ISSN 2347 - 3983
Volume 8. No. 7, July 2020
International Journal of Emerging Trends in Engineering Research
Available Online at http://www.warse.org/IJETER/static/pdf/file/ijeter87872020.pdf
https://doi.org/10.30534/ijeter/2020/87872020

The Effect of Monocrystalline and Polycrystalline Material Structure on Solar Cell Performance

Fitria Hidayanti
Engineering Physics Department, Universitas Nasional, Jakarta 12520 Indonesia
fitriahidayanti@gmail.com

ABSTRACT
Design of solar cell based on monocrystalline and polycrystalline are integrated with illumination to produce good solar cell performance in terms of conversion efficiency (η). The design is tailored to the climate and environmental conditions in Indonesia where the dry season is longer than the rainy season. After designing, data retrieval is done throughout the day when the sun shines with a variation of tilt angle that faces to the east (morning), facing upwards (daytime) and facing west (afternoon). It is intended for solar energy to be absorbed by the solar cells gaining maximum intensity. The solar energy is stored by solar cells to be converted into electrical energy. Conversion result of solar energy into electrical energy is stored by storage device in the form of battery. Electric energy conversion is used to turn on the lamp at night. The results showed monocrystalline-based solar cell efficiency of 9.22% and polycrystalline 7.94%. The monocrystalline-based solar cell performance ratio is 83% and polycrystalline-based solar cell performance ratio is 80%.

Key words: Solar Cell, Monocrystalline, Polycrystalline, Material Structure, Performance

1. INTRODUCTION

Electricity supply in remote areas in Indonesia is very lacking while student lighting needs to study at night is a very important necessity [1, 2]. Lack of electricity supply causes uncertainty for students in learning especially at night. This has an impact on the decline in learning interest in students. Nowadays, the conversion of energy to source electrical energy from various sources is a research concern [3–6].

To utilize solar energy, the device required is a solar cell. Solar cells based in monocrystalline and polycrystalline solar cells are good options for illumination as they have good solar cell efficiency. In the manufacture of solar cells previously has been generated the efficiency of the series of solar cells that are assembled in serial is (11.929 ± 0.480)% and for the solar cells assembled in parallel is (8.737 ± 0.026)%. Efficiency is a comparison of the power generated by solar cells with the power of light falling on the surface of solar cells. In previous research, solar panel data was obtained that resulted in optimum power when the radiation of the sun at 11 a.m. For battery gives optimum voltage also at 11 a.m. Solar panels receive solar radiation starting at 7 a.m.-5 p.m. and the illumination will be lit starting at 6 p.m. with a constant voltage of about 12.13 volts. Based on the results of the study, it is necessary to innovate again to analyze the influence of material structures in solar cell performance.

Electrical energy was very important for our life [7-10]. Nevertheless, the use of electricity in Indonesia is not evenly distributed, especially in remote and rural areas so that solar cell device such as monocrystalline [11, 12] and polycrystalline modules [13, 14] are needed to help the student to get lighting for study at night.

Solar panels are capable of generating electricity using photovoltaic effects, a phenomenon found in the early 19th century when semiconductor materials were gaining sunlight and generating an electric current. Two semiconductor layers combined to produce this photovoltaic effect. When exposed to sunlight, the coating of the material absorbs photons resulting in the excitation of electrons. This excitation causes the electrons to move from layer one to the other to produce an electric current. A semiconductor material widely used to construct solar cells is silicon, which is cut into thin layer wafers. Some of these silicone wafers are doping, resulting in an imbalance of electrons in a wafer. The wafer is then incorporated to produce solar cells [15, 16].

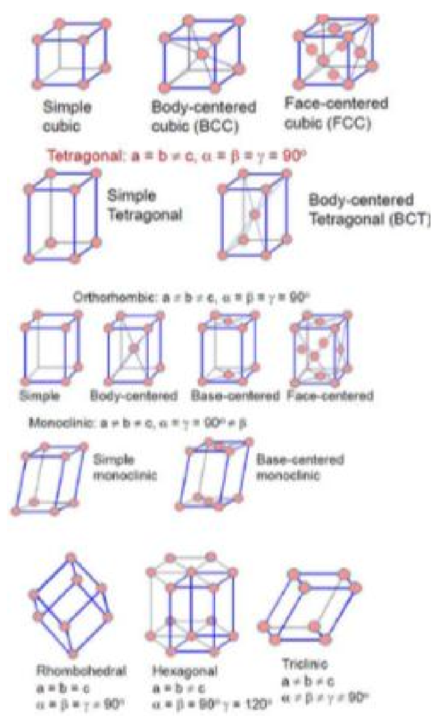


Figure 1: Seven Crystal System with Fourteen Bravais Lattices [17]

The distinctive arrangement of the atoms in the crystals is called crystal structure. The crystalline structure is constructed by a unit cell which is a specially arranged set of atoms, periodically repeated in three dimensions in a crystal lattice.

The crystal geometry in the three-dimensional space, which is characteristic of crystals has different patterns. A crystal consisting of millions of atoms can be expressed by the size, shape, and arrangement of repeated unit cells with repetition patterns characterized by a crystal. The lattice of fields and lattice of space, the crystal has 14 lattices and based on the comparison of crystal axes and one angle relationship with another angle. The crystals are grouped into 7 crystal systems, as can be seen in Figure 1.

