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FABRICATION OF ZINC OXIDE-CUPROUS OXIDE PHOTOVOLTAIC CELL FOR TEACHING PURPOSE USING LOCALLY AVAILABLE MATERIALS

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ABSTRACT
A Photovoltaic cell was fabricated using two simple, cheap, low toxic, environmentally friendly semiconductors (Zinc oxide and Cuprous oxide) to teach student recipients on how to convert light into electricity as obtained with the more complex conventional solar cells. The semiconductors were prepared using wet Chemistry techniques at room temperature. The UV- analysis gave the band gap energy values within the semiconductor range as 3.35eV and 2.51eV respectively. The light related current - voltage characteristics of the fabricated cell and its open circuit voltage for different illumination levels were comparable to those of conventional solar cells. This indicates that it is possible to produce a functional photovoltaic cell through local improvisation that can be used to stimulate the interest of learners.

Key Words: Zinc oxide, Cuprous oxide, Photovoltaic cell, Bandgap energy.

INTRODUCTION
Physics ideas and concepts most of the time, sound abstract to young learners[1] because the materials and equipment required for demonstrating these concepts are inaccessible, sophisticated and costly. In developing nations,the situation is even worse because the conditions required to carry out certain experiments are unattainable in most of their school laboratories. The result is that only theoretical presentations of lessons are done by Teachers while the young learners are left to grope in the dark as to the practicability of what they are taught. The result is that the interest of students is not in any way aroused to the need to study this Physical Science.

Perhaps if there are simpler and cheaper ways of demonstrating Physics concepts using locally available materials, young learners might show more interest for this subject. They may bechallenged to see every lesson presented to them as an opportunity to make improvisations to already existing equipment/material to have a better understanding of the lesson.

Solar energy has been accepted to be an alternative energy source to fossil fuels which are not environmentally friendly, non-renewable and depletable.[2] Different types of solar cells have been produced. The main challenge is producing those using materials can be locally sourced for, are environmentally friendly, and less toxic. Conventional Solar cells are made of Silicon whose conductivity can be manipulated at very high temperatures using special laboratory facilities which most of our local school laboratories cannot boast of. Consequently, there is need to fabricate photovoltaic cells using materials that are handy to demonstrate to learners the conversion of light into electricity which is the main job of Solar cells.

Band gaps which are due to the interaction of the conduction electron waves with the ion cores of a crystalhave received a lot of attention in recent times. Their knowledgeaids in the choice of specific materials for making different devices. Band gap energy value is the difference in energy between the lowest point of the conduction band and the highest point of the valence band[3]. Its width E_g which is measured in electron volts gives an effective assessment of a material[4]. Band gap energygives a direct measure of the energy required to break a bond in a semiconductor lattice and produce a free electron-hole pair[5].When photons of energies greater than E_g are shone on a semiconductor, they get absorbed and electrons are excited to the conduction band. The difference in energy between the valence band energy E_v and the conduction band energy$E_c$is given by $E_c - E_v = E_g$. In electron volts $E_g = \frac{hc}{\lambda e}$ where his Planck constant, c is the speed of light in a vacuum, λ is the wavelength of the light at peak absorption and e is the electronic charge. In this report, a ZnO – Cu_2O photovoltaic cell was fabricated and used to demonstrate photovoltaic effect at a pn-junction.

MATERIALS AND METHOD

Three (3) Bottles of Calamine Lotion each 200mls 5% acidity (apple cider), aluminum foil paper, copper coils(wire), strip of absorbent paper, empty compact disc(CD) case,Methylated spirit, copper sulphate salt, sodium chloride, masking-tape, 4 rubber bands.

