and has been used for space applications. Several tandem structures based on CZTS/CZTSe and perovskite/CZTS multi-junctions have been suggested [10].

In this paper, a dual-junction solar cell based on CZTS and CZTSe absorbers has been simulated. İndeed, The performance of the single CZTSe based cell which represents the bottom part of the studied tandem cell, was primarily examined. Moreover, the absorber thickness has been optimized in order to reach the best efficiency. Furthermore, the thickness of the CZTS absorber of the top cell has been adjusted to achieve the density of current match of top and bottom cells. Then, the light trapping effects was invistigated, through using a back mirror in the bottom cell and a randomly textured surface absorber geometry.

Finaly, replacing the toxic CdS buffer by ZnS material on the device was studied.

2. Tandem Cell Structure

Figure.1 illustrates the targeted tandem cell structure, where are connected in series two cells based on 1.5 eV-CZTS and 1 eV-CZTSe absorbing materials. The top cell architecture consists of the stacking of the following layers ATO/n-ZnO/CdS/CZTS, according to the design reported by Shin [11] , while the bottom cell consists of n-ZnO/CdS/CZTSe.

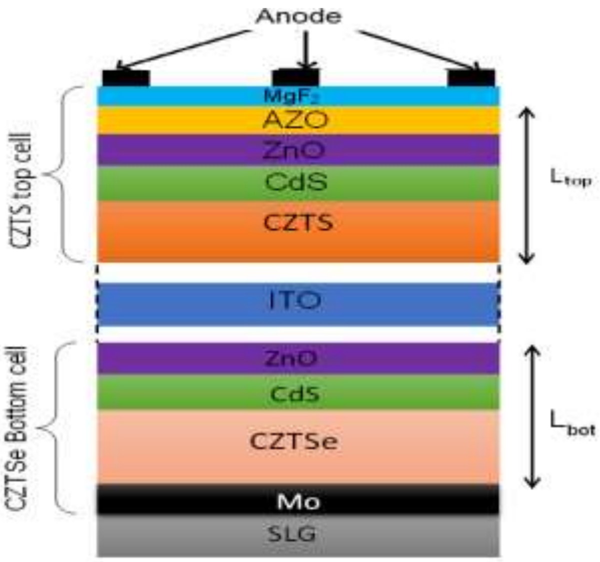

Figure 1. *CZTSe/CZTS Tandem Solar Cell Structure.*

In this simulated device, an ITO tunnel junction was introduced due to its low resistance and high transparency.

3. Simulation Model

In order to calculate the photocurrent densities generated by top and bottom cells, the wavelength-dependent absorption coefficient of the different structure layers was calculated by the well-known expression provided by Tauc and Al model [12]. The photo generated current densities were calcutalted using the equations expressed below, assuming perfect EQE [13]:

$$J_{ph,top} = q.\int_0^{+\infty} \frac{\lambda}{hc}.F(\lambda).\alpha_{top}(\lambda).d\lambda \qquad (1)$$

$$J_{ph,bot} = q.\int_0^{+\infty} \frac{\lambda}{hc}.F(\lambda).(1-\alpha_{top}(\lambda)).\alpha_{bot}(\lambda).d\lambda \ (2)$$

F(λ) represents the wavelength-dependent irradiance spectrum, *h* is the constant of Planck and *c* is the light velocity.

In this work, the absorptivity was calculated according to the model reported by [14]. For planar top absorber surface, the absorptivity $\alpha_{top}(\lambda)$ of top cell and that of bottom cell $\alpha_{bot}(\lambda)$ are expressed, according to equation 3 (not clear). and equation 4. below,as functions of absorption coefficients of CZTS and CZTSe materials, respectively.:

$$\alpha_{top}(\lambda) = 1 - \exp(-\alpha_{CZTS}(\lambda).L_{top}) \qquad (3)$$

$$\alpha_{bot}(\lambda) = 1 - \exp(-i.\alpha_{CZTSe}(\lambda).L_{bot}) \qquad (4)$$

