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EFFECT OF ILLUMINATION INTENSITY ON THE PERFORMANCE OF PHOTOELECTRO CHEMICAL (PEC) SOLAR CELL USING MOSE$_2$ SINGLE CRYSTAL

Ravindrapal M Joshi
M.B. Patel Science College, Anand (Gujarat)

Abstract : The single crystal of MoSe$_2$ grown by chemical vapour transport (CVT)technique are used for the fabrication of Photoelectro chemical (PEC) solar cells. The effect of the illumination intensity on the conversion efficiency of the fabricated PEC solar cell is studied.

Keywords : Single crystal of MoSe$_2$, Photo electrochemical solar cells, illumination intensity variation, conversion efficiency.

I. INTRODUCTION

It has already been seen that transition metal dichalcogenides (TMDCs) materials have considerable importance because of their usefulness as lubricating materials, switching devices, electrodes for photoelectrochemical solar cells, etc. The chemical vapour transport (CVT) techniques using halogen (Br or I) as the transporting agent has been found to be a suitable technique by several researchers[1-7)] for growing the single crystals of layered compounds. It appears from the literature that there has been no previous attempt to grow the single crystals of $MoSe_xTe_{2-x}(0 \leq x \leq 2)$. Kline et al[8)] reported that the transition metal dichalcogenides (TMDC) form a wide range of solid solutions[9,10)] with either mixed metal or chalcogenide composition or both and the properties, like crystal structure, band gap, band positions and stability to corrosion, which are of prime interest to photoelectro chemist might be influenced by changing the composition of the layered crystals.

The author did the growth of MoSe$_2$ single crystal by chemical vapour transport (CVT) technique. The grown single crystals of MoSe$_2$ were used for the fabrication of photoelectrochemical (PEC) solar cells. The PEC studies were undertaken in I_2/I^- electrolytes. The study of varying concentration of iodine in electrolytes was studied. The results obtained are deliberated in this research paper.

II. EXPERIMENTAL

A. Single Crystals Growth

Stoichiometric amounts of 99.999% pure molybdenum and selenium were introduced into a cleaned, etched and vacuum backed quartz ampoule of internal diameter 25 mm and length 200 mm. A total charge of about 9-12 gm was used in the experiment. The transporting agent bromine by weight of 3 mg / cm^3 to 4 mg / cm^3 of ampoules volume of liquid bromine was introduced into the ampoule in a sealed capillary tube. The ampoule was then evacuated to a pressure less than 10^{-5} torr and sealed at the constriction 3 mm in diameter.

The ampoule was vigorously vibrated to ensure that the capillary tube breaks releasing the bromine and the powders were mixed properly. The mixture was distributed along the length of the ampoule and placed in a two zone horizontal furnace and the temperature was slowly increased to 900^0C. The ampoule was left at this temperature for 120 hours.

Then the furnace was shut down and allowed to cool down to room temperature. A free flowing shinning dark mixture resulted from the reaction.

The charge thus prepared was well mixed by vigorous shaking of the ampoule. The powder was then placed at one end of the ampoule known as charge zone whereas the other end of the ampoule was empty for crystal growth to happen and known as growth zone. The ampoule with this distribution of charge was kept in the furnace again for the growth of crystals as shown in fig.1 The furnace temperature was increased slowly, as was done for charge preparation to the required final temperature for growth.

The exact growth conditions adopted for MoSe$_2$ has been describe in table 1 Fig 2. Shows in general the temperature gradient maintained along the ampoule.

After the required period of growth the furnace was shut off and allowed to cool down to room temperature. The ampoule was broken and crystals were removed for further studies.

The crystals obtained are grey black, in colour and plate like with the c axis normal to the plane of the plates and all of them grew over the transported charge inside the ampoule.

TABLE 1

Growth conditions used to produce single crystals of MoSe$_2$

Nominal compositon	**Reaction temperature (^{0}c)**	**Growth temperature (^{0}C)**	**Growth time (hrs)**
MoSe$_2$	900	800	120

B. Photoelectrochemical (PEC) Solar Cells

There have been several discussions in recent years on photoelectrochemical (PEC) methods of solar energy conversion. An important factor affecting the conversion efficiency is the electrolyte. The detailed studies have been carried out by various workers[11-23] on the photoelectrochemical behavior in contact with different aqueous and non aqueous redox electrolytes. Their results have indicate that iodine / iodide, I_2/I^- system to be optimal redox couple for the best performance and stability. Since the light conversion efficiency of the cell based on I_2/I^- depends upon iodine contact of the redox couple, the iodine concentration has been optimized in the present work for better conversion efficiencies of $MoSe_2$ photoelectrodes.