In this work, a ZnO-Cu_2O photovoltaic cell was fabricated and used to demonstrate photovoltaic effect at a pn-junction. The unique thing about this approach is that the two semiconductors were prepared using cheap, locally available materials, at room temperature using wet Chemistry techniques. The ZnO was extracted from Calamine lotion (an aqueous suspension of zinc hydroxyl carbonate and bentonite used for treating skin irritations) which can be picked up from any Patent Medicine Store, while the cuprous oxide was prepared by inserting aluminum foil to reduce cupric ions in a copper sulphate/sodium chloride solution[6]. The absorption spectra of both semiconductors were run using a UV-Vis(Helius Zeta) thermo scientific Alpha double beam spectrometer with wavelength range between λ = 190nm to λ = 1100nm and their bandgap energy values were calculated. The semiconductors were then used to fabricate a photovoltaic cell to illustrate photovoltaic effect at a pn-junction. The current - voltagecharacteristics of this cell were studied. The open circuit voltage of the cell for different illumination levels was also measured.

Preparation of Cuprous oxide: A strip of absorbent paper $7cm \times 5cm$ dimensions was covered with aluminum foil of same dimensions. The two were bound togetherusing 0.5mm diametercopper coils. With the aluminum foil facing downwards, the assemblage was placed in a plastic basin and water was poured on it just enough to

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cover it. Half a teaspoon of sodium chloride and four teaspoons of copper sulphate crystals respectively were spread on the assemblage. After about two minutes, bubbles of hydrogen were seen on the foil as it disintegrated leaving behind a fine copper precipitate that got oxidized to the desired reddish brown cuprous oxide precipitate. Two teaspoons full of honey was poured on this precipitate to stop further oxidation to cupric salt.[7]Twenty mls(20mls) of the cuprous oxide solution was diluted to 10.00mls to get 0.1% concentration of it. This was poured into the sample tube of the spectrometer to display its absorption spectra.

Preparation of Zinc oxide: Two hundred mls (200mls) of Calamine lotion was dissolved in about 320mls of 5% acidity vinegar(applecider). After about 30minutes,the solution was filtered and the filtrate was sun dried. This was then dissolved in 50mls of methylated spirit and a few pellets of sodium hydroxide added to get the required Zinc oxide paste. Twenty mls (20mls) of the Zinc oxide solution was diluted to 100mls to get 0.1% concentration of it. This was then placed in the sample tube of the spectrometer and different wavelengths of light was shone at each sample for the comparator to display its corresponding absorption spectra.(Figure 1). The UV-Vis spectrometer used for running the absorption spectra works in accordance with Beer Lambert's principle.

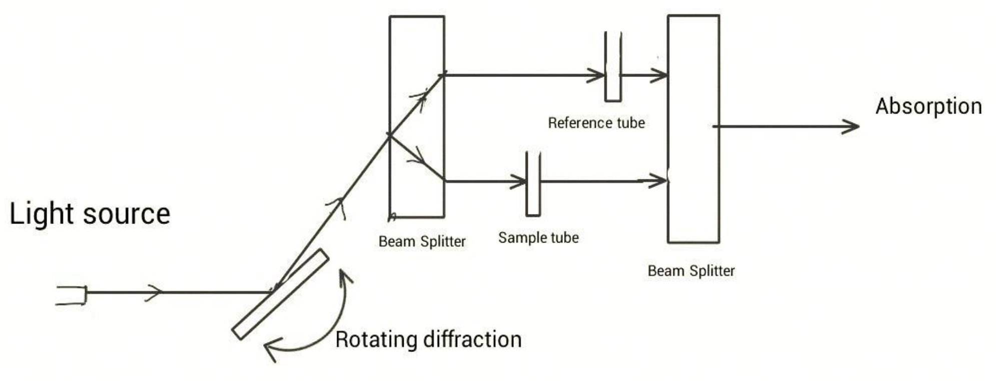

Fig 1: Sample illumination to produce the absorption spectra of the semiconductors.