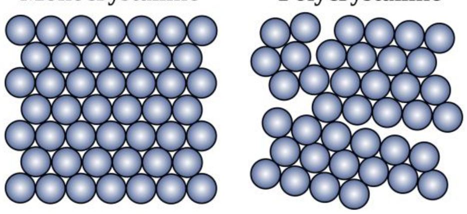


Figure 2: Crystal Structure of Monocrystalline and Polycrystalline [17]

The solar cells are polycrystalline and monocrystalline (Figure 2). Polycrystalline solar cells are made from many solar cells that are each of the silicon wafers while monocrystalline solar cells are made of many smaller solar cells, than one single silicon wafer. In the study of Jumrusprasert, P et al. [18], it is explained that monocrystalline and polycrystalline solar cells placed on fixed-panel rigs with a south-facing tilt angle of 30^0 provide 6.8% efficiency for monocrystalline and 5.7% for polycrystalline. This corresponds to the research of Zhou, J. C., et al. [19] where higher efficiency in monocrystalline silicon because of its nature has a very small defect density of less than $1{,}0x10^{11}$ cm^{-3}, small bulk barriers are 0.5 Ωm to 10 Ωm with a thickness of cells between 100-200 μm so that the absorption of solar energy will be higher.

The ideal crystal is the crystal that each atomic has a certain place of equilibrium on a regular lattice [20-22]. But in fact, in the crystal there is an atom that lies out of place, lost or misplaced by foreign atoms, the state is named imperfections of crystals or crystal defects. Even though we consider the crystals to be perfect and follow the rules, we cannot ignore the existing irregularities. In various situations, this irregularity is beneficial to the development of useful and desirable properties [17].

2. MATERIALS AND METHODS

This research was conducted gradually

a. Design of Monocrystalline and polycrystalline-based solar cell designs that will be integrated into illumination.
b. The performance of Monocrystalline-based solar cells and polycrystalline on illumination is done by:
- Measurement of solar panel voltage on time
- Measurement of solar panel current on time
- Solar panel power measurements on time
- Calculation of Fill Factor of solar panels on time
- Calculation of battery voltage on time
- Measurement of lamp voltage on time
- Measurement of lamp current on time
- Measurement of lamp power on time
- Measurement of time of lamp lights
- Measurement of solar panel efficiency on time
- Measuring solar radiation on time

The measurement was done in the slope angle variation of the solar panels that face east in the morning, facing south during the day and facing west in the afternoon, as stated in Figure 3.

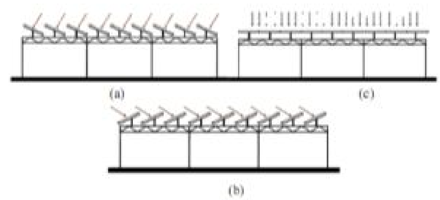


Figure 3: Solar Panel Orientation (a) solar panel orientation facing east (morning), (b) panel orientation directly (daytime) (c) panel orientation facing west (afternoon)

The design of solar cells in illumination is shown in Figure 4.

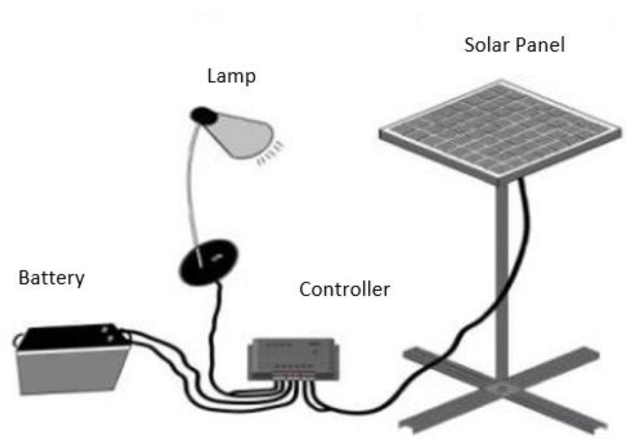


Figure 4: Scheme of Solar Panel integrated with Lamp

Some of the variables used in testing solar cells are utilized for illumination, i.e. current (I), voltage (V), lighting (lux meter), time of lamp flame and solar cell efficiency (%). Data retrieval is done throughout the day when the sun shines. It is intended to allow solar energy to be absorbed by the solar cells at maximum intensity. The solar energy is stored by solar cells to be then converted into electrical energy. Conversion result of solar energy into generating energy is stored by storage device in the form of rechargeable battery. Electric energy conversion is used to turn on the lights at night. The test results of the solar cells performed to compare the performance between polycrystalline and monocrystalline-based solar cells applied to the illumination.

3. RESULTS AND DISCUSSION

3.1 Testing of Solar Cell

Testing was conducted using two types of solar panels, monocrystalline and polycrystalline with a specification in Table 1. The position of the solar panel at 7 a.m.-10 a.m. is facing east, 11 a.m.-1 p.m.. is facing upwards, while 2 p.m.-7 p.m. is facing west.

Table 1: Specification of Solar Panel

Specification	Monocrystalline	Polycrystalline
Maximum Power (Pmax)	10 Wp	10 Wp
Open Circuit Voltage (Voc)	18.57 V	18.25 V
Short Circuit Current (Isc)	0.54 A	0.55 A
Max. Power Voltage (Vmp)	22.64 V	21.96 V
Max. Power Current (Imp)	0.58 A	0.59 A
Max. System Voltage	1000 VDC	1000 VDC
Normal Operating Cell Temp (NOCT)	47±2°C	47±2°C
Dimensions	250x370x18 mm	275x360x18 mm

Figure 5 shows solar radiation for the fourth day of data retrieval where the graph is obtained on average solar radiation for each day i.e. day 1 as 49.06 W/m^2, day 2 as 92.68 W/m^2, day 3 as 43.81 W/m^2, and day 4 as 49.24 W/m^2. With the average temperature of the solar panel day 1 as 30.2 ^{0}C, day 2 as 31.7 ^{0}C, day 3 as 30.8 ^{0}C and day 4 as 30.2 ^{0}C. It is seen that the increase of solar radiation is directly proportional to the increase in solar panel temperature (Figure 6).

