# REPORT

## Photovoltaic Characterization of a $MoS_2/MoS_2$ p-n junction under Dark and Illuminated conditions

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# ABSTRACT

This study reports the fabrication and photovoltaic characterization of a $MoS_2/MoS_2$ p-n homojunction device on an ITO (Indium Tin Oxide) glass substrate. The electrical characteristics were analyzed using a Keithley Parameter Analyzer under both dark and illuminated conditions. The key photovoltaic parameters were successfully extracted from the I-V curve: $I_{sc}$ (Short circuit current), $V_{oc}$ (Open circuit voltage), FF (Fill Factor), Efficiency ($\eta$) and were plotted against different Intensities. These results highlight the potential of Molybdenum Disulfide homojunctions as a promising material platform for developing next-generation 2D optoelectronic and flexible solar cell technologies.

# INTRODUCTION

Traditional silicon-based solar cells are mature but suffer from high material consumption and rigidity. This has driven the exploration of Two-Dimensional Transition Metal Dichalcogenides (TMDs) such as Molybdenum Disulfide ($MoS_2$). The band gap of $MoS_2$ - 1.12 eV (indirect) and 1.8 eV (direct), making it highly suitable for thin optoelectronic devices.

Role of the PN Junction: The fundamental building block of almost all semiconductor devices is the p-n junction. While most 2-D Photovoltaic research focuses on heterojunctions, the $MoS_2/MoS_2$ homojunction provides a simplified, clean interface free from the complex band alignment and lattice mismatch issues often encountered in combining different materials. The use of Indium Tin Oxide (ITO) glass as a transparent conductive substrate offers a high-performance electrical contact and optical window for light delivery to the active $MoS_2$ layer.

**Objective:** This report will focus on characterization of a $MoS_2/MoS_2$ p-n homojunction device. We will analyze and extract the values such as short circuit current, open circuit voltage, fill factor and efficiency using data acquired with the Keithley Parameter Analyzer and processed via Origin software.

# METHODOLOGY

**Substrate:** The device was fabricated on an ITO (Indium Tin Oxide) glass substrate.

**Active Material:** $MoS_2$ (Molybdenum Disulfide).

**Junction Formation:** The p-n junction was formed using a $MoS_2/MoS_2$ homojunction.

**Device Area:** Active area of the $MoS_2$ junction is 5 x $10^{-9}$ $m^2$.

**Equipment:** Keithley Parameter Analyzer.

**Type of sweep:** The voltage was swept in a dual sweep fashion from -2 to +2 and back.

**Data Analysis:** Graph plotting, Linear fitting and the extraction of photovoltaic parameters ($I_{sc}$, $V_{oc}$, Fill factor and Efficiency) were performed using Origin software.