Fabrication of the ZnO–Cu_2O Photovoltaic cell: The Cuprous oxide electrode which acts asp-type semiconductor[8] was placed on one side of an empty compact disc (CD) case while the Zinc oxide the n-type semiconductor [9] was placed next to it with a salt bridgein between the two semiconductors. The leads from the cuprous oxide electrode and that from the Zinc oxide electrode were left outside the CD case for connection purposes as shown (Figure. 2). The two electrodes are held in place in the CD case using masking tape. The CD case was then covered and wrapped up with the rubber bands to minimize the evaporation which was likely to occur.

The fabricated photovoltaic cell, was irradiated with a 12V, 20W halogen lamp [10]and a micro ammeter and a millivoltmeter were used for the current – voltagereadings. The lamp was connected to a variable dc power supply(0 – 15V)(Figure 3).By varying the current across the halogen lamp, different light intensities were produced and these were read off from a lux meter.

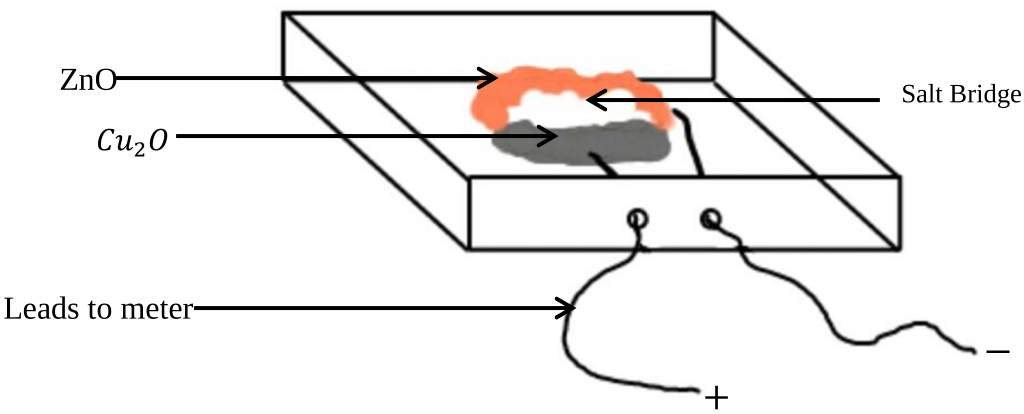

Fig. 2 Fabricated cell showing the arrangement of ZnO and Cu_2O electrodes in a CD container