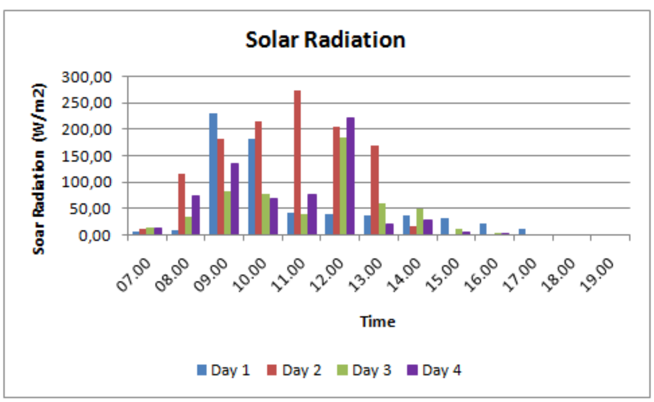


Figure 5: Effect of Solar Radiation on Time

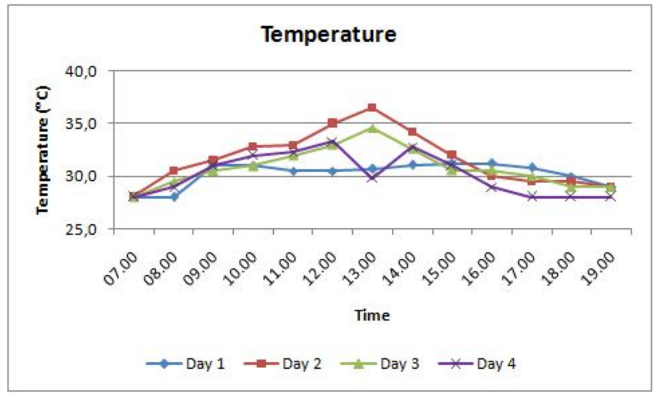
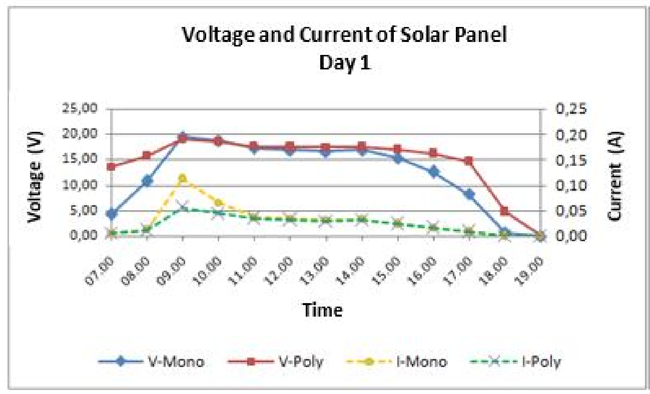
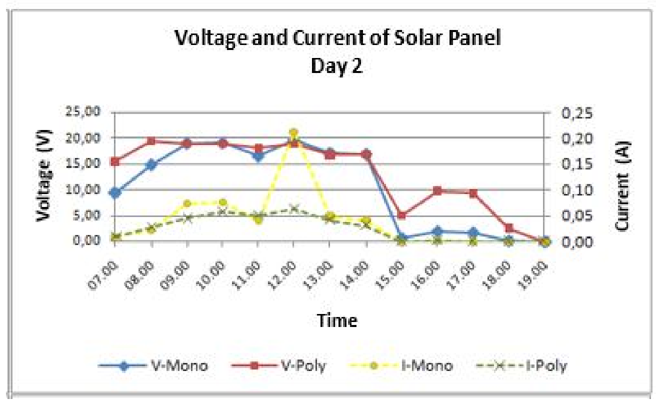
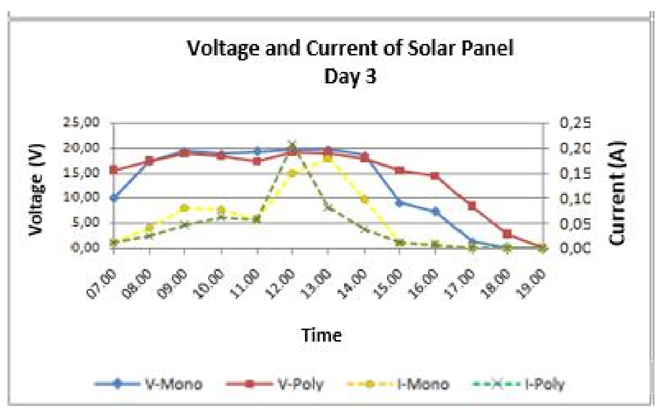