i=1, if there is no back mirror in bottom cell; while *i=2*, in the case of back mirror presence.
L_{top} and L_{bot} represent top and bottom cell thicknesses respectively.
In the case of randomly textured surface absorber, the expressions become:

$$\alpha_{top}(\lambda) = 2.\int_0^{\pi/2}\left(1 - e^{\alpha_{CZTS}(\lambda).\frac{L_{top}}{cos\theta}}\right).cos\theta.sin\theta.d\theta \ (5)$$

$$\alpha_{bot}(\lambda) = \frac{4.n_{ref}^2.\alpha_{CZTSe}(\lambda).L_{bot}}{1+4.n_{ref}^2.\alpha_{CZTSe}(\lambda).L_{bot}} \qquad (6)$$

n_{ref} is the CZTSe refractive index.
Ferhati has reported that saturation current densities of both CZTS and CZTSe cells could be expressed as follows [15] :

$$J_s = q.Nc_{Abs}.Nv_{Abs}.(\frac{1}{Na}.\sqrt{\frac{Dp}{\tau p}}.\exp\left(\frac{-E_{g,Abs}}{V_{th}}\right) + q.Nc_{Buff}.Nv_{Buff}(\frac{1}{Nd}.\sqrt{\frac{Dn}{\tau n}}.\exp(\frac{-E_{g,Buff}}{V_{th}})) \qquad (7)$$

$N_{v\,Abs}$, Nc_{Abs} are the effective densities of states for each absorber.
N_a,N_d represent doping concentrations of the absorber and buffer materials respectively.
$E_{g,\ Abs}$ and $E_{g,\ Buff}$ are the band gap energies of the absorber and the buffer layers.

The photovoltaic parameters were calculated using the expressions reported in literature.
The open circuit voltage of a tandem cell is the sum of individual open circuit voltages of the top and bottom cells. However, the total current density is limited to the lower value associated with the sub cells [16].

4. Results and Discussions

İn this study, photovoltaic parameters such as V_{oc}, J_{ph} and efficiency of the single CZTSe cell wich was used as the lower part of the tandem cell were fistly

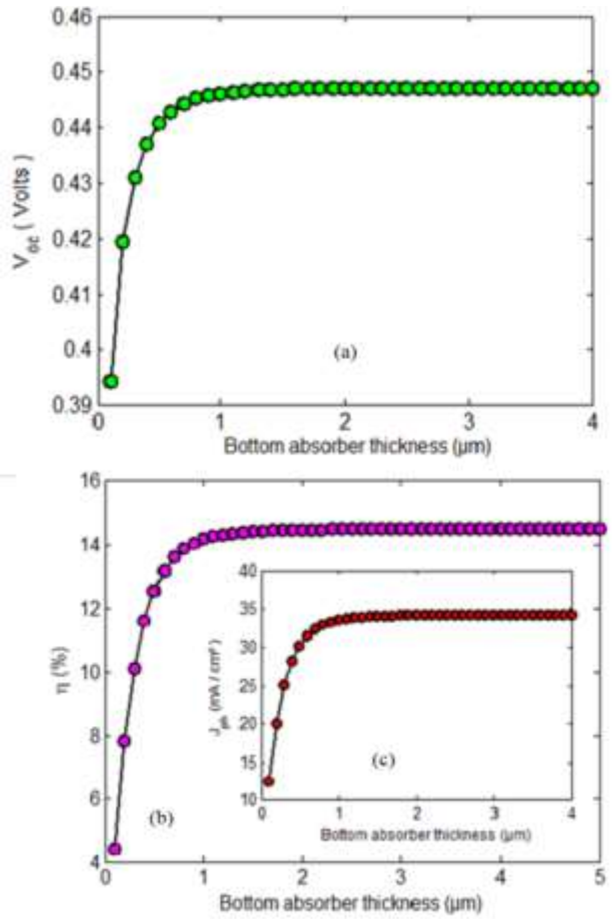

Figure 2. *V_{oc}, J_{ph} and η of Single-CZTSe solar cell as function of CZTSe thickness.*

examined as function of the absorber thickness augmentation. Figure.2 shows the obtained results. An optimal thickness of 2 µm was considered for where a maximum efficiency of 14.46 % was reached with J_{ph} = 34.18 mA/cm² and V_{oc}= 0.4472V. The matched photocurrent density condition should be achieved in a tandem cell in order to avoid unnecessary losses. The current matching analysis represented on figure.3 shows that both cells match with a value of J_{ph} = 16.54 mA /cm² for a top cell absorber thickness of about 414 nm.