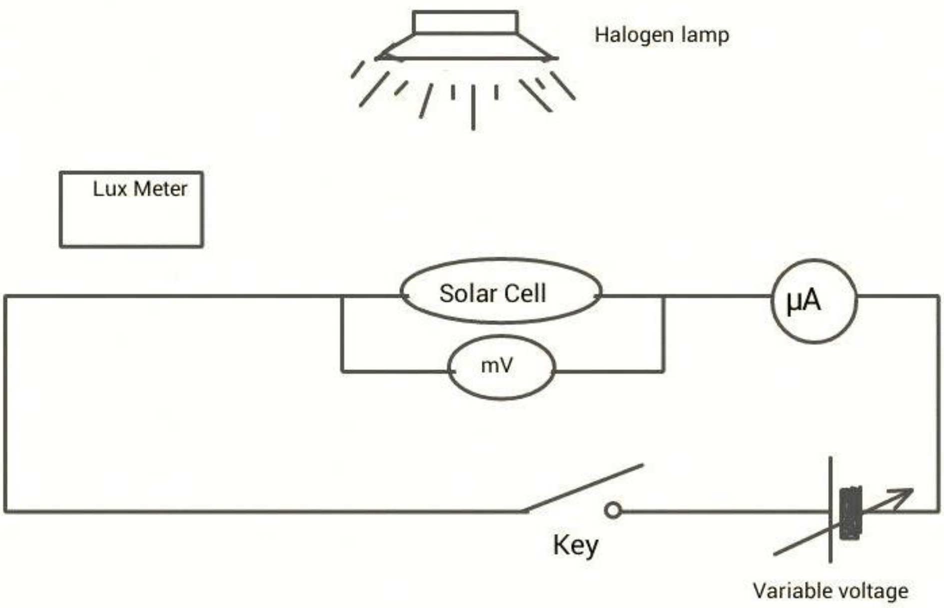

Fig.3:*Circuitfor illumination I-V Characteristics of fabricated cell*

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RESULTS

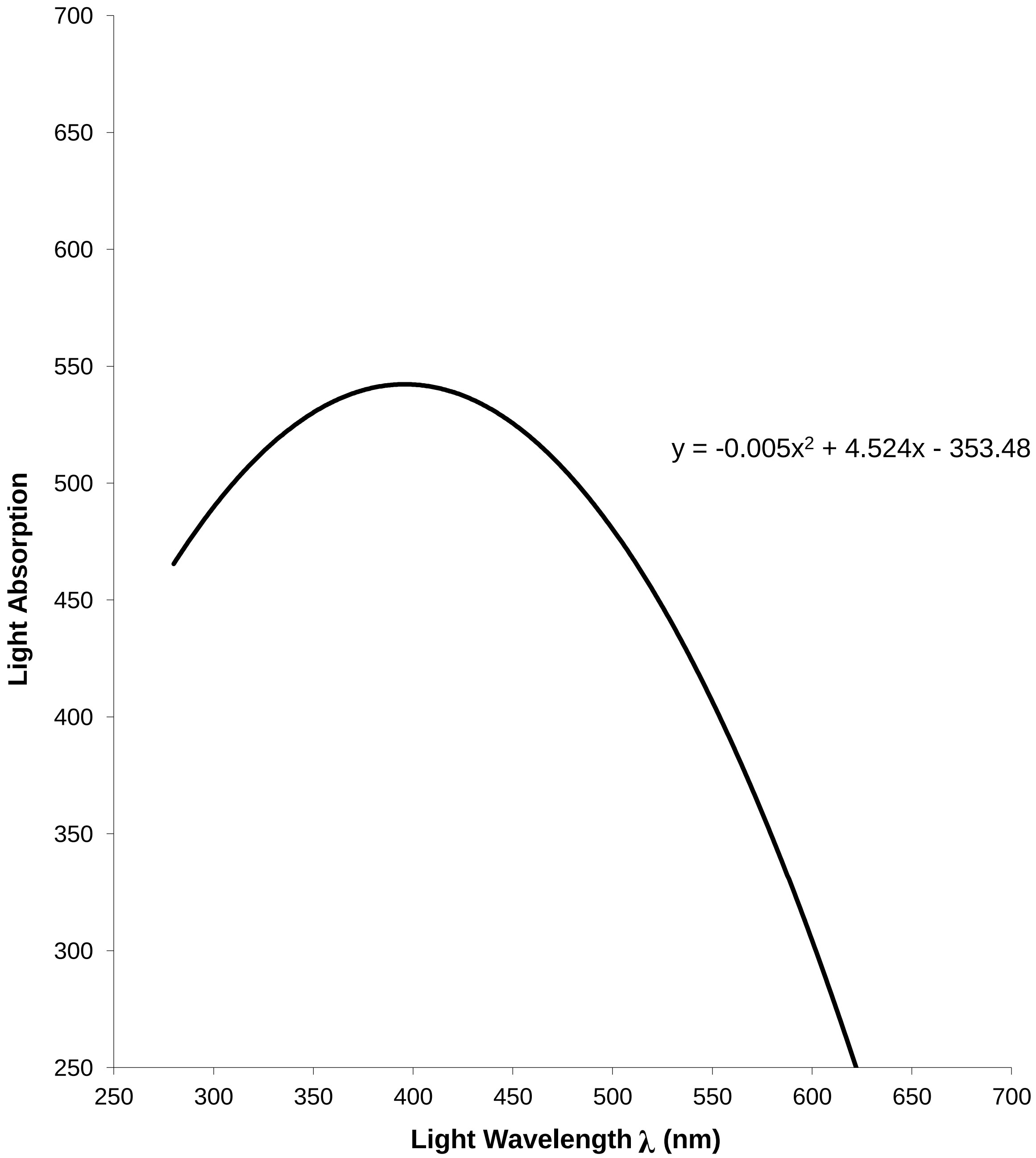

Fig.4: Absorption spectra of Zinc oxide.