# RESULTS

## 1. I-V Graph characteristics

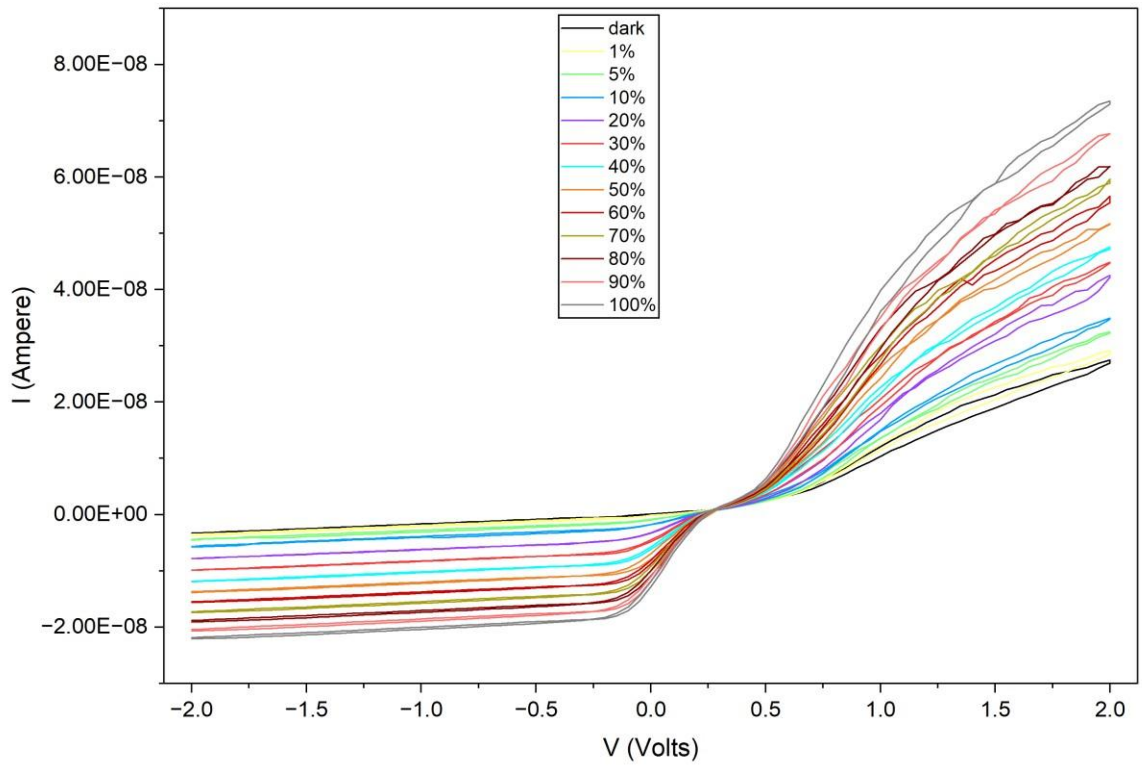


*Figure 1 shows the I-V graph of p-n ($MoS_2$/$MoS_2$) under the influence of light at different intensities*

Forward Bias: Current exponentially increases with Voltage. Reverse Bias: Current is low (almost at a constant value).

We are going to extract parameters like $I_{sc,}$ $V_{oc,}$ Fill factor and Efficiency from this graph (with the set of given data values).