Figure 6: Effect of Temperature on Time







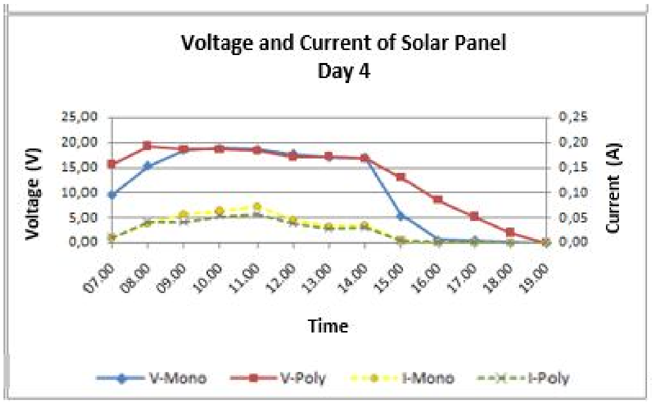
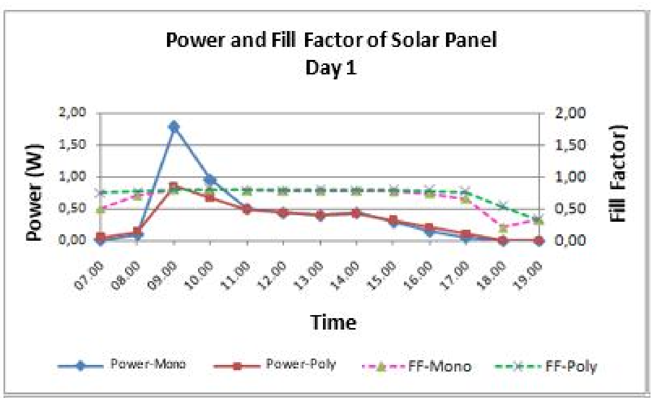
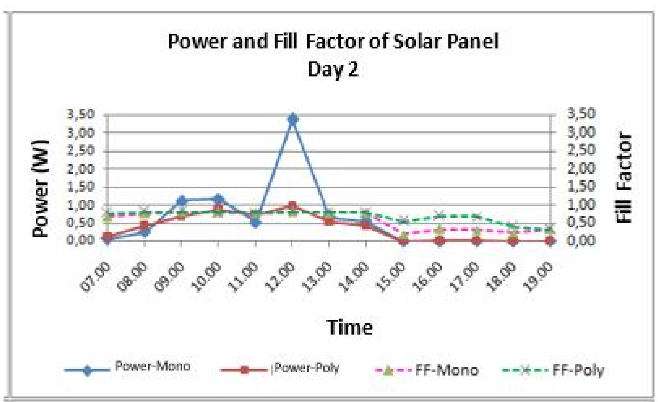
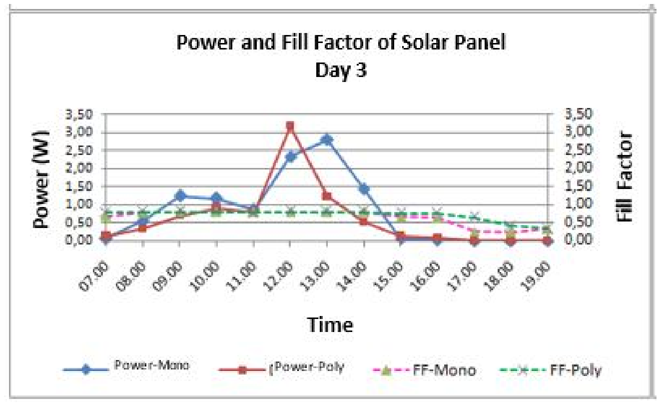


Figure 7: Effect of Voltage-Current on Time

Figure 7 depicts a short circuit voltage (V_{OC}) and short-circuiting (I_{SC}). Voc maximum on day 1, monocrystalline as 19.57 V, polycrystalline as 18.94; day 2, monocrystalline as 19.68 V, polycrystalline as 19.34 V; day 3, monocrystalline as 19.62V, polycrystalline as 19.13 V; and day 4, monocrystalline as 18.93 V, polycrystalline as 19.32 V. Ideally the maximum voltage and current is obtained during 11 a.m.-1 p.m. when the solar panel was facing upwards. But in this study only on day 2 and day 3 that can reach the condition due to the frequent weather conditions change.







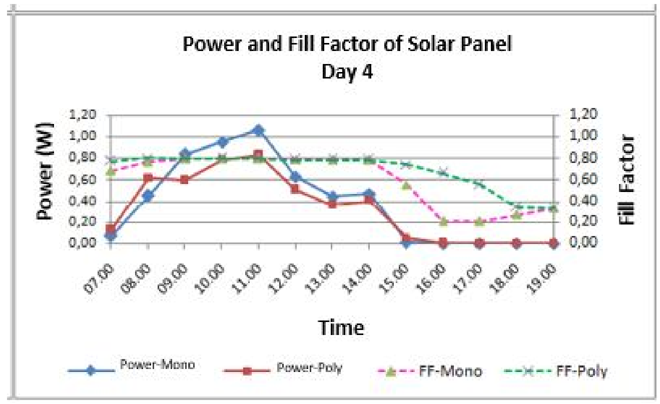


Figure 8: Effect of Power-Fill Factor on Time

Figure 8 shows the power and fill factor (FF) influence over time. Maximum power and FF, day 1 as 1.78 W (monocrystalline), 0.85 W (polycrystalline); FF as 0.81 (monocrystalline), 0.80 (polycrystalline). Day 2 power as 3.37 W (monocrystalline), 0.97 W (polycrystalline); FF = 0.81 (monocrystalline), 0.81 (polycyrstalline). Day 3 power as 2.81 W (monocrystalline), 3.18 W (polycrystalline); FF as 0.81 (monocrystalline), 0.80 (polycrystalline). Day 4 power as 1.06 W (monocrystalline), 0.83 W (polycrystalline); FF as 0.80 (monocrystalline), 0.80 (polycrystalline). Its generally FF value is about 0.7-0.85. The greater FF value of solar panel, then the performance of the solar panel was better.

Figure 9 shows the power output efficiency ((p) and solar radiation where the largest radiation day 1 as 231.47W/m^2 ; η_p as 17.77% (monocrystalline), η_p as 8.54% (polycrystalline). Day 2 solar radiation as 274.92W/m^2 ; η_p as 33.67% (monocrystalline), η_p as 9.69% (polycrystalline). Day 3 solar radiation as 184.86W/m^2 ; η_p as 28.06% (monocrystalline), η_p as 31.75% (polycrystalline). Day 4 solar radiation as 221.20W/m^2 ; η_p as 10.64% (monocrystalline), η_p as 8.33% (polycrystalline).