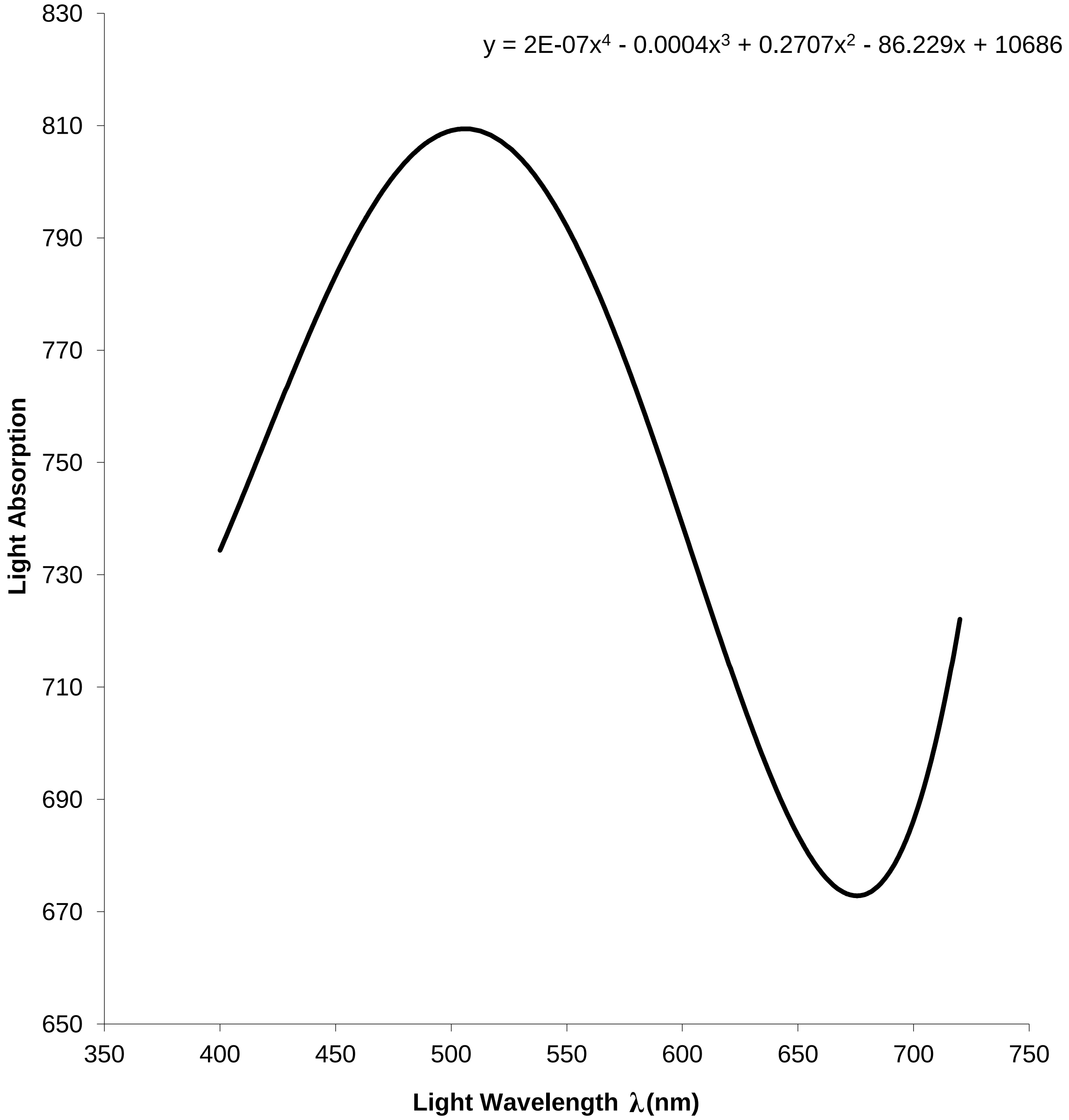

Fig. 5: Absorption spectra of Cuprous oxide.