## 2.Short Circuit Current ($I_{sc}$) vs Intensity (%)

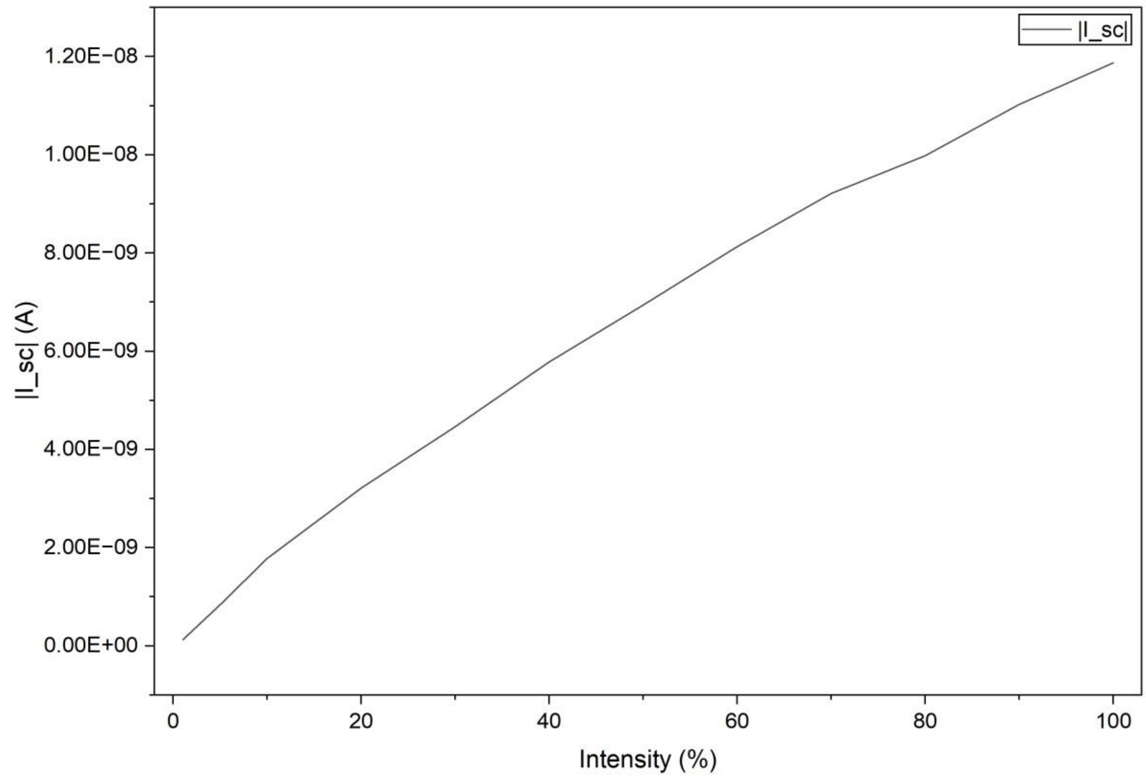


*Figure 2 shows the variation of |I_sc| with Intensity*

$I_{sc}$ (Short circuit current) is defined as the point in the I-V curve when it crosses the y-axis (Current) corresponding to V = 0 V.

This figure shows that magnitude of $I_{sc}$ increases with the Intensity (almost a linear curve – sublinear).

The value starts from 0 A (dark condition) and goes till a value of 1.1877E-8 A (100%).

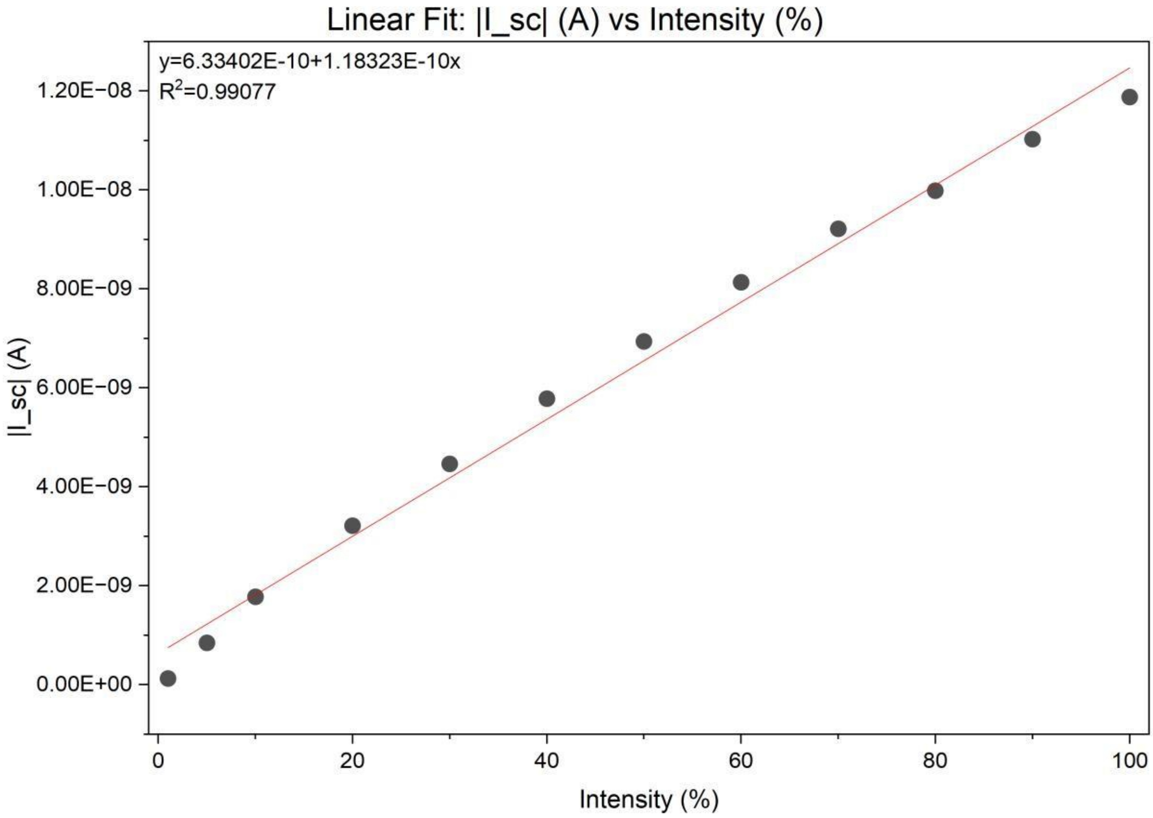


*Figure 3 shows the Linear fit of |I_sc| vs Intensity*

In an ideal solar cell, $I_{sc}$ is expected to be perfectly linear with intensity as the number of generated photocarriers is directly proportional to the number of incident photons.