The results of this study regarding the optimised absorber thickness determined above show an achieved efficiency of 24.68%, with an open circuit voltage of 1.33 V, a short circuit current density of 16.56 mA/cm² and a fill factor of 78.2% .

The resulted current density-voltage characteristics of top, bottom and of the whole tandem cells are shown in figure.4.

Light trapping techniques are generally used in order to improve the performance of the cells. In this section, we have replaced the previous CZTS absorber by a randomly textured surface of the same material, for trapping more light and increase absorption.

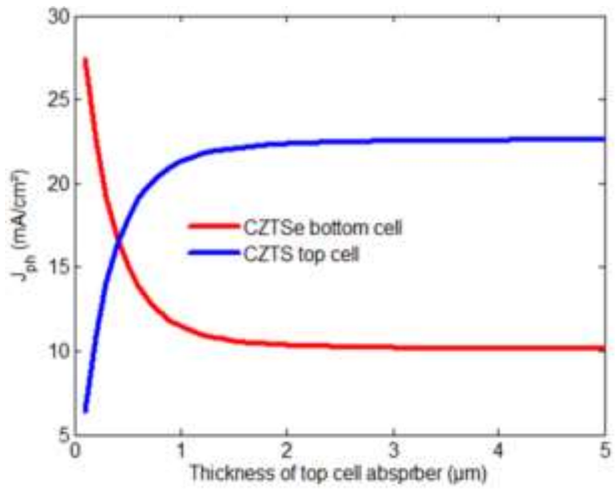

Figure 3. *Photocurrent Density as Function of Top Cell Absorber thickness.*

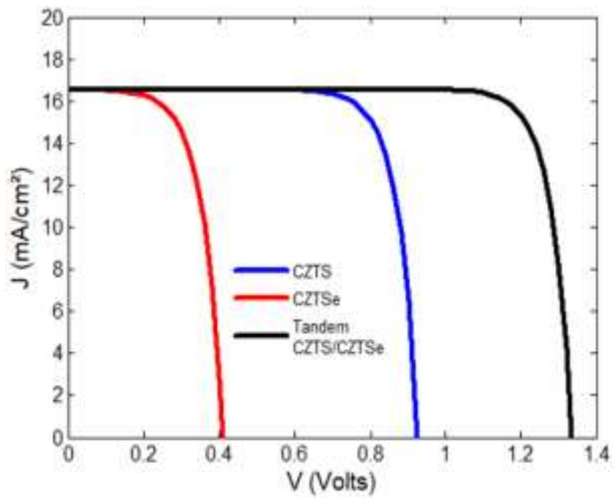

Figure 4. *J(V) Characteristics of CZTSe,CZTS and CZTS/CZTSe Tandem cells.*

The absorptivities of top and bottom cells were calculated according to equation 5. and equation 6.

In this part of the study,the thickness was also determined according to the current match condition. The results showed that current densities of top and bottom cells share the same value at a thickness of 269.8 nm, which is thinner than the flat surface absorber studied above. An efficiency of 24.71 % was obtained with an open circuit voltage of 1.33 V, a fill factor of 78.2 % and a short current density of 16.56 mA/cm².

CdS deposited by chemical bath CBD [17,18] is the most used material as a buffer layer in CIGS and CZTS solar cells. However, this material contains cadmium which is highly toxic.To conclude, this study investigated the effect of replacing the CdS buffer material by ZnS in the tandem device.

The results showed that 1.5 µm was the optimal thickness of the CZTSe bottom absorber. The photocurrent density of top and bottom cells matches with 16.67 mA/cm² at a thickness of 410 nm of the CZTS absorber of the top cell. The current density-.