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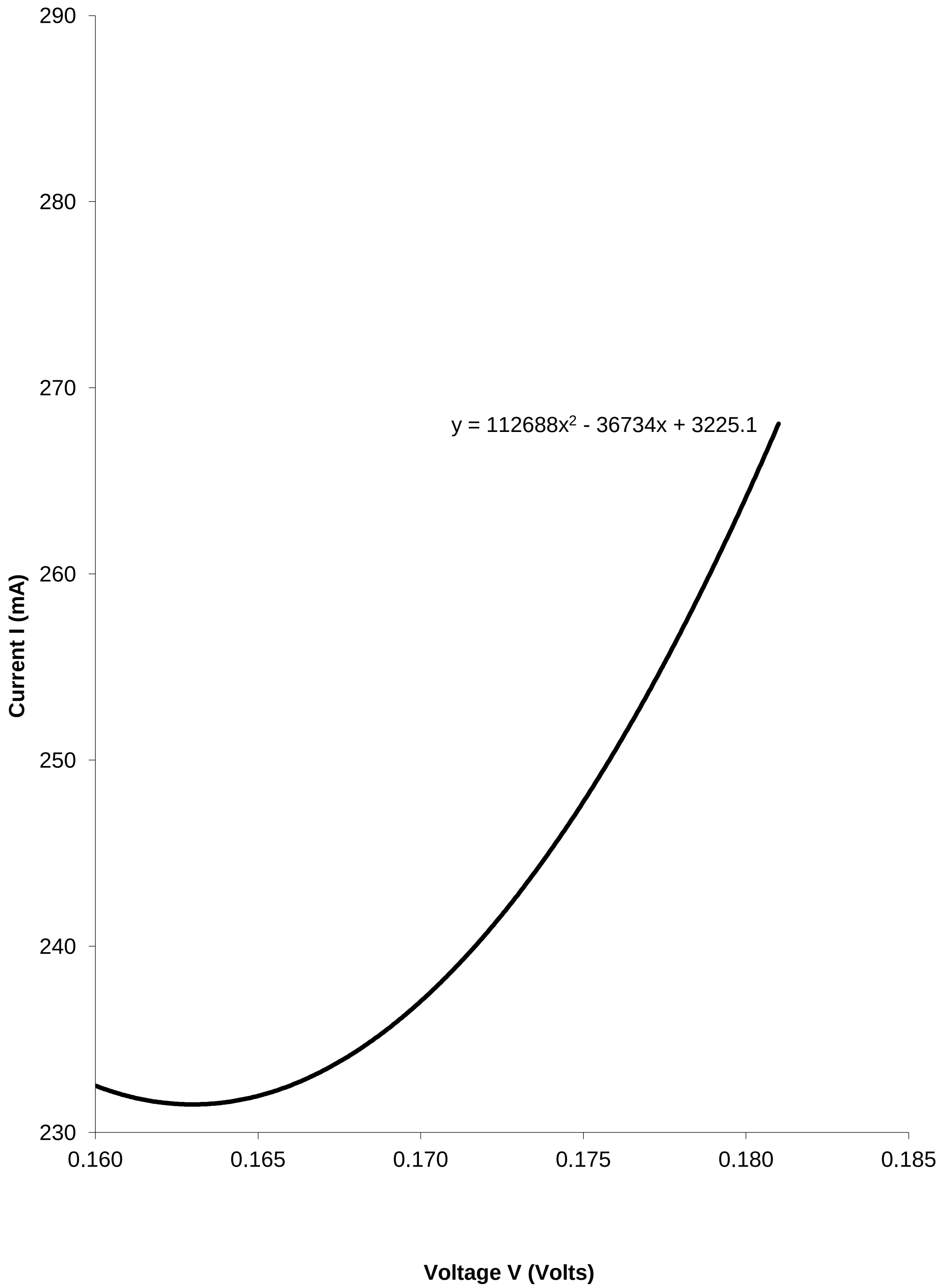

Fig6:Intensity related I-V characteristics of fabricated photo voltaic cell.