## 3.Open circuit Voltage ($V_{oc}$) vs Intensity (%)

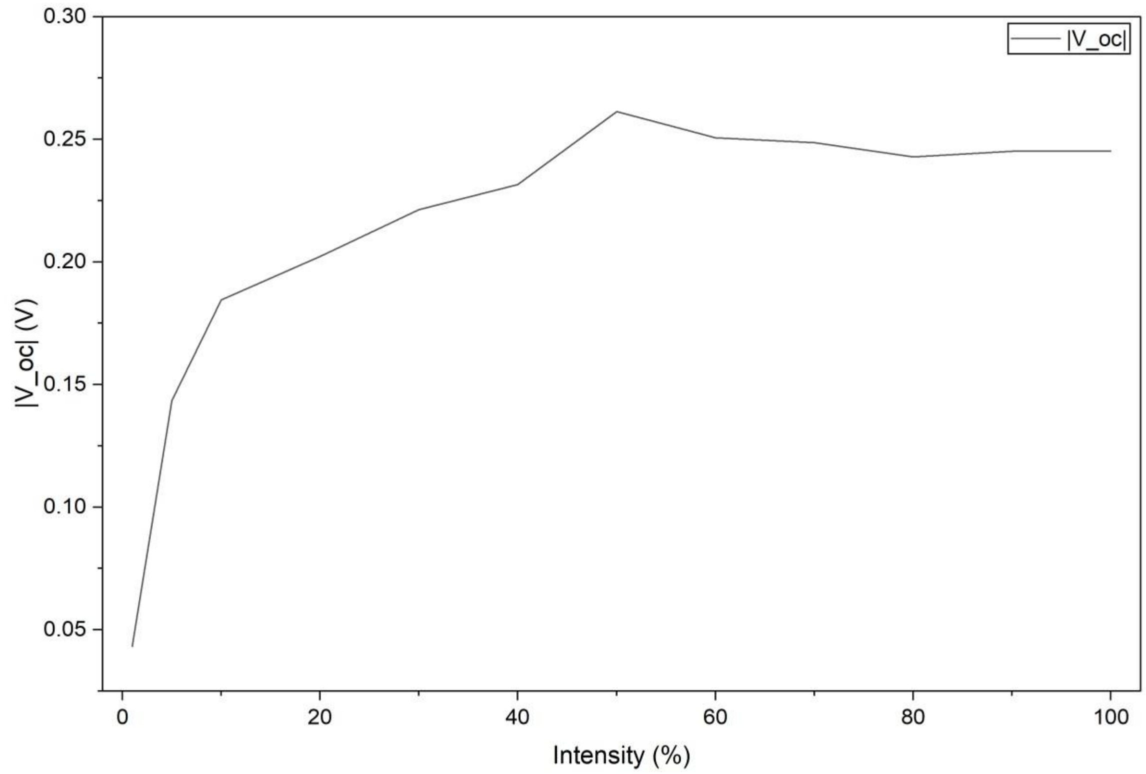


*Figure 4 shows the variation of |V_oc| vs Intensity*

$V_{oc}$ (Open circuit voltage) is defined as the point in the I-V curve when it crosses the x-axis (Voltage) corresponding to I = 0 A.

The trend follows a logarithmic relationship before plateauing at around 60% intensity. We can observe that voltage saturates at around 60% illumination after which the value varies between 0.22 V to 0.26 V.