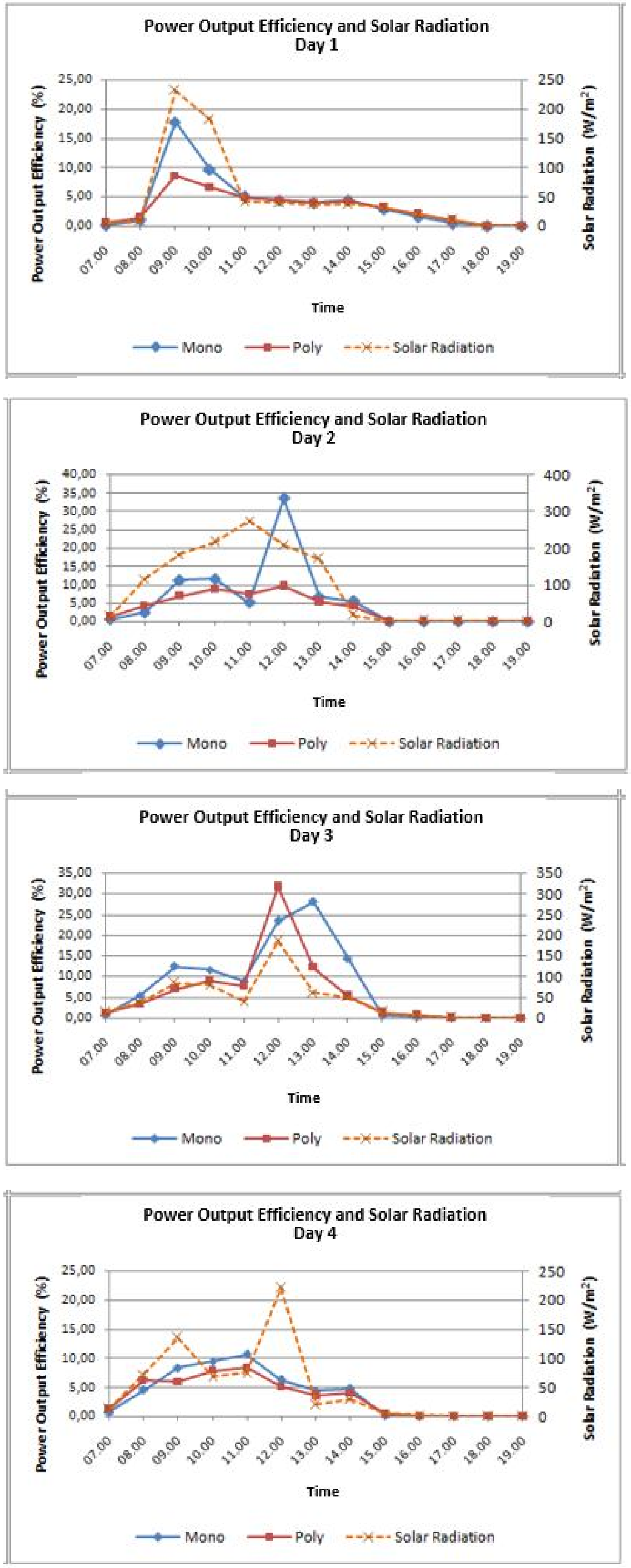


Figure 9: Effect of Power Output Efficiency-Solar Radiation on Time

The battery voltage used can be seen in Figure 10. Based on the figure, the battery voltage is relatively stable. For the polycrystalline solar panels, the battery voltage is greater than the monocrystalline.

