# Artikel 6_2

*by* Ariswan Ariswan

**Submission date:** 29-Apr-2019 09:17PM (UTC+0700)
**Submission ID:** 1121340505
**File name:** Artikel_6_2.pdf (839.07K)
**Word count:** 2845
**Character count:** 14406

IOP Conference Series: Materials Science and Engineering



# Crystal Structure, Optical, and Electrical Properties of SnSe and SnS Semiconductor Thin Films Prepared by Vacuum Evaporation Techniques for Solar Cell Applications

# Crystal Structure, Optical, and Electrical Properties of SnSe and SnS Semiconductor Thin Films Prepared by Vacuum Evaporation Techniques for Solar Cell Applications

**Ariswan[1], H Sutrisno[2] and R Prasetyawati[1]**

[1]Department of Physics Education, Faculty of Mathematics and Natural Sciences, Yogyakarta State University, Kampus Karangmalang, Jl. Colombo 1, Yogyakarta, 55281, Indonesia
[2]Department of Chemistry Education, Faculty of Mathematics and Natural Sciences, Yogyakarta State University, Kampus Karangmalang, Jl. Colombo 1, Yogyakarta, 55281, Indonesia

Email: ariswan@uny.ac.id

**Abstract.** Thin films of SnSe and SnS semiconductors had been prepared by vacuum evaporation techniques. All prepared samples were characterized on their structure, optical, and electrical properties in order to know their application in technology. The crystal structure of SnSe and SnS was determined by X-Ray Diffraction (XRD) instrument. The morphology and chemical composition were obtained by Scanning Electron Microscopy (SEM) coupled with Energy Dispersive of X-Ray Analysis (EDAX). The optical property such as band gap was determined by DR-UV-Vis (Diffuse Reflectance-Ultra Violet-Visible) spectroscopy, while the electrical properties were determined by measuring the conductivity by four probes method.The characterization results indicated that both SnSe and SnS thin films were polycrystalline. SnSe crystallized in an orthorhombic crystal system with the lattice parameters of $a$ = 11.47 Å, $b$ = 4.152 Å and $c$ = 4.439 Å, while SnS had an orthorhombic crystal system with lattice parameters of $a$ = 4.317 Å, $b$ = 11.647 Å and $c$ = 3.981 Å. Band gaps ($Eg$) of SnSe and SnS were 1.63 eV and 1.35 eV, respectively. Chemical compositions of both thin films were non-stoichiometric. Molar ratio of Sn : S was close to ideal which was 1 : 0.96, while molar ratio of Sn : S was 1 : 0.84. The surface morphology described the arrangement of the grains on the surface of the thin film with sizes ranging from 0.2 to 0.5 microns. Color similarity on the surface of the SEM images proved a homogenous thin layer.

**Keywords:** Vacuum evaporation, solar cell, SnSe semiconductor, SnS semiconductor.

## 1. Introduction

The studies of semiconductor materials, i.e. tin monoselenide or monosulfide are mostly done by researchers because the materials are semiconductor materials that can be applied in several areas of technology. One of their applications is in solar cell technology, due to the band gap of both materials that falls in the photon energy range of the spectrum of solar cells [1]. The study of SnSe has been widely conducted by several researchers, for example, research related to the structure and optical properties of SnSe thin film obtained by Chemical Bath Dedosition (CBD) [2]. Other researchers

obtained SnSe using Aqueous Solution Method [3], and had also been reported that SnSe thin film were prepared by photoelectrochemical techniques deposition [4]. Research on SnS thin film had also been successfully produced by spray pyrolysis method [5], electrodeposition technique [6] and of course with other techniques.

## 2. Experimental Procedure

### *2.1 Preparation of SnSe and SnS Semiconductors*

At first, the vacuum system equipment consisting of a primary pump in the form of rotary van pump capable of suppressing the pressure up to $10^{-3}$ Torr was prepared. The primary pump was connected to the secondary pump in the form of diffusion pumps which were capable of decreasing the pressure of evaporator chamber at $10^{-6}$ Torr. Evaporator was equipped with boat-shaped crucible made of molybdenum (Mo) and connected to a power supply system that can generate electrical currents of up to 300 A. Crucible was mounted above the support where the substrates can be put and equipped with electrodes that can be connected to a power supply to set the substrate temperature.