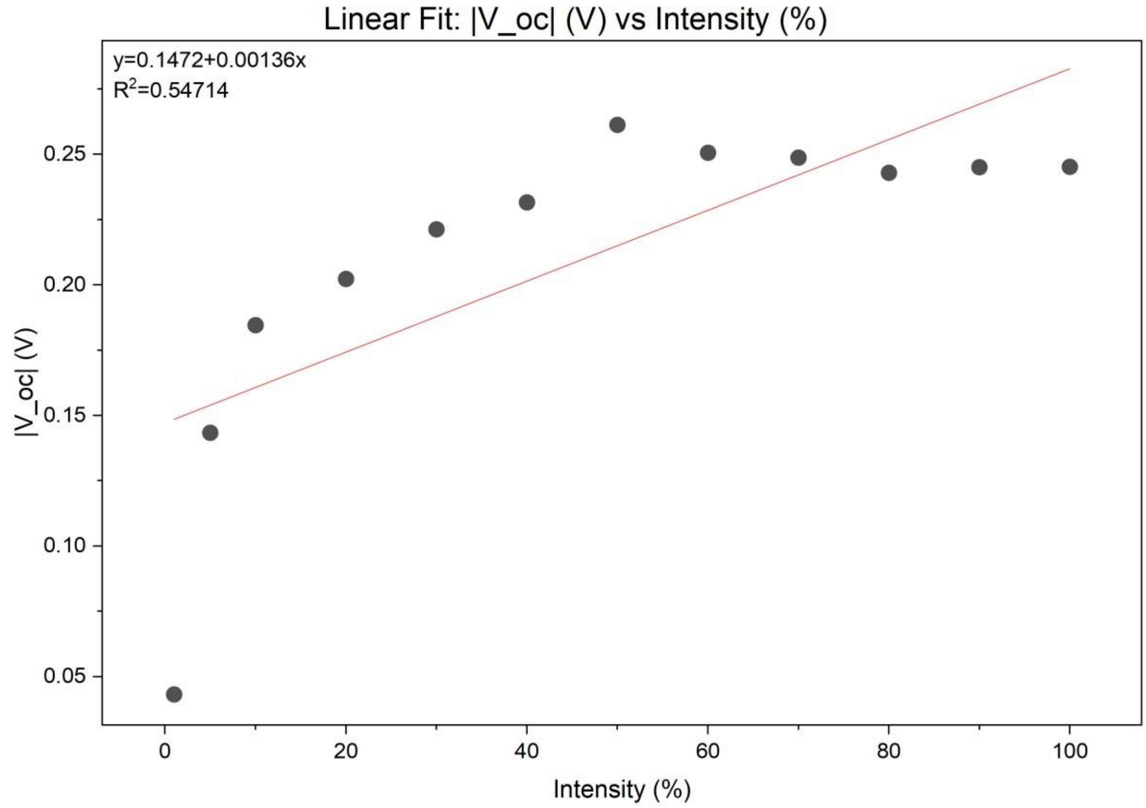


*Figure 5 shows the Linear fit of |V_oc| vs Intensity*

Due to the discrete nature of the voltage sweep, the data set did not contain an exact point corresponding to zero current. Therefore, the $V_{oc}$ was precisely determined for each illumination intensity by linear interpolation of the I-V data.