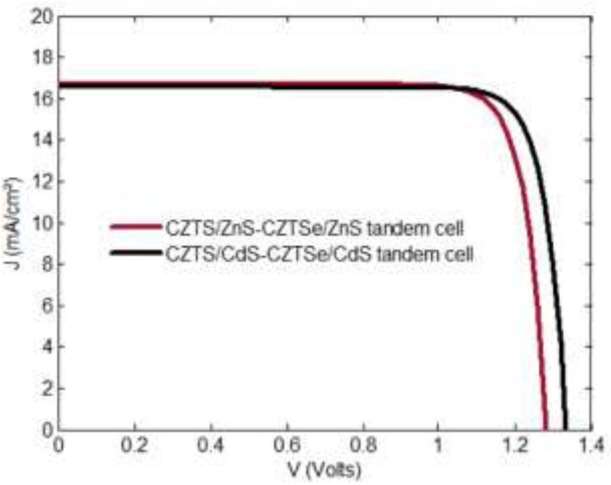

Figure 5. *J(V) Characteristic of ZnS Buffered CZTS/CZTSe Tadem Cell.*

voltage characteristics of the ZnS and CdS buffered tandem solar cells are represented in figure.5.

The results of the simulation showed that CZTS/CZTSe tandem solar cell based on ZnS buffer material reached a 23.83 % efficiency with 1.28 V open circuit voltage, 16.67 mA/cm² short circuit current density and 78% fill factor.

The numerical values of the photovoltaic parameters of the structures simulated in our work have been grouped in table 1.

Table 1. *Results of the Simulation.*

Structure	V_{oc} (V)	J_{sc}(mA/cm²)	FF (%)	η (%)
CZTSe Cell	0.4472	34.18	78.5	14.46
CZTS/CZTSe Tandem Cell	1.335	16.56	78.2	24.68
Textured-CZTS/CZTSe Tandem cell	1.336	16.56	78.2	24.71
CZTS/CZTSe Tandem cell, ZnS buffer	1.28	16.67	78.0	23.83

The results indicate the superiority of the tandem device based on kestrite absorbers to achieve high efficiencies compared to single-junction kestrite cells.

5. Conclusions

In this study, a tandem solar cell based on kestrite CZTS and CZTSe absorbers, was investigated. The simulation results showed that both top and bottom cells matche with a photocurrent density value of 16.54 mA / cm² when top cell CZTS absorber thickness is 414 nm. An efficiency of 24.68 % was achieved with an open circuit voltage of 1.33 V and a fill factor of 78.2%. The use of randomly textured CZTS top cell absorber surface allowed the reduction of its thickness to 270 nm. An efficiency of 24.7% was reached with V_{oc} = 1.33 V and J_{ph} = 16, 56 mA / cm². Finally, the use of ZnS buffer as an alternative material to toxic CdS in the tandem structure was investigated. The results showed that for a thickness of 1.5 µm of CZTSe and a thickness of 410 nm of CZTS, an efficiency of 23.83% is obtained with Voc = 1.28 V , Jph = 16, 67 mA / cm², and FF = 78%.

This work has demonstrated the ability of the tandem structure device based on kestrite materials absorber material not only to achieve efficiencies close to 25% but also to improve the open circuit voltage value.

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- **Ethical approval:** The conducted research is not related to either human or animal use.
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Research Article

Evaluation of Ergonomic Conditions using Fuzzy Logic in a Metal Processing Plant

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Abstract:

Ergonomic conditions of workplace settings is important for the performance of companies. Especially in the manufacturing industry, the employees are required to have convenient workplace conditions. If this is not the case, it is most likely to have a decrease in work efficiency, increase in workload, and negative impacts on employee health. In this study, we evaluate two ergonomic conditions, illumination and noise level, in different departments of a metal processing plant, to find the initial department to work on the improvement of ergonomic conditions. The evaluation of ergonomic conditions is done through a fuzzification process. The quantitative measurement results of illumination and noise level are fuzzified by Mamdani method. The fuzzified measurement values are scored with respect to specified interval lengths. As a result of this scoring process, ergonomically the worst conditioned department is found to start the improvement process.