A key element of PEC devices is the semiconductor electrolyte interface. The degree of effectiveness of minority carrier charge transfer across their interface will have direct bearing on the ultimate energy conversion efficiency of the system.

The strategy of enhancing this charge exchange by electing the temperature has the added advantage of utilizing the near IR region of solar spectrum, which otherwise would be wasted. Temperature also has beneficial effects on the optical properties of the semi conductor.

Further, since the efficiency and behavior of most photoelectrodes in photoelectrochemical solar cells depends on the characteristics of the incident light, author has described such studies on PEC cells based on $MoSe_2$ in this paper.

III. RESULTS AND DISCUSSION

Single crystals of $MoSe_2$ have been grown by the chemical vapour transport (CVT)technique because it yields large single crystals with relative ease.

The crystals were strain free because they grow vertically in the form of thin platelets directly above the transported charge. The X-ray diffraction studies of $MoSe_2$ indicate that the crystal formed are single phase .

Effect of illumination Intensity

The schematic diagram of experimental set up for studying the effect of intensity of illumination is shown in fig. 3 The Fresh iodine / iodide electrolyte was prepared by mixing AR grade 0.025 M I_2,5.0 M NaI, 0.5 M Na_2SO_4 in double distilled water. The incident light intensity was adjusted by changing the distance between PEC cell and light source.

The effect of illumination (light) intensity on the photocurrent photovoltage characteristics of $MoSe_2$ is illustrated in fig.4 . Treating semiconductor electrolyte interface as Schottky barrier, the current voltage characteristic is represented by the following expression.

$$J=J_{ph}-J_d=J_{ph}-J_0[\exp(qv/nkT)-1] \qquad (1)$$

Here J is net current density, J_{ph} and J_d are photocurrent and dark current densities. J_0 is the reverse saturation current density, V is voltage, n is “Junction Ideality” factor and other terms have their usual significance. According to Rajeshwar et.al. [24] at equilibrium (open circuit condition), J_{ph}=Jd and V=v_{oc} so that rearrangement of equation (1) yields.

$$V_{oc} = nKT/q \ \ln J_{SC}/J_o \qquad (2)$$

where V_{OC} is the open circuit voltage and J_{SC} is the short circuit current density.

If we further assume that $J_{SC} \propto J_C$(=incident light intensity) and $J_{SC} >> j_0$, (Equation 2) reduces to following expression

$$V_{OC} \propto nKT/q \ \ln I_L$$

A plot of V_{OC} against $\ln I_L$ yields a straight line from which n can be determined for particular device. An ideal device should have an n value of unity.

Figure 5. shows the plots of light intensity I_L , versus open circuit voltage $V_{OC,}$ short circuit current I_{SC} and logarithm of light intensity versus open circuit voltage for $MoSe_2$

It is observed that the short circuit current varies linearly with light intensity, i.e.

$$I_{SC} = C \ I_L$$

where C is constant and I_L is the intensity of light.

It is observed that the open circuit voltage (V_{OC}) is a linear function of logarithm of incident light intensity (I_L) Fig 5.

The junction ideality factor for $MoSe_2$ was determined from the plots of open circuit voltage V_{OC} versus log I_L from Fig. 5. The high value of junction ideality factor indicate the characteristics of recombination process in space charge layer. Tunneling currents and interfacial layers can result in considerable higher values of n equal to or greater than 2[25].

The effect of light intensity on the light to electricity conversion efficiency (n) and fill factors of $MoSe_2$ are given in Fig. 6. The decrease in efficiency at higher light Intensities was attributed to [26] loss of fill factor at higher light intensities.

TABLE 2

Junction ideality factor for $MoSe_2$

Compound	Ideality factor calculated ‘n’
$MoSe_2$	2.0

IV. CONCLUSION

- It is observed that the short circuit current varies linearly with light intensity.
- The open circuit voltage V_{OC} is a linear function of logarithm of incident light intensity (I_L)

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Author’s Profile

Dr. Ravindrapal M. Joshi received the Ph.D. degree in Physics from Sardar Patel University, Vallabh Vidyanagar, Gujarat in 1990. Currently he is working as Assistant Professor in M.B. Patel Science College, Anand, Gujarat.