## 4.Fill Factor (FF) vs Intensity (%)

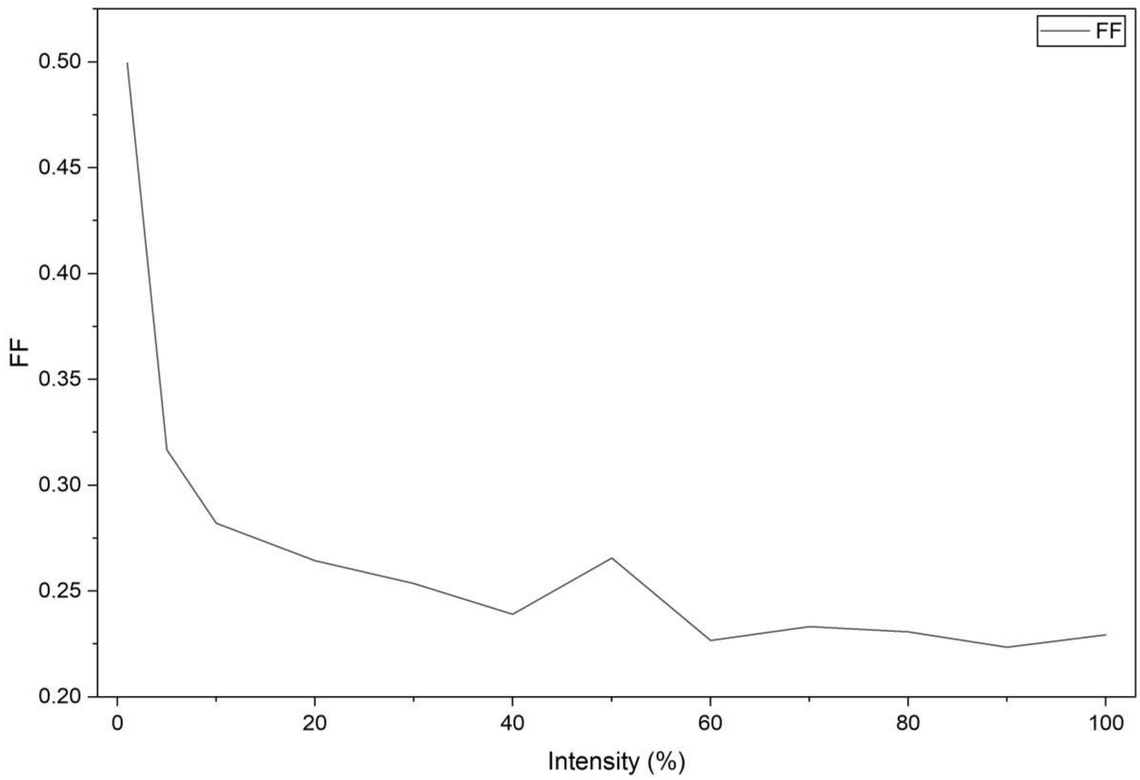


*Figure 6 shows the trend between FF and Intensity*

Fill factor (FF) is defined as the ratio of the actual maximum power output ($P_{out}$) to the theoretical maximum power output.

Mathematically it can be given as:

$$FF = \frac{P_{max}}{V_{oc} \cdot I_{sc}}$$

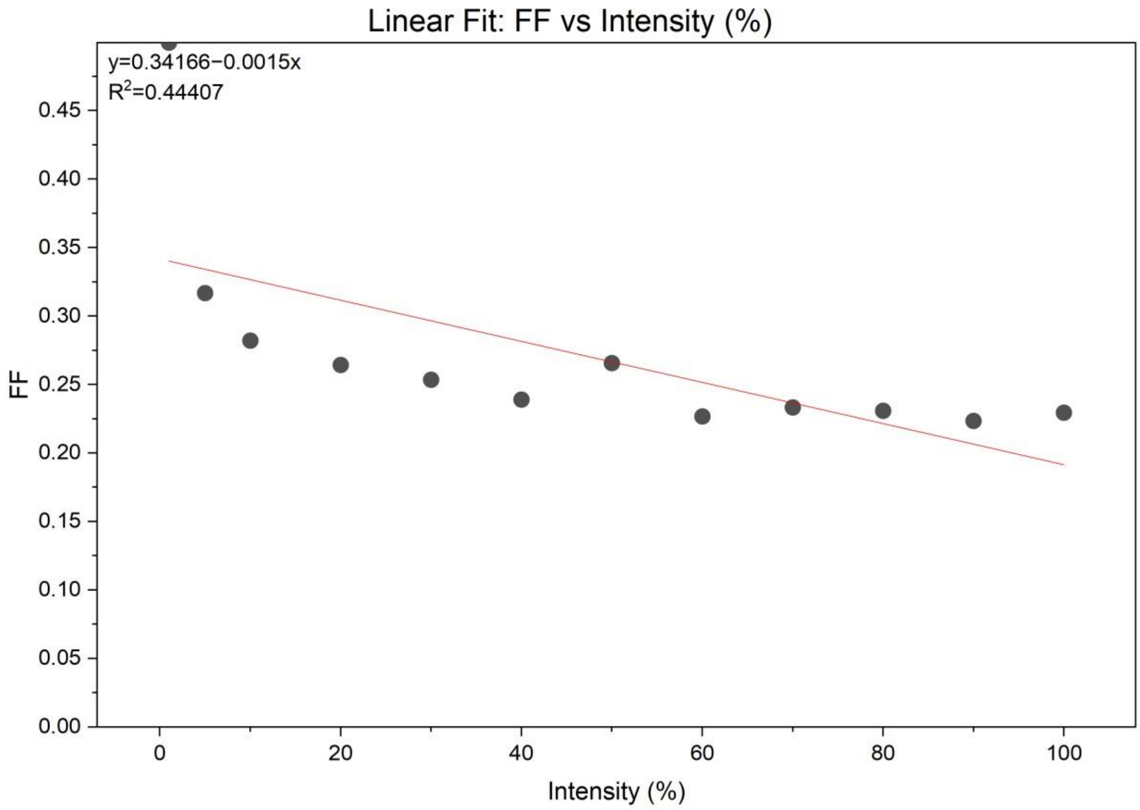


*Figure 7 shows the Linear fit of FF vs Intensity*

The trend shows a negative correlation between FF and intensity, which is a key indicator of internal loss mechanisms in the device.