1. Introduction

Uncertainty is a common phenomenon almost in all fields of our lives and precise information is not available where uncertainty exists. The uncertainty and the lack of information result in subjective evaluations when we make decisions. Therefore we need an effective method to aid us in decision making and evaluation processes under uncertainty. At this point, using the fuzzy logic approach is a highly effective method for solving problems. An important difference of fuzzy logic from other logic systems is the use of linguistic variables.
Many terms that we use randomly in everyday life are often not clear and may refer to a concept, purpose or a system. In 1965, Lotfi A. Zadeh [1] developed a way of expressing this fuzziness. In his study, Zadeh put forward the fuzzy set theory of events with uncertain boundaries. With this development, the examination of systems containing uncertainty has gained a new dimension. In short, fuzzy logic can be called a grading system. There is no probability of uncertainty, there are uncertainties related to human intuition. Fuzzy logic can be used to improve system performance, simplify the implementation of the process, and reduce cost. It does not require much manpower. There is also a general definition known as approximate reasoning. However, the most commonly used expression of fuzzy logic [2] is as follows:
"In fuzzy logic, values 1 and 0 are considered as bounds, not absolute values, and intermediate values are also used. In other words, assets can belong to more than one cluster, not a single cluster. For example, a fuzzy controlled washing machine can choose the most effective laundry and water usage program based on the type, quantity, and soiling of the laundry. Face recognition systems can also be given as examples."
The word ergonomics is derived from the Greek words ergon (work) and nomos (law). In many

countries, the term 'human factors' is also used instead of ergonomics. Ergonomics can be expressed as the design of tools, technical systems, and works in a way to increase human health, safety, comfort, and performance. The official definition of ergonomics, approved by the International Association of Ergonomics (IEA), is as follows:
“Ergonomics (or human factors) is a scientific discipline, a field of pursuit that tries to understand the interaction between other elements of a system and people, and that applies theory, principles, knowledge, and methods that will optimize the overall system performance and human comfort. Ergonomics is the focus of the design of situations in business and daily life [3].”
Ergonomics is a science that ensures the adaptation of workers to today's aggravating and fast-paced working order by considering health factors. The first aim of ergonomics is to increase the efficiency of worker-machine combination and worker health. Since lifting, holding, and carrying activities can tire a person very quickly and cause serious health problems, a lot of research has been done on this subject and it is still going on [4]. Ergonomic conditions are important for increased work efficiency and for employees to work safely and healthily. For this reason, ergonomic risk analysis of defined work activities should be done, the factors that cause physical strain on the human should be determined, and necessary corrective measures should be defined to eliminate these factors [5]. In a competitive environment, businesses must effectively manage and direct production inputs such as raw materials, energy, labor, and the capital. It is clear that among these inputs, the workforce (employees) has an important place. Besides, work arrangements of employees directly affect production efficiency [6].
The main purpose in the ergonomic study of work environments is not only to ensure the health and safety of employees, but also to establish a working environment where employees can put their physical and psychological abilities in the most effective way. By this way, it is possible to increase the efficiency of the employees and the quality of the work done [7].
In this study, investigations are made in a metal factory regarding lighting and noise conditions. Measurements of these two variables are made for each department. Then measurements are expressed and fuzzified with linguistic data. According to the results of the evaluation, we determine the department for which the ergonomic improvement studies should start.

2. Methodology

This study is done for a plant located in Ankara Ostim Industry Area. The plant has three workshops and production areas. It provides sheet cutting service in its workshops and provides project design, sheet cutting, bending, welding, painting, and assembly services as a whole. The measurement was carried out at three different departments of the plant: laser-1, welding-1 and welding-3.