SnSe powder was placed on the crucible, and then heated by slowly flowing current to crucible until the temperature reached above 1000 °C. The powder reached the point of vapor and deposited on the substrate at a temperature of 500 °C. After the deposition,the thin layers were left for 12 hours and then the evaporator was opened and a number of thin films were obtained. An equal treatment was done for the SnS powder.

### *2.2 Characterization*

To determine the structures and parameters of the crystal lattice, the SnSe and SNs thin film were characterized by XRD. Both thin films were examined using powder X-ray diffraction (XRD). The XRD patterns were obtained on a Rigaku MiniFlex 600-Benchtop XRD instrument, operated in the Bragg configuration using Cu Kα radiation ($\lambda$ = 1.5406 Å). The XRD instrument ran at 40 kV and 15 mA. The intensities were determined in the 2θ interval ranging from 3° to 90°. The surface morphology and chemical composition of SnSe and SnS thin films were investigated by Scanning Electron Microscopy (SEM) coupled with Energy Dispersive Analysis of X-Ray (EDAX). To calculate the energy gap of the prepared samples, Diffuse Reflectance UV-Vis-UV 1700 Pharmaspec Spectroscopy at wavelengths ranged from 200 nm up to 900 nm was used. To specify the electrical properties such as conductivity and resistivity of the thin films, four-point probe technique was used.

## 3. Results and Discussion

SnSe and SnS thin films have been successfully obtained by vacuum evaporation techniques through the implementation of following variables variation. Variable control include vacuum pressure, the mass of material, and the temperature source (crucible) and the distance between the crucible and substrate, while the independent variables in this study were four variations of the temperature of the substrate, namely without heating, 250, 350, 500 and 550 °C [7]. In this article, only substrate temperature at 500 °C was reported to get the best values of the physical parameters after the characterization had been done. The characterization includes the structure and parameters of the crystal, the composition of the sample, optical properties and electrical properties of the thin film prepared using vacuum evaporation techniques.

### *3.1 XRD spectra of SnSe and SnS thin films*

XRD (X-Ray Diffraction) can be used to determine the crystal lattice parameters and the structure of thin films. The data obtained from XRD analysis were in the form of a graph of intensity ($I$) and the spectrum of diffraction angle ($2\theta$). Diffractogram displays spectral peaks that appeared in the samples. XRD analysis showed the distance among the crystal planes $hkl$ ($d_{hkl}$). Diffraction patterns obtained from the sample were then compared with the data of JCPDS (Join Committee on Powder of Diffraction Standards) so it can be determined the Miller index from the diffraction peaks was formed.

The calculation of parameters can also be done once the crystal structure was known. Figure 1 shows the diffractogram of SnSe and SnS samples. The lattice parameters of orthorhombic crystal system can be calculated using the following equation [8].

$$2d \sin\theta = n\lambda$$

where $d$ can be calculated by $\frac{1}{d^2} = \frac{h^2}{a^2} + \frac{k^2}{b^2} + \frac{l^2}{c^2}$, so the following relationship can be applied:

$$\sin^2\theta = \frac{\lambda^2}{4}\left(\frac{h^2}{a^2} + \frac{k^2}{b^2} + \frac{l^2}{c^2}\right)$$

where $d$ is the distance of crystal planes, $\theta$ is the diffraction angle, $\lambda$ is X-ray wavelengths, $h\ k\ l$ is Miller Index, and $a$, $b$, $c$ are the crystal lattice parameters. The calculation of each SnSe and SnS sample presented the crystal parameters of $a$= 11.47 Å, $b$= 4.152 Å and $c$ = 4.439 Å for SnSe, and $a$ = 4.317 Å, $b$ = 11.647 Å and $c$ = 3.981 Å for SnS. These results were consistent with other researchers' research findings [9,10].