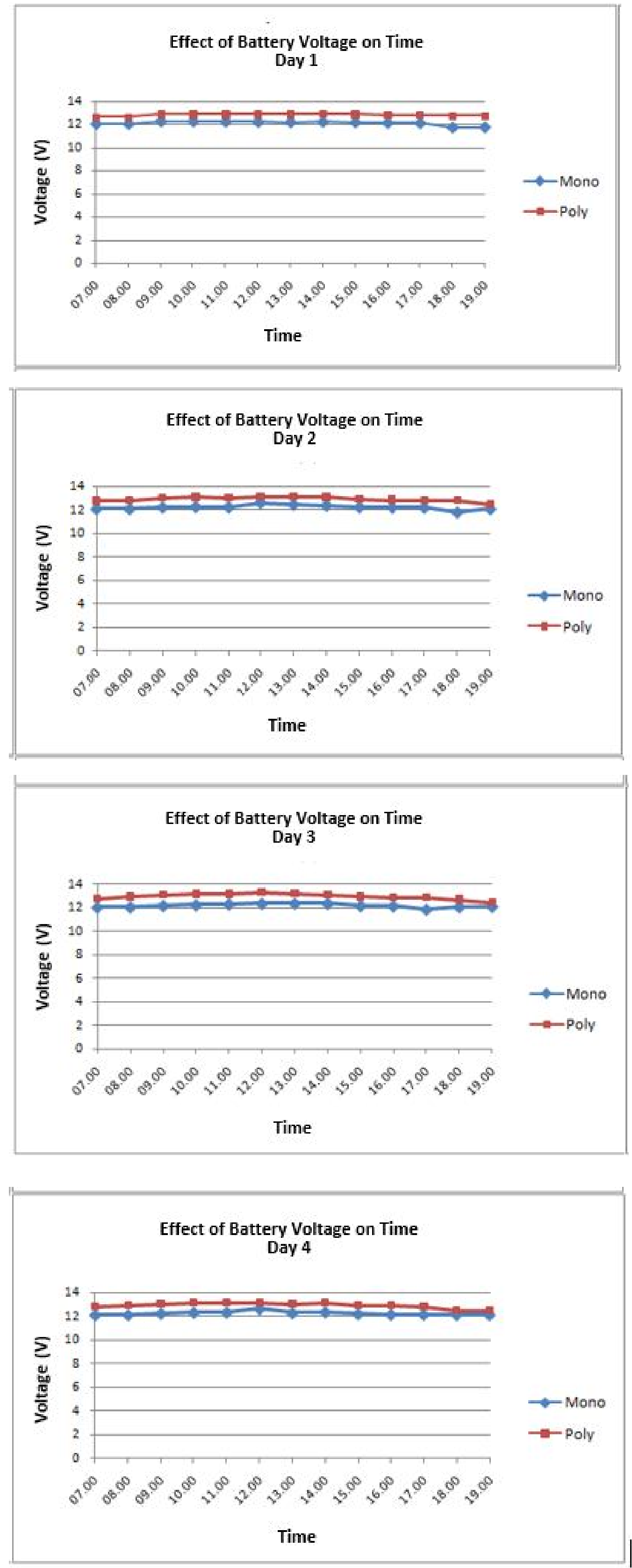


Figure 10: Effect of Battery Voltage on Time

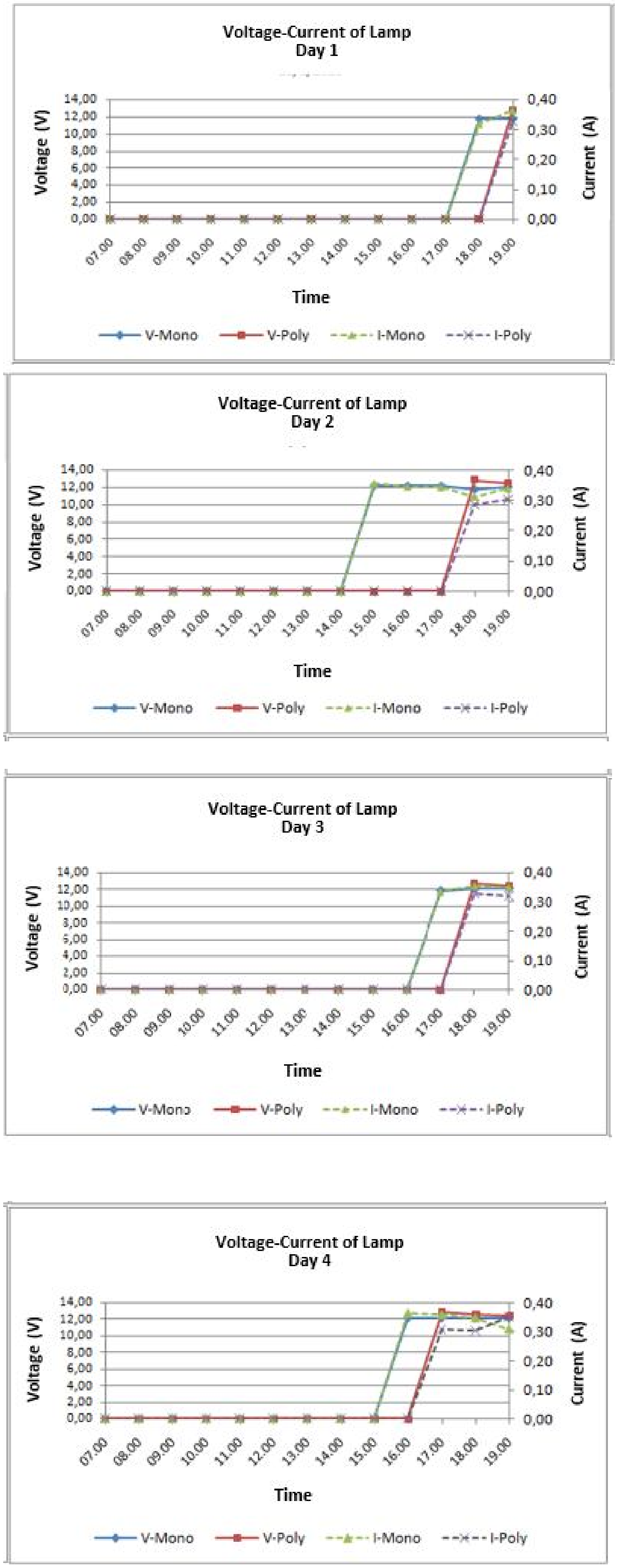
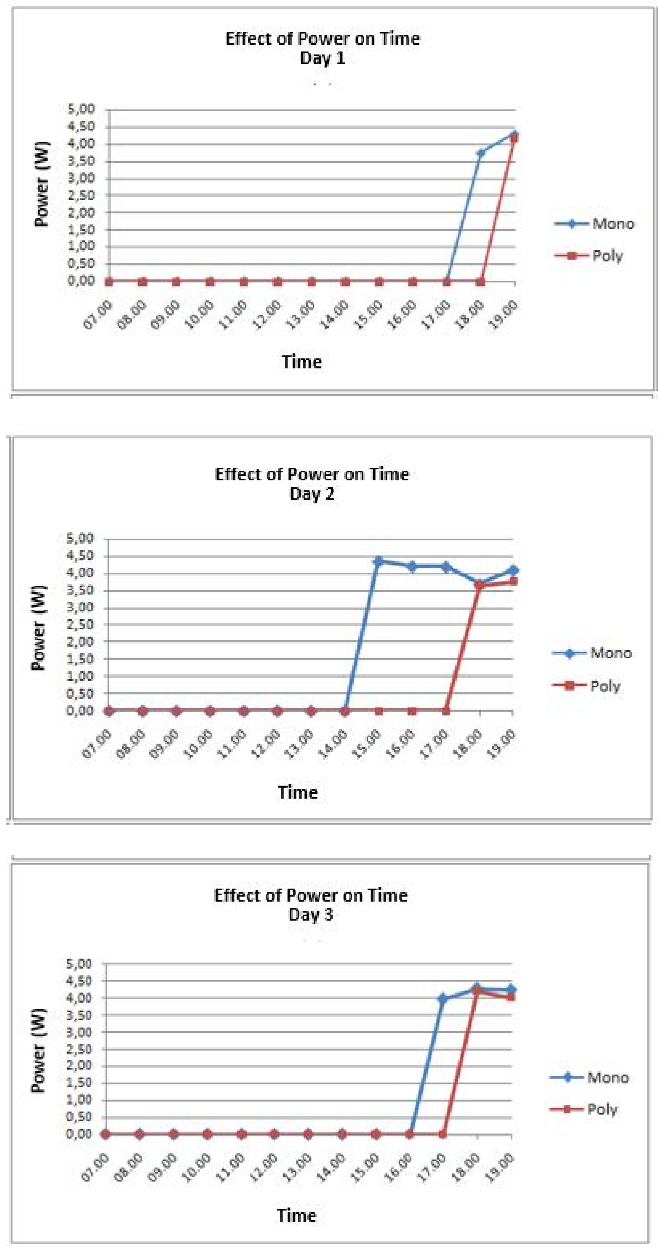


Figure 11: Effect of Voltage and Current of Lamp on Time

Figure 11 shows the effect voltage-current of the lamp on time. The voltage and current rise when a load or lamp lights up. The time difference on the light depends on weather conditions. When solar panels do not receive sunlight exposure, then the light will light up. For example, on the 2nd day, the lamp on the monocrystalline solar panel lit at 3 p.m. because at that time the weather was very cloudy. This is in accordance with the characteristics of the monocrystalline panel where when the weather is cloudy, the voltage (V_{OC}) will drop significantly.