2.1 Measurement of Physical Conditions

For two different criteria, illumination and noise levels, the measurements are taken for the three departments in the plant. The devices used for the measurement processes and the factors taken into consideration are explained below:
Extech SDL400 light meter / data logger device is used during the illumination level measurements (Figure 1) It is capable of measuring up to 10,000Fc or 100kLux. Illumination level measurements are taken by keeping the device sensor parallel to the working floor through the field of vision. During the noise level measurements, the device receiver is placed close to the ear of the employee and the employee is requested to have his daily working tempo, not to turn off the lapel microphone, Measurements are made with SL355: Personal Noise Dosimeter / Datalogger device (Figure 2). The device is verified both before and after measurements with the TES 1356 Sound calibrator (Figure 3). The exposure is calculated by taking three measurements for each task.

2.2 Data

As mentioned in the previous section, measurements are taken for two different

Figure 1. *Light meter*

Figure 2. *SL355: Personal Noise Dosimeter/Datalogger*

Figure 3. *TES 1356 Sound Calibrator*

ergonomic variables (noise and illumination levels) from three different departments in the plant. The average values of the measurements for each department are given in table 1. In order to evaluate the measurement values with fuzzy logic, three linguistic variables, "bad", "average" and "good" are determined for each ergonomic factor.

Table 1. *Average values of the measurements*

	Laser 1	**Welding 1**	**Welding 2**
Noise	91,1 dB(A)	94,3 dB(A)	88,4 dB(A)
Illumination	857	712	575

The evaluations regarding noise are made in accordance with the Regulation No. 28721 on the Protection of Employees from Risks Related to Noise, which is published in the Official Gazette on 28/07/2013. For evaluating the measurement results of the plant, 8 hours/day work time is taken as the basis of the noise exposure in accordance with the physical conditions of the plant from the values of Noise Control Regulation in table 2.

Table 2. *Noise level control regulation [8]*

Lowest exposure action value	(LEX, 8hours) = 80 dB(A)
Highest exposure action value	(LEX, 8hours) = 85 dB(A)
Exposure limit value	(LEX, 8hours) = 87 dB(A)

Illumination measurements are taken during the day. Recommended illumination levels are given in table 3. Minimum illumination level is based on 700 lux.

Table 3. *Lower values of the recommended intensity of illumination (Taken from [9])*

Vision Type	**Least Light Intensity at the Location (LUX)***	**Typical Examples**
General	20-100 Lux	Boiler room (Coal and ash removal tasks), coarse material warehouses, storage, dressing places.
Rough	150 Lux	Rough tasks and sorting tasks on work desks and benches, general examination and counting of stored materials, assembly of heavy machinery.
Pretty critical	300 Lux	Moderately hard tasks at work desks and benches, as well as assembly and control jobs, general office work, literacy and recording jobs.
Critical	700 Lux	Sensitive tasks on work desks and benches, assembly and control tasks, very delicate dyeing tasks, sewing of dark fabrics.
Very critical	1500 Lux	Assembly and control of sensitive parts, tool and gauge production, their control, sensitive grinding work.
Very difficult or important	3000 Lux	Watch making and repair work or similar sensitive tasks.

2.3 Application of Fuzzy Logic

Membership functions and fuzzy ranges of the linguistic assessment, which we named as "bad", "average", and "good" for two different physical conditions are determined according to the given limit values in tables 2 and 3. This process is done separately for each department depending on the requirements of the departmental tasks. Triangle and trapezoid membership functions are used in definitions of membership functions, as is frequently used in the literature. Examples for the triangular and trapezoidal membership function are shown in figures 4 and 5, respectively [10].

$$\mu\left(\frac{x}{\widetilde{M}}\right)\begin{cases} 0, & x < a_1, \\ \frac{x-a_1}{a_2-a_1}, & a_1 \le x \le a_2, \\ \frac{a_3-x}{a_3-a_2}, & a_2 \le x \le a_3, \\ 0, & x > a_3, \end{cases}$$