*3.2 SEM and EDAX*

Scanning Electron Microscopy (SEM) is an instrument used to determine the morphology of the surface of a material. The morphology of the surface of SnSe and SnS thin films were obtained through capturing and processing the secondary electrons emitted by a thin film when subjected to electron beams. The results of SEM characterization were images that depicted the surface of a crystal. The surface morphology characterization of SnSe and SnS samples with 40,000 times magnification is shown in Figure 2.

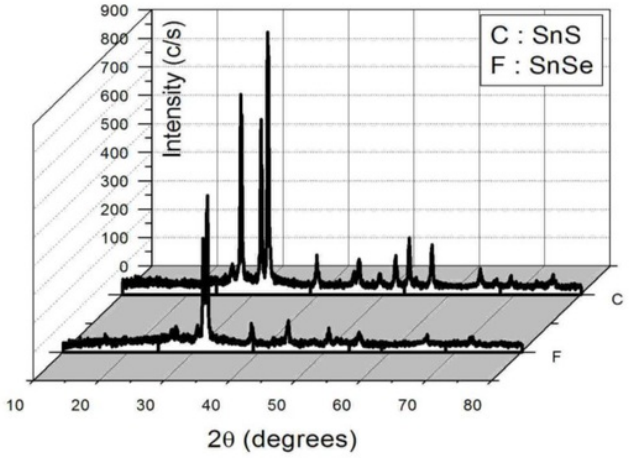



**Figure 1.** Diffraction patterns of SnSe and SnS thin films

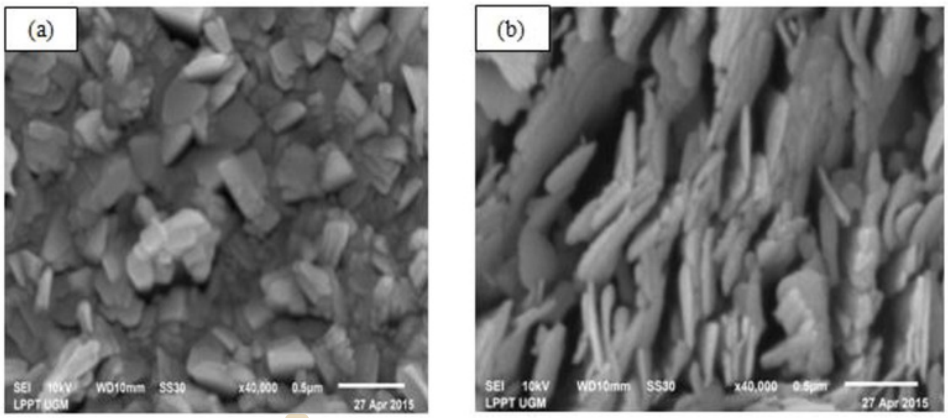
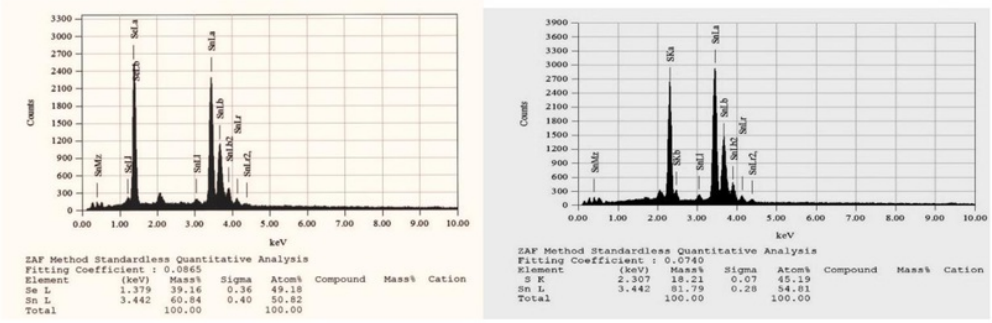