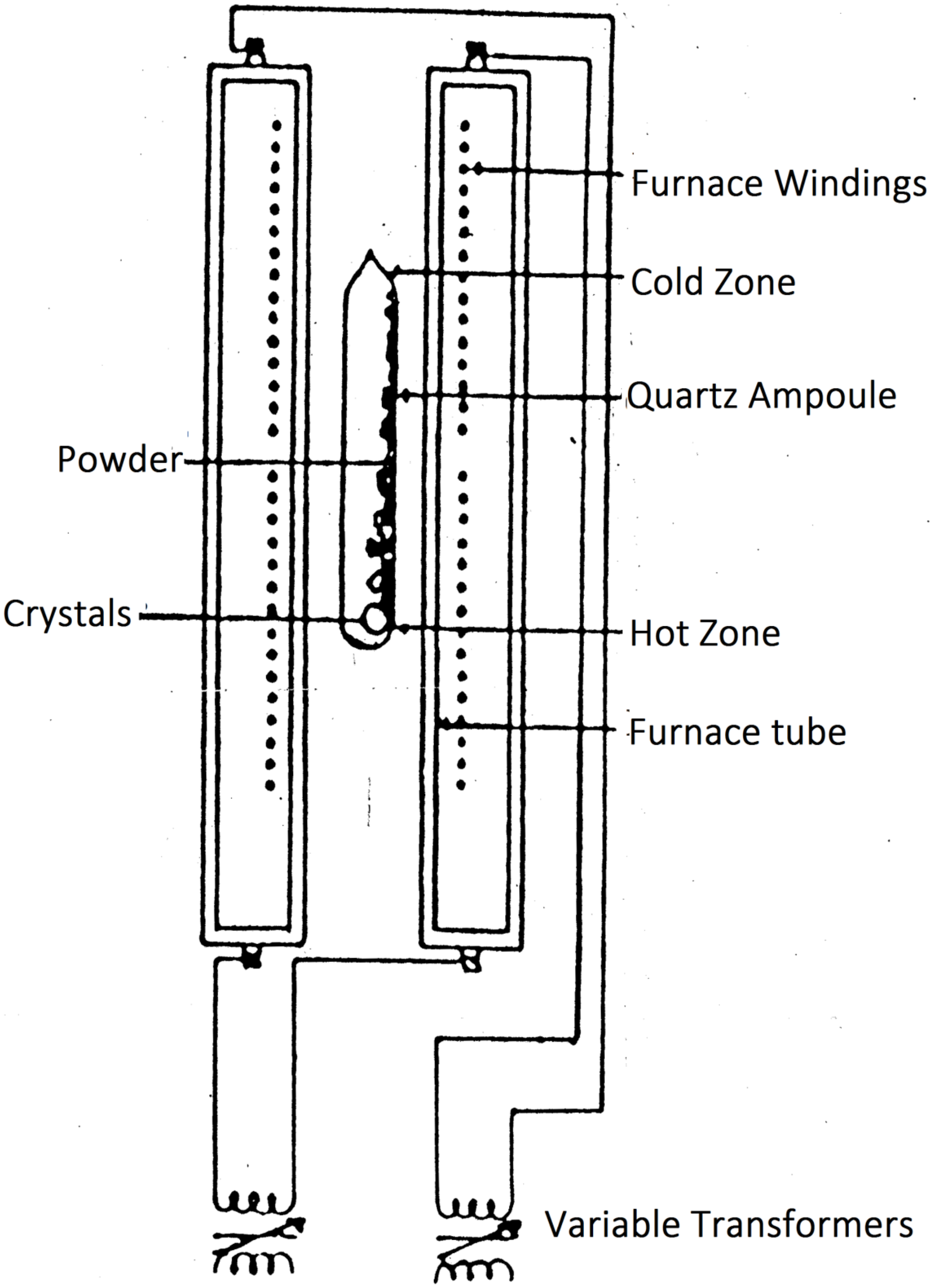


Fig 1 : Schematic view of the furnace showing the position of ampoule inside the two furnace during crystal growth.