Fill factor strongly indicates that this $MoS_2$ homojunction device is resistance-limited.

## 5.Efficiency (η) vs Intensity (%)

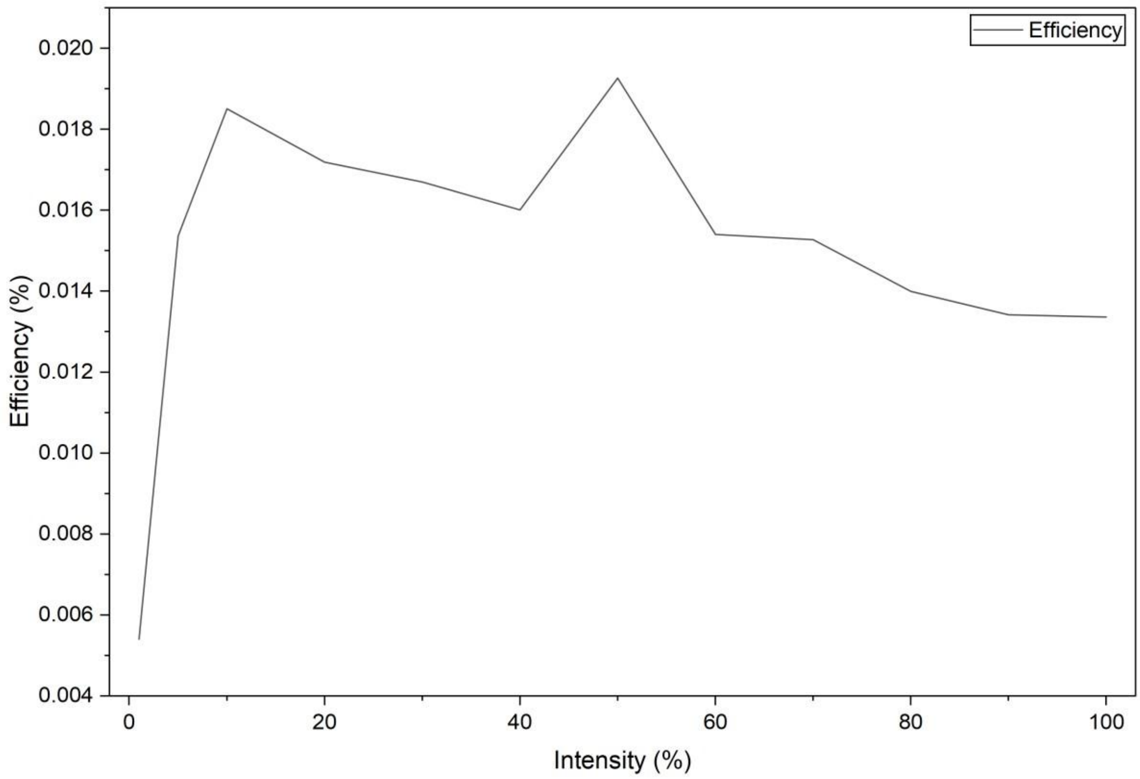


*Figure 8 shows how Efficiency varies over Intensity*

Efficiency (η) is defined as the ratio of the maximum electrical power output ($P_{max}$) to the incident light power ($P_{in}$) over the active area of the device.

Mathematically it can be given as:

$$\eta = \frac{V_{oc} \cdot I_{sc} \cdot FF}{P_{in}} \times 100\%$$

$P_{in}$ can be given as:

$$P_{in}(s) = Area * s * 1000$$

Here,

s = Intensity (%)/100

Area = 5 x $10^{-9}$ $m^2$

1000 $W/m^2$ is the incident Solar power

Figure 8 shows that the device efficiency exhibits a characteristic behavior: an initial rapid rise at low intensity, followed by a peak and then a gradual decline.