**Figure 2.** SEM images of (a) SnSe and (b) SnS thin films




(a) (b)

**Figure 3.** EDAX on chemical compositions of (a) SnSe and (b) SnS samples

Based on the morphological images resulted from the characterization by SEM as in Figure 2, it appears that there is homogeneity of Se and S crystals in the thin film. The SEM images showed that the structures of the sample are in bead and angled beam shapes and scattered on a regular basis. The granular form according to orthorhombic crystal structure which has an axis perpendicular to each other and had one parameter longer compared with the two other lattice parameters. The chemical composition of the thin films analyzed by EDAX can be seen in Figure 3.

EDAX is integrated with SEM and it cannot work without SEM. Therefore, the EDAX was integrated with SEM device. The results of EDAX are in the form of aspectrum describing the relationship among the energy intensities resulting from firing electron beam on the sample. EDAX testing would produce two forms of analysis: qualitative and quantitative analyses. Qualitative analysis was used to calculate the type of element that was present in the sample where energy peaks appear on the curve being analyzed, whereas quantitative analysis was used to determine the composition of the constituent elements of the material being analyzed. From this quantitative analysis, the identification of elements completed with mass and atomic percentages are shown. The expected value of molar ratio of Sn and Se, also of Sn and S is 1: 1. Based on EDAX characterization results, the SnSe and SnS thin films contained Tin (Sn), Selenium (Se) and sulfur (S). But the result was slightly deviate from expectations. The molar ratio of Sn and Se in SnSewas51.03% : 48.97% or 1 : 0.96, and of Sn andS in SnS was 54.47% : 45.53% or 1:0.84.

*3.3 Optical and electrical properties*

The sample characterization for optical properties was carried out by UV-VIS spectroscopy with a wavelength ranged from 200 nm up to 900 nm. This equipment was not perfect because it could not reach up to the NIR with a wavelength of about 4000 nm. However, specifically for SnSe and SnS materials, it can be used to show the band gap width of both materials in the wavelength range of the spectrum. The absorption of wavelength can occur when radiation passes through the band gap of the material.

The phenomenon arose when inside the energy is passed so that the absorbance is very smalla band gap. When a photon of energy was equal to or greater than the band gap, the absorption will occur so that the absorbance ($A$) would go up significantly. The absorbance spectrum as a function of photon energy can be shown in Figure 4.

The calculation of the band gap of materials can be done using the formulation as follows. Absorption coefficient $\alpha$ is proportional to the absorbance $A$, so it can be stated that $\alpha = 2.303A/d$, where $d$ is the thickness of the thin films. Then the relationship between $\alpha$ and the photon energy $h\nu$ for direct band gap semiconductor material was given by the equation of $(\alpha, h\nu)^2 = B^2(h\nu - Eg)$, where $B$ is a constant between $10^5$ and $10^6$ $cm^{-1}eV^{-1}$ [11]. The result of this calculation produced the width of SnSe and SnS band gaps of 1.63 eV and 1.35 eV respectively. The results are consistent with the results obtained by other researchers [12,13].

The data, such as shown in Figure 4, can be processed to produce $(\alpha, h\nu)^2$ as a function of photon energy $h\nu$ as shown in Figure 5. Based on the measurement of electrical properties, it can be seen that all SnSe and SnS samples hadthe same conductivity type,which is p-type, with average specific resistivity of 4.6 $10^{-2}$ ohm-cm and 4.4 x $10^{-2}$ ohm-cm, respectively. Both samples were prepared atthe same substrate temperature which was 500 °C. This result was in accordance with the range of resistance values of semiconductor materials.