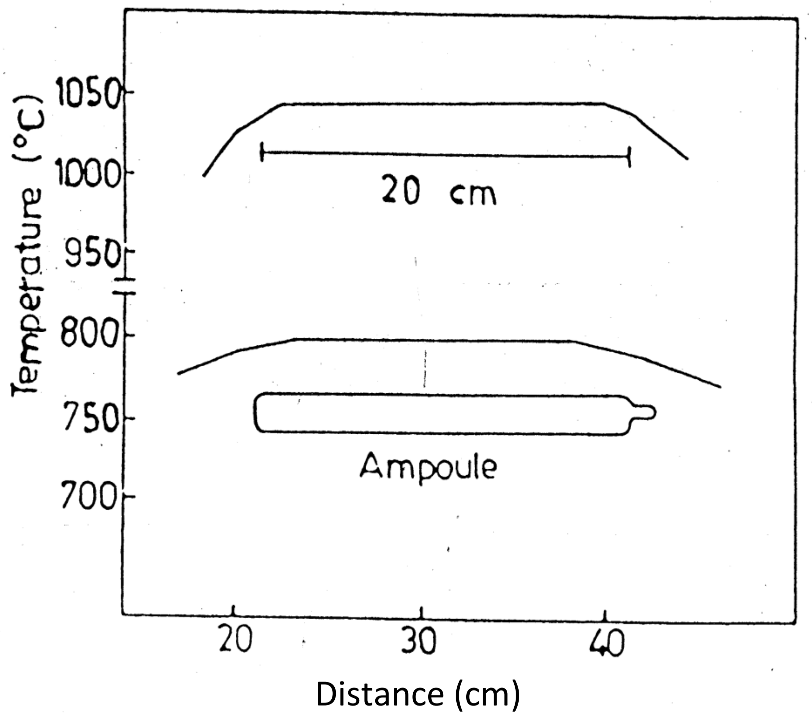
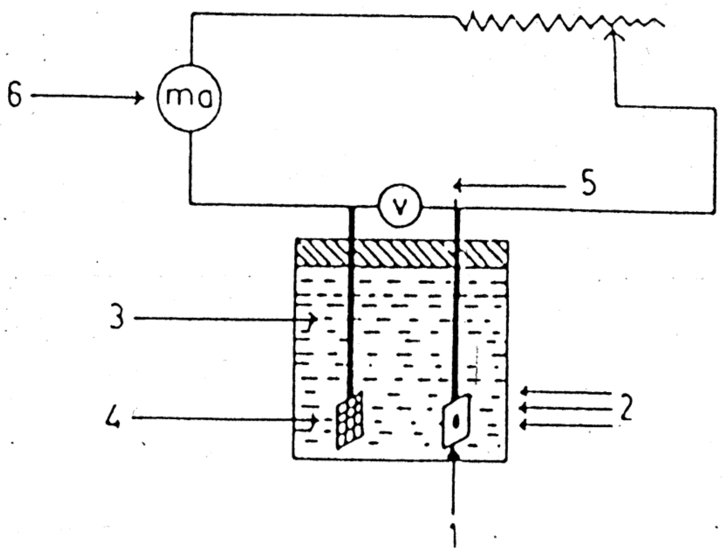


Fig 2: Temperature profile of the furnace.



1. Semi Conducting Crystal
2. Incident Light
3. Electrolyte
4. Platinum grid
5. Voltmeter
6. Miliameter

Fig. 3: PEC solar cell using $MoSe_2$ crystals as photoelectrodes and platinum grid as counter electrode.