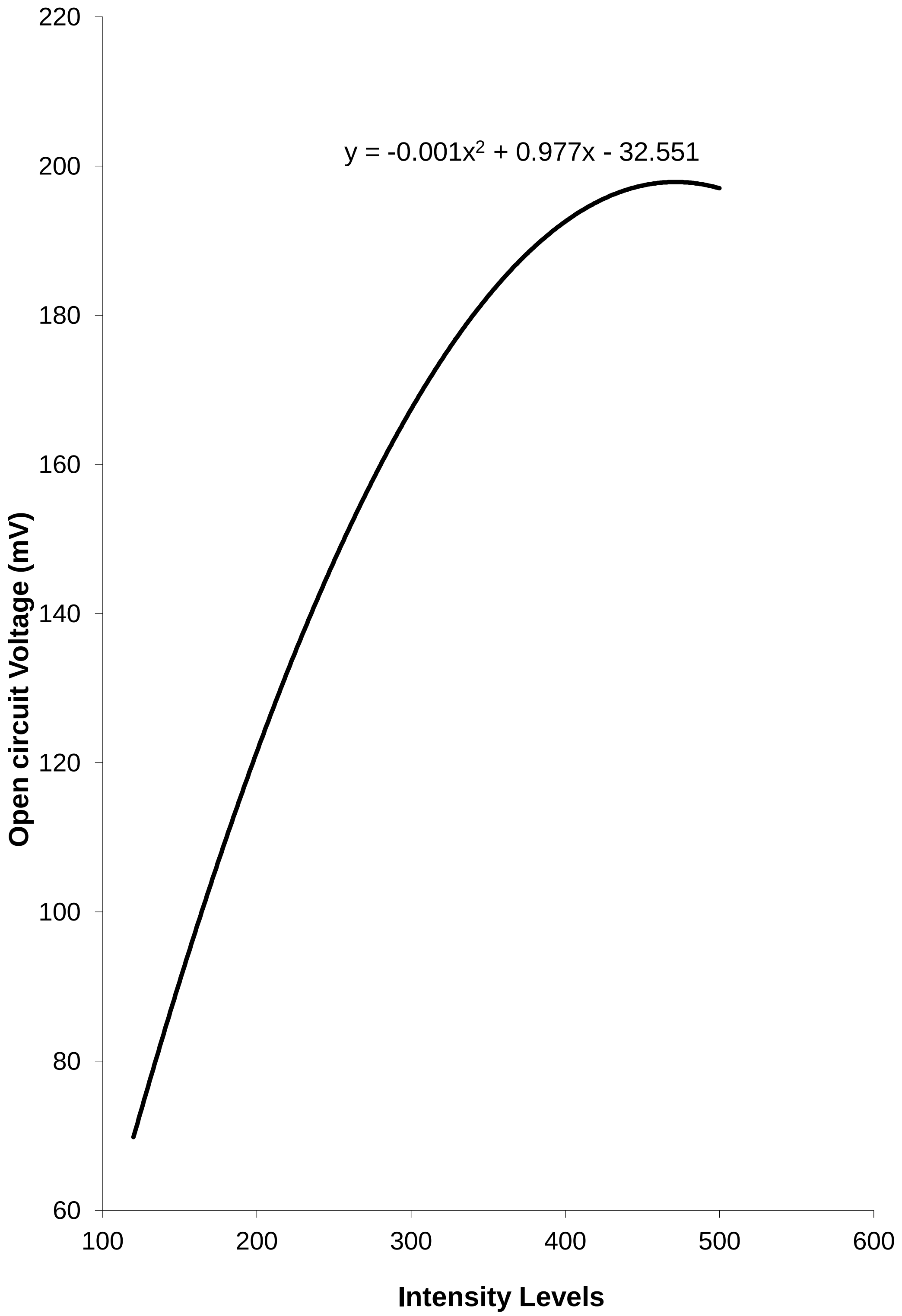

Fig. 7: Intensity versus open circuit voltage of fabricated cell for different illumination levels