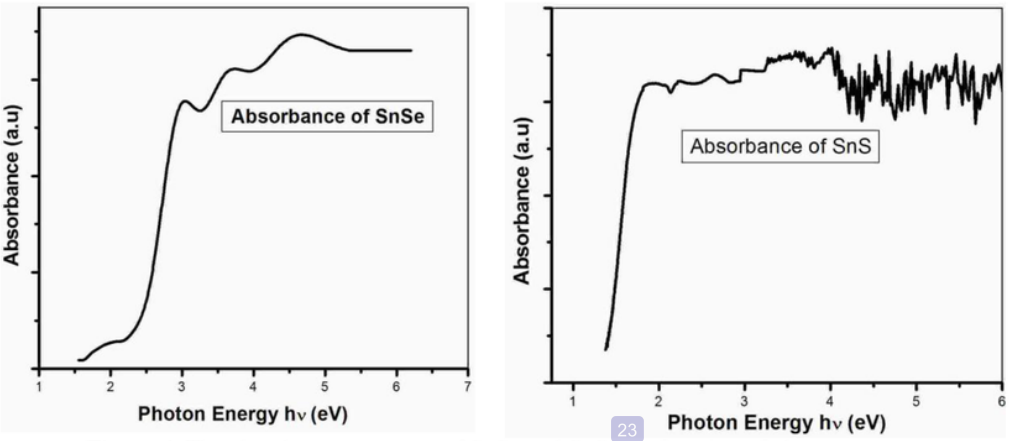



**Figure 4.** The absorbance spectrum of SnSe and SnS as a function of photon energy

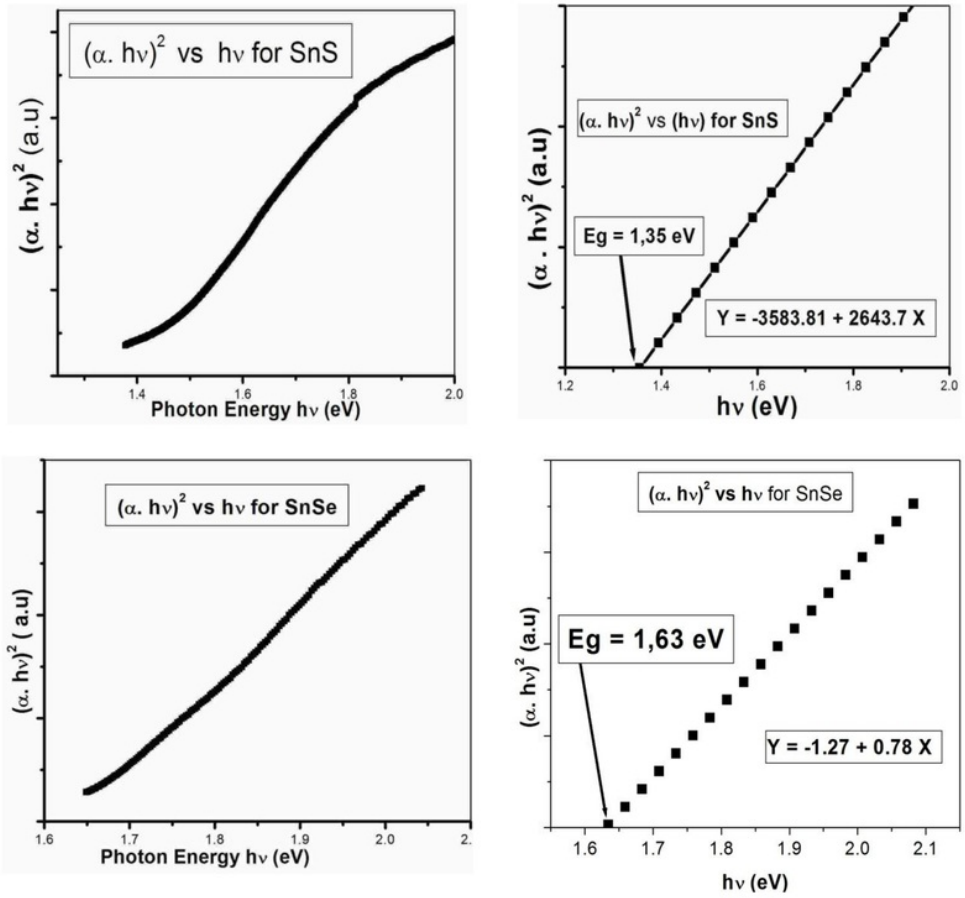



**Figure 5.** $(\alpha.h\nu)^2$ as a function of photon energy hν of SnS and SnSe thin layers

## 4. Conclusion

SnSe and SnS semiconductor thin films had been successfully prepared by vacuum evaporation techniques. The thin films were composed of atoms in orthorhombic crystal structure with the lattice parameters of $a$ = 11.47 Å; $b$= 4.152 Å and $c$ = 4.439 Å for SnSe, and $a$= 4.317 Å, $b$ = 11.647 Å and $c$ = 3.981 Å for SnS. The observations from EDAX indicated that SnSe and SnS samples were both non-stoichiometric with molar ratio of Sn:Se = 1:0.96 and Sn:S = 1:0.84. Electrical and optical properties of SnSe and SnS indicated that both materials have p-type conductivity with an average of resistivity of 4.6 $10^{-2}$ ohm-cm and 4.4 × $10^{-2}$ohm-cmand with band gaps of ($Eg$) of 1.63 eV and 1.35 eV, respectively.

## 5. References

[1] Kumar N, Sharma V, Parihar U, Sachdewa R, Padha N and Panchal C J 2011 *J. of Nano Electron. Physics* **3** 117-126
[2] Okereke N A and Ekpunobi A J 2010 *Journal of Chalcogenide Letters* **7**(9) 531
[3] Solanki G K, Gosai N N and Patel K D 2015 *Research Journal of Chemical Sciences* **5**(3) 1-5