Figure 12 shows the lamp power graph against the time in which the chart is the same shape as the voltage and lamp current graphs. This is because power is a multiplication between voltage and lamp current. The lamp power will increase when there is a load or lamp turn on.



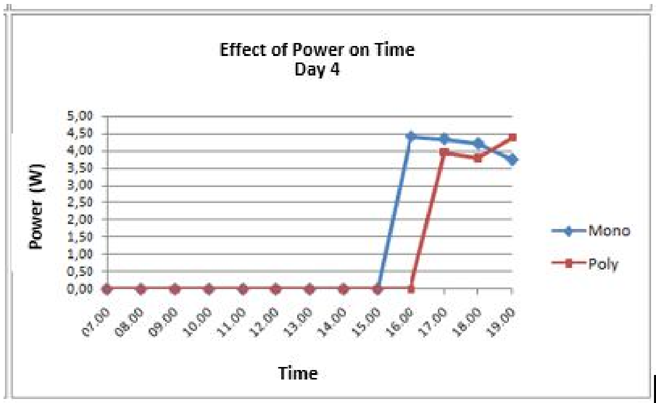


Figure 12: Effect of Power of Lamp on Time

Table 2: Power Output, Module Efficiency and solar Panel Performance Ratio

Day	Average Temperature (^{0}C)	Average Solar Radiation (W/m^2)	Average Power (W)	Average Module Efficiency (%)	Performance Ratio
			Monocrystalline		
1	30.2	49.06	0.39	8.18	0.74
2	31.7	92.68	0.59	6.40	0.58
3	30.8	43.81	0.82	14.53	1.31
4	30.2	49.24	0.38	7.78	0.70

Day	Average Temperature (^{0}C)	Average Solar Radiation (W/m^2)	Average Power (W)	Average Module Efficiency (%)	Performance Ratio
			Polycrystalline		
1	30.2	49.06	0.31	8.96	0.90
2	31.7	92.68	0.37	5.14	0.51
3	30.8	43.81	0.61	10.17	1.02
4	30.2	49.24	0.33	7.47	0.75

Table 2 shows the average data taken from monocrystalline and polycrystalline solar panels. Solar panel efficiency (Figure 13) was measured based on the ability of solar panels to turn sunlight into electrical energy that can be utilized by humans. Panel efficiency is crucial in selecting the right panel in a solar power generation system. Panel efficiency is determined based on the power output of the panels per unit area. The efficiency graphs of each solar panel per day. Monocrystalline efficiency 9.22% higher compared to polycrystalline 7.94%, except on the 1st day of polycrystalline efficiency was higher than 0.78% when compared with monocrystalline.

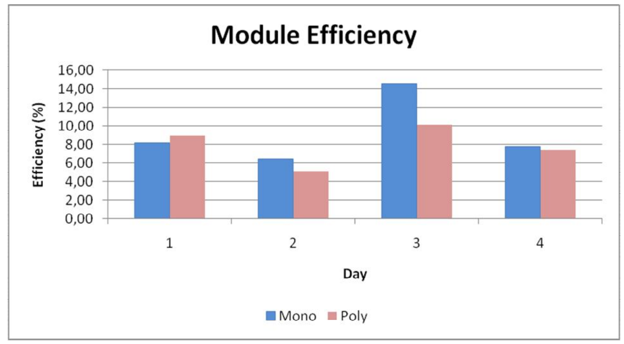


Figure 13: Module Efficiency of Solar Panel

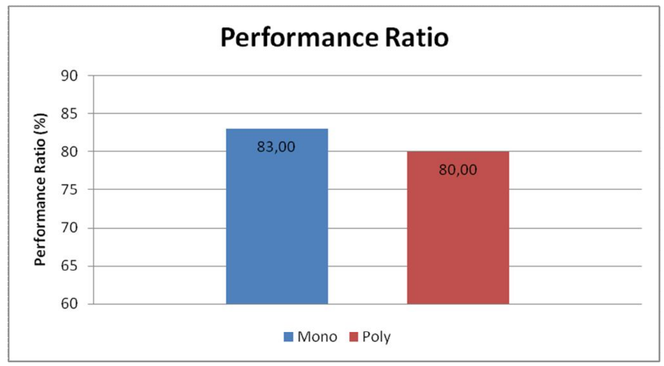


Figure 14: Performance Ratio of Solar Panel

Figure 14 shows the performance ratio for solar panels (monocrystalline and polycrystalline). The performance ratio is one of the important variables to evaluate the efficiency of solar panels. The performance ratio is the comparison of actual and theoretical output energy. The monocrystalline performance ratio is 83.0% higher than 3% when compared to polycrystalline 80.0%.

4. CONCLUSION

In summary, this research designed monocrystalline and polycrystalline-based solar cells that are applied for illumination has been conducted. Overall monocrystalline-based solar cell efficiency is higher compared to polycrystalline, which is 9.22% for monocrystalline and 7.94% for polycrystalline. The Performance ratio of solar cells based on monocrystalline is higher 3% when compared to polycrystalline-based solar cells.

ACKNOWLEDGEMENT

Thank you for Lembaga Penelitian dan Pengabdian kepada Masyarakat (LPPM) Universitas Nasioal and my colleagues at Faculty of Engineering and Science, Universitas Nasional, Jakarta, Indonesia.