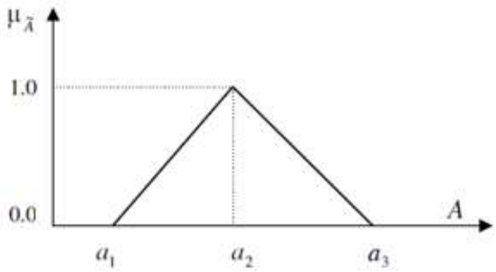

Figure 4. *Triangular membership function*

$$\mu_{\tilde{A}}(\mathrm{x}) = \begin{cases} 0, & x < a_1 \\ \frac{x-a_1}{a_2-a_1}, & a_1 \le x \le a_2 \\ 1, & a_2 \le x \le a_3 \\ \frac{x-a_4}{a_3-a_4}, & a_3 \le x \le a_4 \\ 0, & x > a_4 \end{cases}$$

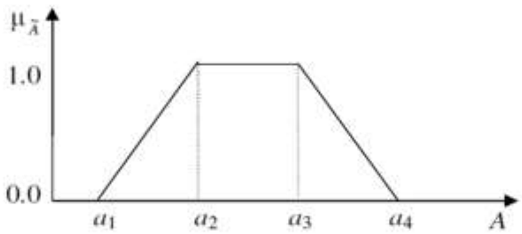

Figure 5. *Trapezoidal membership function*

In figure 4, for the triangular membership function $\mu_{\tilde{A}}(x)$, a_1 and a_3 show the base of the triangle, and a_2 show the peak value. In figure 5, for the trapezoidal membership function $\mu_{\tilde{A}}(x)$, a_1, a_2, a_3, and a_4 correspond to lower limit, lower support limit, upper support limit, and upper limit, respectively.

Use of fuzzy logic for ergonomics is a common method in the literature. (Ex. [11], [12]). In this study, for the fuzzy logic evaluation, “Mamdani Method” which is the most applied fuzzy inference method was used. This method was developed by Ebrahim Mamdani in 1974 [13]. This novel notion provides a fuzzy control that is “model free” and it does not require a system's mathematical model to be available. The model is not needed partially because the system's behavior is, to a large extent, captured and represented in a vague fashion in the forms of fuzzy sets and fuzzy control rules provided by the human control expert. In other words, the model information was integrated into the fuzzy controller [14]. The Mamdani's method has a simple structure of min-max operations and is, therefore, very commonly used in applications.

The fuzzy inference process comprises four subsequent steps: evaluating the antecedent for each rule, obtaining a conclusion for each rule, aggregating all conclusions, and finally defuzzifying [15].

All the operations related to fuzzy logic application have been carried out in MATLAB software. Considering the standard values for the physical conditions given above, individual membership functions are defined for each ergonomic variable. The membership function plots for illumination and noise level variables are given in figures 6 and 7, respectively. As seen in these plots, illumination levels above 700 Lux and noise levels below 80 db(A) can be in good category.

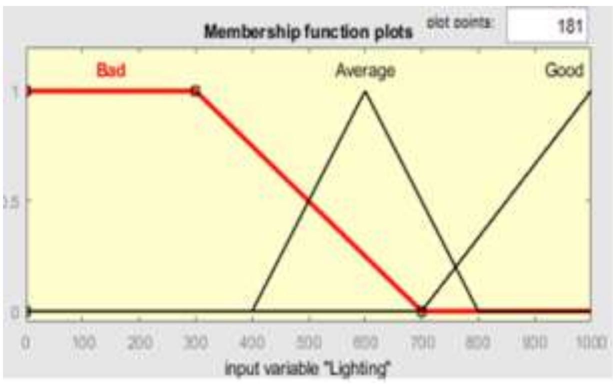

Figure 6. *Illumination level membership function*

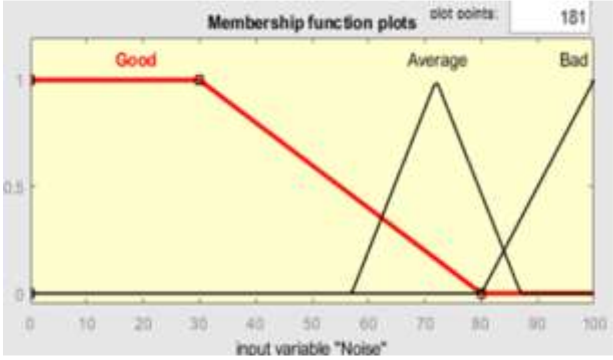

Figure 7. *Noise level membership function*

After determining the membership function types and definitions to be used in the calculations, the types and definitions of the output functions for the departments to be evaluated are determined (Figure 8). The output function is formed with trapezoidal membership functions with an evaluation range of 0-100. The linguistic expressions for evaluation were created in 5 different classifications: "very bad", "bad", "average", "good" and "very good".