[4] Sunyoung H A M, Choi S, Chae Y, Lee W J, Paeng K J, Kim W G and Bull N M 2010 *Korean Chem Soc* **31**(11) 3043-3046
[5] Helal M O A and Boshta 2012 *Journal of American science* **8**(8) 61-63
[6] Maripan R, Ragavendar M and Ponnuswamy V 2011 *Optica Applicata* **XLI**(4) 989-997
[7] Zouaoui A, Lachab M, Hidalgo M L, Chaffa A, Llinares C and Kesri N 1999 *Thin Solid Films* **339** 10
[8] Suryanarayana C and Norton M G 1998 *X- Ray Diffraction A Practical Approach* Plenum Press- New York and London
[9] Salgado E B, Nair M T S and Nair P K 2014 *ECS Journal of Solid State Science and Technology* **3**(8) 169- 175
[10] Yanuar, Guastavino F and Llinares C 2001 *Jurnal of Materials Sciences*
[11] Sakata H and Ogawa H 2000 *Solar Energy Materials and Solar Cells* **63** 25
[12] Kumar N, Parihar U, Kumar R, Patel K J, Panchal C J, Padha N 2012 *American Journal of Materials Science* **2**(1) 41-45
[13] Ogah O E, Zoppi G, Forbes I, Milles R W 200 *Properties of Thin Films of Tin Sulphide Produced Using The Thermal Evaporation Method* 23rd European Photovoltac Solar Energy Conference

**Acknowledgments**
Researchers would like to thank to Yogyakarta State University (UNY) that has funded this research. Also, thanks to the technical expert of Chemistry Department's Laboratory, Gadjah Mada University, for the measurement of X- Ray Diffraction and thin films' optical properties.