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Figure 4 shows the Absorption spectra of the Zinc oxide sample. The Absorption Spectra showed a prominent peak at λ = 370nm and the band gap energy value for the Zinc oxide was calculated to be 3.35eV±0.01eV. Figure 5 shows the Absorption spectra of theCuprous oxide. The strongest absorption was at λ = 495nm and the calculated bandgap energyfor the cuprous oxide at room temperature was 2.51eV±0.01eV. The I –V characteristics of the cell are as shown (Figure 6). The obtained values showed that though increased illumination of the cell increased the I-V values, not all parts of the illumination gave a photovoltage. The open circuit voltage of the cell for different light intensities are also shown (Figure 7). In the forward-bias mode it was observed that the current I increased linearly with voltage V up to a maximum saturation value of 0.181Volt while in the reversed mode, the cell demonstrated a rectifyingbehavior. Figure 7 shows the Intensity versus Open-circuit voltage graph of the fabricated cell.

A gradual increase of the Open circuit voltage with light intensity was observed up to a maximum value of 0.198 Volts (Figure 7). The life span of the fabricated cell was estimated tobe about two days.

DISCUSSION

The fabricated photo voltaic cell delivered a maximum current of 280μA. Thisseems to be an improvement on a similar Cu_2O–ZnO solar cell (which used ZnO extracted from a white Zinc sunscreen cream containing about 25% of ZnO using white spirits and methylatedspirit) which gave a voltage of 0.1V and produced a maximum current of 250μA in sunshine[7].

The fabricated cell's dysfunction was however gradual and its short lifespan could probably beattributed to some oxidation/reduction processes which may have occurred in the cell.

Futhermore,the interface between the cuprous oxide and zinc oxide may have been a source of significant loss in photo collection [11]

The Band gap energy value of the Zinc oxide made from wet chemistry techniques was found to be 3.35eV±0.01eV.

This falls within the range quoted as 3.35eV in a research Article[9]

The Cuprous-oxide band gap energy value determined to be 2.51eV is slightly higher than the range 2.00-2.2eV reported by Grozdanov in 1994 and mentioned in a research on Solar cells [8]The I -V Characteristics of the fabricated photovoltaic cell was for the forward bias mode only and it was found that the current increased with voltage up to a maximum saturation value of 0.181 Volts.

The intensity versus open circuit voltage curve shows a gradual increase up to a maximum value of 0.198 Volts. The maximum current delivered by the cell was measured and found to be 280μA which is an improvement on that of a similar cell which gave a voltage of 0.1V and produced a current of 250μA in sunshine [7].

Attempts have beenmade to show that Physics concepts which should excite young learners can be brought home to them using cheap, locally available, low toxic environmentally friendly materials. We also illustrated photovoltaic effect at a pn-junction using a fabricated cell made with semiconductor materials prepared using wet chemistry techniques at room temperature.The semiconductors showed photoconductivity because they absorbed photons to produce free carriers[11] .The fabricated photovoltaic cell had a low output voltage and short life span which indicates that its usefulness will be limited to work which requires such low voltages. However we believe that if the semiconductors are derived from other inorganic materials and at higher temperatures, the performance of the cell might improve. Local schools that cannot afford Silicon solar cells could take a cue from this work and try similar improvisations to make their own photovoltaic cells using materials they can locally source for. The set objectives for this work were achieved and the experience was rewarding.

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