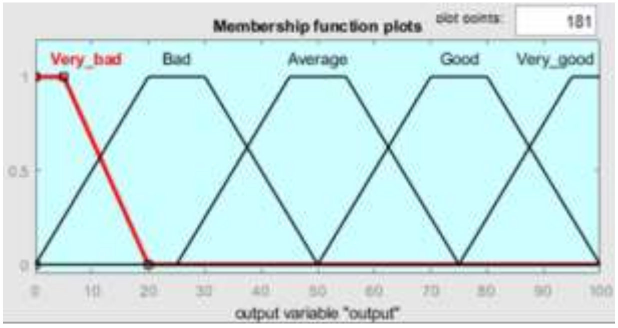

Figure 8. *Output functions*

Fuzzy rules are determined to provide all the conditions that may occur after all the input and output functions are created. These rules are again expressed in terms of linguistic variables. As seen in table 4, three different linguistic evaluations for membership function, two different variables for physical conditions and 3^2 = 9 conditions were created. Centroid method is chosen for defuzzification in the study.

3. Results

For each department, the arithmetic mean values of ergonomic variables are entered in MATLAB Fuzzy Toolbox and the results are obtained (Figure 9). With the help of "Centroid" method, a net value in the range of 0-100 is obtained for each department. These values are given in table 5. By ordering these results from the lowest to the highest, we determine the order of departments to

Table 4. *Fuzzy conditions table (A=Average, V=Very, B=Bad, G=Good)*

		Noise Level		
		Bad	**Avg.**	**Good**
Illumination Level	Bad	V.B	B	A
	Avg.	B	A	G
	Good	A	G	V.G

start the improvement studies in physical conditions. As seen in table 5, Laser 1 department is in good condition with an evaluation score of 51.2 compared to the welding departments. Although both welding departments have close evaluation scores (23.6 and 26.9), since Welding 3 department has the lowest score, it is necessary to give the priority to Welding 3 department for improvement studies. Also considering that Welding 1 department has also a low evaluation score (26.9), the improvement studies for this department should not be delayed much, either.

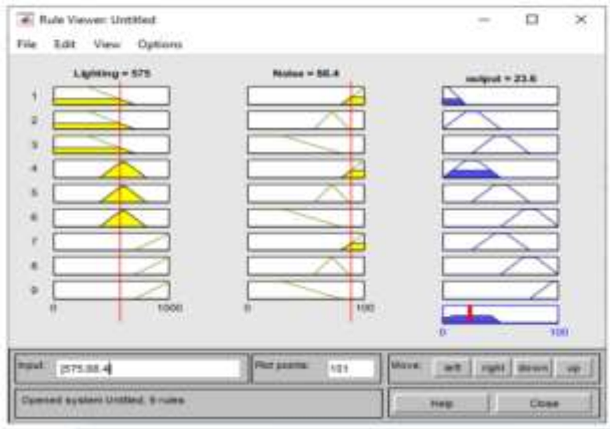

Figure 9. *MATLAB fuzzy toolbox image*

Table 5. *Priority decision table for improvements*

Departments	Evaluation Score	Priority
Laser 1	51.2	3
Welding 1	26.9	2
Welding 3	23.6	1

4. Conclusions

In this study, we evaluate the working conditions in three departments of a plant in terms of illumination and noise level ergonomic variables. Taking several measurements from these three departments, numerical measurement values are obtained. Then using Mamdani method and

MATLAB Fuzzy Toolbox, evaluation scores for each department is obtained. If a department gets a lower score, this shows that the department needs immediate attention for improvement. This study can be extended to by increasing the number of departments. Also other environmental variables like temperature, humidity, weather quality can be included in the analysis of working conditions.

Author Statements:

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