# Artikel 6_2

ORIGINALITY REPORT

| 26% | 19% | 23% | 15% |
|---|---|---|---|
| SIMILARITY INDEX | INTERNET SOURCES | PUBLICATIONS | STUDENT PAPERS |

PRIMARY SOURCES

| | | |
|---|---|---|
| 1 | china.iopscience.iop.org<br>Internet Source | 7% |
| 2 | Submitted to Politeknik Negeri Bandung<br>Student Paper | 6% |
| 3 | repository.ubaya.ac.id<br>Internet Source | 2% |
| 4 | Submitted to School of Business and Management ITB<br>Student Paper | 1% |
| 5 | www.scribd.com<br>Internet Source | 1% |
| 6 | Koteeswara Reddy, N., M. Devika, and E. S. R. Gopal. "Review on Tin (II) Sulfide (SnS) Material: Synthesis, Properties, and Applications", Critical Reviews in Solid State and Material Sciences, 2015.<br>Publication | 1% |
| 7 | www.iiste.org<br>Internet Source | 1% |

| | | |
|---|---|---|
| 8 | mdpi.com<br>Internet Source | 1% |
| 9 | Submitted to Universitas Negeri Surabaya The State University of Surabaya<br>Student Paper | 1% |
| 10 | Submitted to Universitas Diponegoro<br>Student Paper | 1% |
| 11 | Srinivasan, Nagendra B., Tobias B. Thiede, Teresa de los Arcos, Detlef Rogalla, Hans-Werner Becker, Anjana Devi, and Roland A. Fischer. "MOCVD of tungsten nitride thin films: Comparison of precursor performance and film characteristics : MOCVD of tungsten nitride thin films", physica status solidi (a), 2013.<br>Publication | 1% |
| 12 | Carmel B. Breslin, Amy L. Rudd. "Activation of pure Al in an indium-containing electrolyte — an electrochemical noise and impedance study", Corrosion Science, 2000<br>Publication | 1% |
| 13 | Submitted to Universitas Islam Indonesia<br>Student Paper | 1% |
| 14 | Cha Li-Mei, Zhang Peng-Xiang, H.-U. Habermeier. "Preparation and properties of bilayer manganite films", Physica B: Condensed Matter, 2003 | <1% |

Publication

| | | |
|---|---|---|
| 15 | Submitted to Higher Education Commission Pakistan<br>Student Paper | <1% |
| 16 | Jorge Sergio Narro-Rios, Dalia Martinez-Escobar, Aaron Sanchez-Juarez. "Tin Selenide Thin Films Deposited by Ultrasonic Spray Pyrolysis for Photovoltaic Applications", 2018 15th International Conference on Electrical Engineering, Computing Science and Automatic Control (CCE), 2018<br>Publication | <1% |
| 17 | Robert W. Miles, Ogah E. Ogah, Guillaume Zoppi, Ian Forbes. "Thermally evaporated thin films of SnS for application in solar cell devices", Thin Solid Films, 2009<br>Publication | <1% |
| 18 | archive.org<br>Internet Source | <1% |
| 19 | E Y Muslih, K H Kim. " Preparation of Zinc Oxide (ZnO) Thin Film as Transparent Conductive Oxide (TCO) from Zinc Complex Compound on Thin Film Solar Cells: A Study of O Effect on Annealing Process ", IOP Conference Series: Materials Science and Engineering, 2017<br>Publication | <1% |

| | | |
|---|---|---|
| 20 | f.library.uny.ac.id<br>Internet Source | <1% |
| 21 | Sara Majid, Khuram Shahzad Ahmad. "Optical and morphological properties of environmentally benign Cu-Tin sulphide thin films grown by physical vapor deposition technique", Materials Research Express, 2018<br>Publication | <1% |
| 22 | C. Guillén. "Characteristics of SnSe and SnSe2 thin films grown onto polycrystalline SnO2-coated glass substrates", physica status solidi (a), 03/2011<br>Publication | <1% |
| 23 | Ebrahim Hasani, Monir Kamalian, Maryam Gholizadeh Arashti, Lida Babazadeh Habashi. "Effect of Substrate Properties on Nanostructure and Optical Properties of CdTe Thin Films", Journal of Electronic Materials, 2019<br>Publication | <1% |

| | | | |
|---|---|---|---|
| Exclude quotes | On | Exclude matches | < 2 words |
| Exclude bibliography | On | | |

# Artikel 6_2

GRADEMARK REPORT

FINAL GRADE

/100

GENERAL COMMENTS

**Instructor**

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8