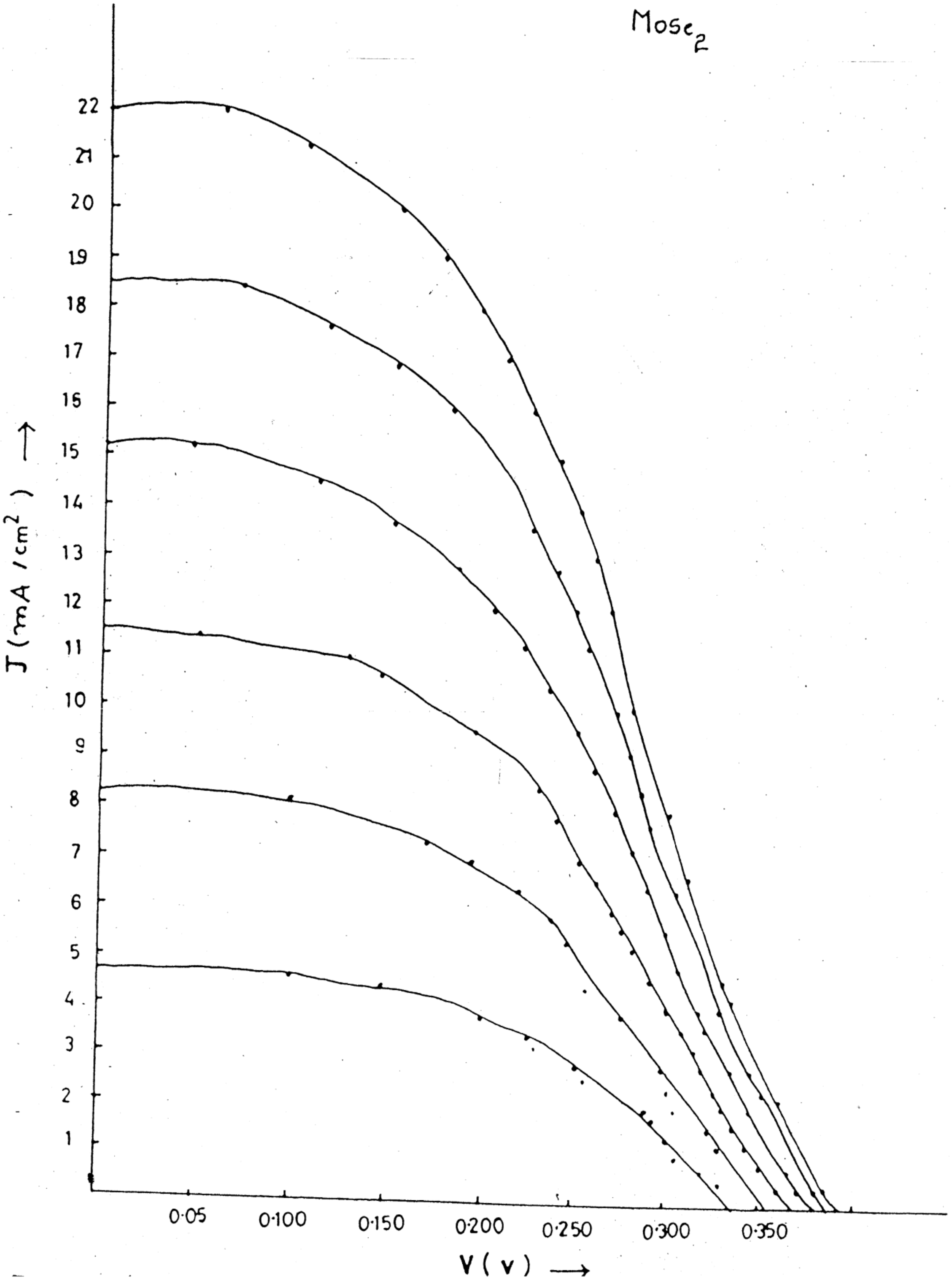

Mose2
J (mA / cm²) →
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0·05
0·100
0·150
0·200
0·250
0·300
0·350
V (v) →

Fig. 4: Photocurrent density (J_{sc}), photovoltage (V_{oc}) characteristics at different levels of illumination of PEC cell based on $MoSe_2$