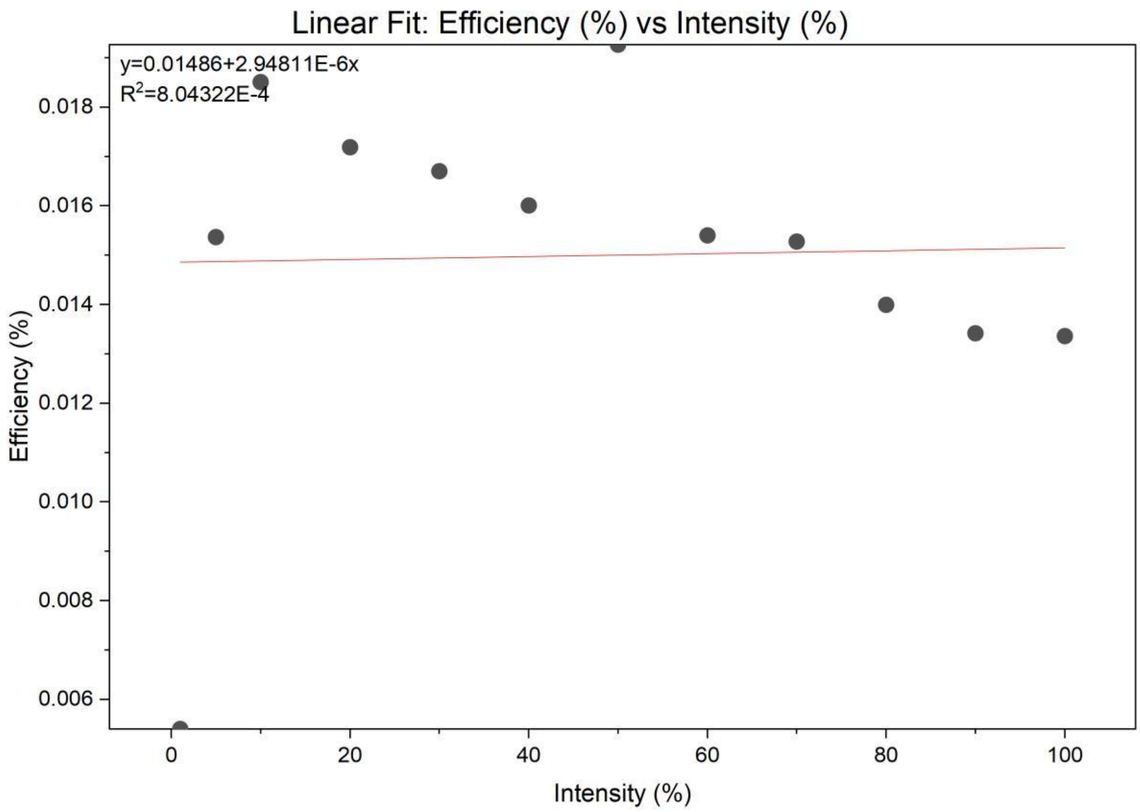


*Figure 9 is the Linear fit of Efficiency vs Intensity*

The shape of the efficiency curve is controlled by the trade-off between increasing photocurrent and decreasing Fill Factor.

The rapid increase in efficiency at low intensities (below 50%) is primarily driven by the logarithmic increase of $V_{oc}$.

From the Linear fit graph in the figure 9, we can observe that there is virtually no linear correlation between efficiency and light intensity.

# CONCLUSION

The $MoS_2/MoS_2$ homojunction successfully functioned as a photovoltaic device, demonstrating an effective short-circuit current ($I_{sc}$) proportional to illumination and open-circuit voltage ($V_{oc}$), which is expected to have a logarithmic relationship with intensity and then saturate at the later stage. Performance degradation was observed in the low magnitude of the Fill Factor (FF), which decreased monotonically with increasing light intensity. However, the overall efficiency ($\eta$) showed an optimum point at moderate intensity before undergoing a noticeable decline.

# REFERENCE

**Fundamental PV Device Physics:** *S. M. Sze, K. K. Ng, and P. D. L. C. P. Sze, Physics of Semiconductor Devices. 3rd ed. John Wiley & Sons.*