REFERENCES

1. Blum, N. U., Wakeling, R. S., & Schmidt, T. S. **Rural electrification through village grids—Assessing the cost competitiveness of isolated renewable energy technologies in Indonesia**. *Renewable and Sustainable Energy Reviews*, 22, 482-496. 2013. https://doi.org/10.1016/j.rser.2013.01.049
2. Derks, M., & Romijn, H. **Sustainable performance challenges of rural microgrids: Analysis of incentives and policy framework in Indonesia**. *Energy for Sustainable Development*, 53, 57-70. 2019. https://doi.org/10.1016/j.esd.2019.08.003
3. Hidayanti F., Wati E.K., and Miftahudin M. F. **Design of Energy Harvesters on Motorcycle Exhaust using Thermoelectric Generator for Power Supply Electronic Device**. *International Journal of Renewable Energy Research*. 10(1), 251 - 259. 2020.
4. Hidayanti F., Wati E.K., and Akbar H. **Energy Harvesting System Design for Converting Noise into Electrical Energy**. *International Journal of Advanced Science and Technology*. 29(03), 4791 - 4802. 2020.
5. Hidayanti F., Rahmah F., and Wiryawan A. **Design of Motorcycle Security System with Fingerprint Sensor using Arduino Uno Microcontroller** . *International Journal of Advanced Science and Technology*. 29(05), 4374 - 4391. 2020.
6. Hidayanti F., Santoso H. H., and Amalia D. **Induction Measurement of Extra High Voltage Air Duct**. *International Journal of Emerging Trends in Engineering Research*. 8(4), 1424 - 1427. 2020. https://doi.org/10.30534/ijeter/2020/78842020
7. Hidayanti F., Rahmah F., and Sahro A. **Mockup as Internet of Things Application for Hydroponics Plant Monitoring System**. *International Journal of Advanced Science and Technology*. 29(05), 5157 - 5164. 2020.
8. Hidayanti F., Rahmah F., and Septratama S. **Design of Single-Axis Solar Tracker based on Arduino Uno Microcontroller**. *International Journal of Emerging Trends in Engineering Research*. 8(4), 983 - 986. 2020. https://doi.org/10.30534/ijeter/2020/07842020
9. Hidayanti F., **Extraction of Limonite Nickel Ore of Tanjung Buli, Halmahera by Coal Roasting and Acid Leaching**. *International Journal of Mechanical and Production Engineering Research and Development*. 10(2), 513 - 522. 2020.
10. Hidayanti F., **Development of Mercury Film Electrode for Cadmium Ion Determination using Voltammetry**. *International Journal of Advanced Science and Technology*. 29(03), 5156 - 5163. 2020.
11. Bahabry, R. R., Kutbee, A. T., Khan, S. M., Sepulveda, A. C., Wicaksono, I., Nour, M., ... and Syed, A. **Solar Cells: Corrugation Architecture Enabled Ultraflexible Wafer‐Scale High‐Efficiency Monocrystalline Silicon Solar Cell** (Adv. Energy Mater. 12/2018). *Advanced Energy Materials*, *8*(12), 1870055. 2018. https://doi.org/10.1002/aenm.201870055
12. Hashmi, G., Akand, A. R., Hoq, M., and Rahman, H. **Study of the enhancement of the efficiency of the monocrystalline silicon solar cell by optimizing effective parameters using PC1D simulation**. *Silicon*, *10*(4), 1653-1660. 2018.
13. Saga, T., **Advances in crystalline silicon solar cell technology for industrial mass production**. *npg asia materials*, 2(3): p. 96. 2010.
14. Gordon, I., Carnel, L., Van Gestel, D., Beaucarne, G., and Poortmans, J. **8% Efficient thin‐film polycrystalline‐silicon solar cells based on aluminum‐induced crystallization and thermal CVD**. *Progress in Photovoltaics: Research and Applications*, *15*(7), 575-586. 2007. https://doi.org/10.1002/pip.765
15. Fthenakis, V.M. and P.A. Lynn, **Electricity from Sunlight". Photovoltaic-systems Integration and Sustainability**. *John Wiley & Sons*. 2018.
16. Hidayanti F., Rahmah F., and Agusto J. **Design of Solar Tracker on Solar Panel with Fresnel Concentrator**. *International Journal of Advanced Science and Technology*. 29(05), 1014 - 1025. 2020.
17. Callister Jr, W. D., and Rethwisch, D. G. **Fundamentals of materials science and engineering: an integrated approach**. *John Wiley & Sons*. 2012.
18. Jumrusprasert, P., Smith, G., and Kirkup, L. **Comparing the efficiency of fixed solar cell panels in a tropical location**. In *Proceedings of ISES World Congress 2007* (Vol. I–Vol. V) (pp. 1478-1483). Springer, Berlin, Heidelberg. 2008.
19. Zhou, J. C., Chen, Y. M., Li, L., Li, F., and Zhao, B. X. **A study on the key factors affecting the electronic properties of monocrystalline silicon solar cells**. *Optoelectronics Letters*, 5, 422-426. 2009. https://doi.org/10.1007/s11801-009-9131-6
20. Beiser, A., Mahajan, S., and Choudhury, S. R. **Concepts of modern physics**. *Tata McGraw-Hill Education*. 2003.
21. Hidayanti F., Rahmah F., and Ikrimah M. **Dual-Axis Solar Tracking System Efficiency for Hydroponics Pump**. *International Journal of Emerging Trends in Engineering Research*. 8(6), 2631 - 2634. 2020. https://doi.org/10.30534/ijeter/2020/67862020
22. Hidayanti F., Lestari K.R., and Anwar R. **Arduino Based Conductive Silver Lamination Device**. *International Journal of Emerging Trends in Engineering Research*. 8(2), 265 - 270. 2020. https://doi.org/10.30534/ijeter/2020/04822020