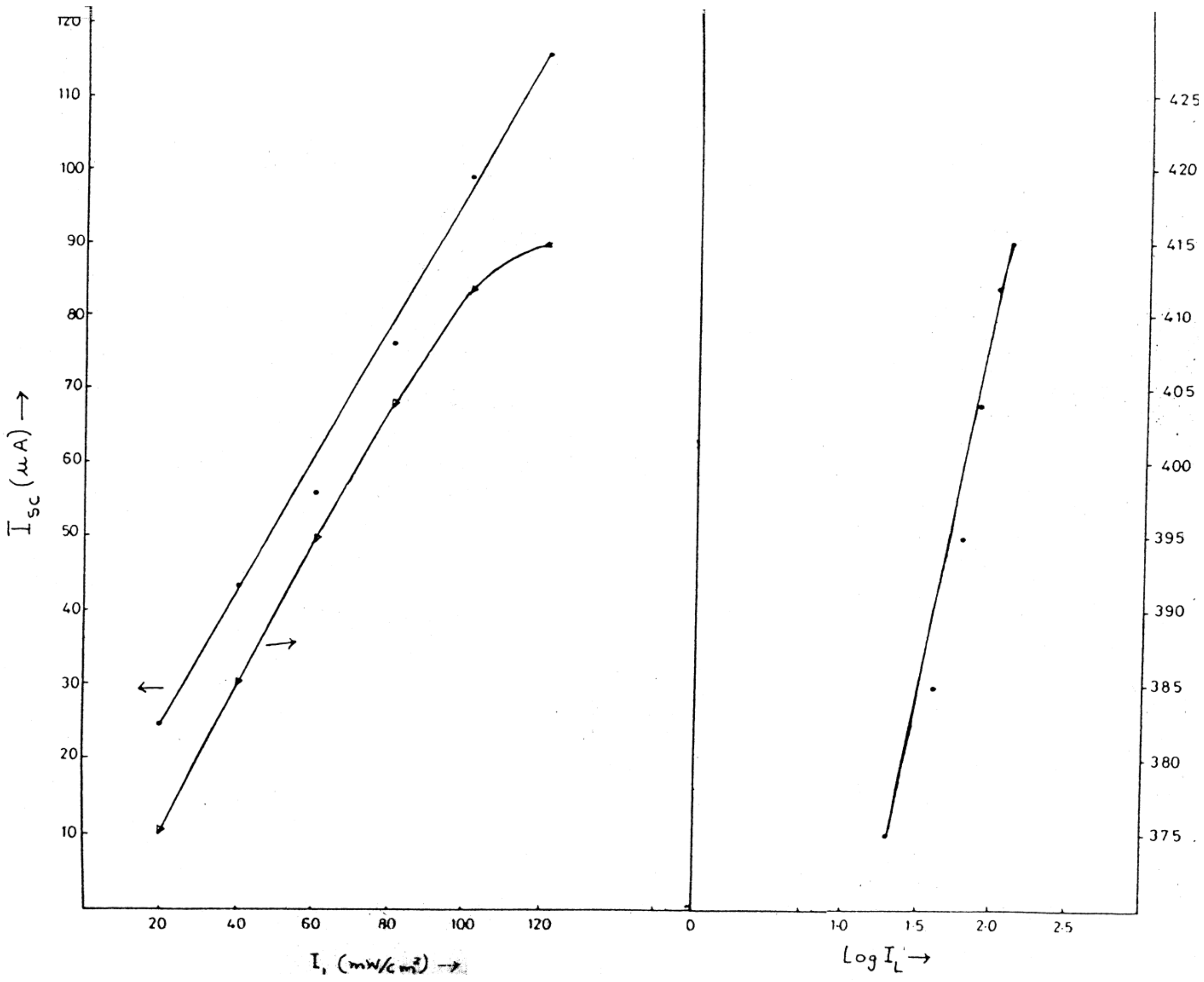


Fig. 5: Plots of V_{OC} and I_{SC} as a function of I_L and plots of V_{OC} as a function of Log I_L for PEC cell based on $MoSe_2$

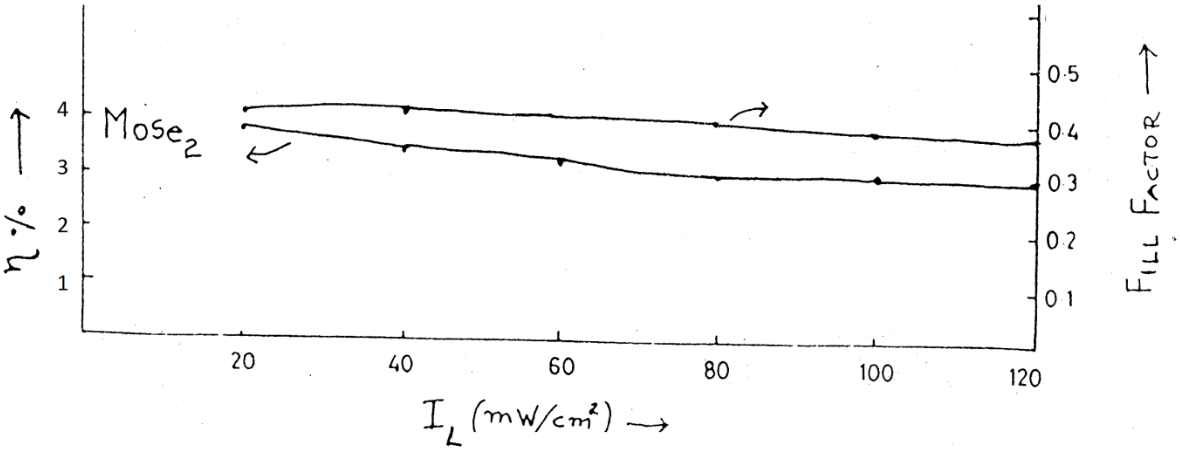


Fig 6: Plot of efficiency (*η%*) and Fill factor as a function of I_L for PEC cells based on $MoSe_2$