# ANSOLE Mini-Symposium in Kenya

# (AMSK 2013)

## 9. May 2013, Nairobi Kenya

***Venue***: *Department of Physics, Chiromo Campus, University of Nairobi, Nairobi Kenya*

## Organising Committee

Prof. Dr. Bernard O. C. Aduda, PD Dr. Daniel A. M. Egbe, Dr. Robinson J. Musembi, Dr. Sebastian Waita, Dr. Kenneth A. Kaduki, Dr. Justus Simiyu, Dr. Alex. Agacho, Dr. Francis Nyongesa

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# LIST OF PARTICIPANTS

| | Name | Institution |
|---|---|---|
| 1 | Dr. Daniel A. M. Egbe | African Network for Solar Energy |
| 2 | Dr. Robinson Musembi | University of Nairobi |
| 3 | Dr. Sebastian Waita | University of Nairobi |
| 4 | Dr. Justus Simiyu | University of Nairobi |
| 5 | Dr. Alex Ogacho | University of Nairobi |
| 6 | Dr. Francis Nyongesa | University of Nairobi |
| 7 | Dr. Silas Mureramanzi | University of Nairobi |
| 8 | Mr. Charles Wangati | Technical University of Kenya |
| 9 | Mr. John Njagi Nguu | University of Nairobi |
| 10 | Dr. Alix Deyahem-Massop | University of Nairobi |
| 11 | Mr. Steve Biko Omolo | EPIXSOLAR |
| 12 | Mr. Lawrence Munguti | Kenyatta University |
| 13 | Mr. Godwin Mwebaze A. | Makerere University, Uganda |
| 14 | Mr. Victor Odari | Masinde Muliro University of Science and Technology |
| 15 | Mr. Peter Kinyua | Kenyatta University |
| 16 | Mr. Boniface Muthoka | University of Nairobi |
| 17 | Mr. Eneku John Paul | Makerere University, Uganda |
| 18 | Dr. Najya Muhammed | Pwani University |
| 19 | Dr. Kenneth A. Kaduki | University of Nairobi |
| 20 | Mr.Peter Cheruiyot Korir | University of Eldoret |
| 21 | Mr. Boswell Wanyoike Gathu | University of Nairobi |
| 22 | Mr. Nicholas Musila | Kenyatta University, Nairobi |
| 23 | Ms Belinda Spira | ANSOLE Germany e.V |
| 24 | Mr. James Wafula | University of Nairobi |

| | | |
|---|---|---|
| 25 | Mr. Calvince Odhiambo | Technical University of Kenya |
| 26 | Mr. Musa Ayoro | University of Nairobi |
| 27 | Mr. Thomas Nyang'onda | University of Nairobi |
| 28 | Mr.Ipalei Kelvin Omonya | University of Nairobi |
| 29 | Mr. Jonathan Ganira | University of Nairobi |
| 30 | Mr. Alvin Mutisya | University of Nairobi |
| 31 | Mr. Roy Allela | University of Nairobi |
| 32 | Mr. S. M. Mutunga | University of Nairobi |
| 33 | Prof Bernard Aduda | Principal, CBPS, University of Nairobi |
| 34 | Ms Everlyne Akinyi Odera | University of Nairobi |
| 35 | Ms Esther Wanjiru Ngugi | University of Nairobi |

# PROGRAMME

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|---|---|
| 10.00-10.10 | Welcome addresses by Dr **Robinson Musembi**, national representative of ANSOLE in Kenya and by PD Dr **Daniel A. M. Egbe,** ANSOLE coordinator |
| **Part I** | ***Chairmen***: Dr. Juma Robinson Musembi, Dr. Francis Nyongesa |
| 10.15-10.30 | *"An overview of renewable energy and material research at the department of physics, University of Nairobi*", **Sebastian Waita,** University of Nairobi, Nairobi Kenya |
| 10.30-10.45 | *"Overview of PV Education in Kenya :Status and Role of CMG"* **Justus Simiyu**; University of Nairobi, Nairobi Kenya |
| 10.45-11.00 | "*Fabrication $TiO_2/Nb_2O_5$ composite electrode thin films deposited using electrophoretic deposition technique*" **John Njagi Nguu,** Robinson J. Musembi, Francis Nyongesa, Bernard, O. C. Aduda**,** Department of Physics, University of Nairobi, Nairobi Kenya |
| 11.00-11.20 | **"***Presentation of EPIXSOLAR"* **Steve Biko Omolo,** CEO of EPIXSOLAR , Nairobi Kenya |
| 11.20-11.40 | *"The synthesis of juglone as a fine chemical in super critical carbon dioxide"* **Najya Muhammed,** David Worrall, Pwani University, Kilifi, Kenya, & Loughborough University, Leicester, UK |
| 11.40-12.00 | **SHORT BREAK** |
| **Part II** | ***Chairmen:*** Dr. Justus Simiyu, Dr. Alex Ogacho |
| 12.00-12.20 | *"CdX – based PV/PEC solar cells"* **Silas Mureramanzi,** University of Nairobi, Chiromo Campus, Nairobi, Kenya |
| 12.20-12.35 | Welcome address by the Principal of the College of Biological and Physical Sciences, University of Nairobi: **Prof. Bernard O. C. Aduda** |
| 12.35-12.55 | *" Effect of sputtering power on structural and optoelectronic properties of $CUAl_XB_{1-X}Se_2$ thin films for photovoltaic application (Ph. D. proposal)"* **Charles Wangati,** Technical University of Kenya (TUK), Nairobi, Kenya |
| 12.55-13.30 | *"A novel design and evaluation of a solar module - charge controller configuration for maximum power generation under partially shaded conditions (Ph.D. Proposal)"* **James Wafula,** Justus Simiyu, Bernard O. C. Aduda, University of Nairobi, |

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| | Nairobi Kenya |
| 13.30-13.50 | "*ZnO:Sn Deposition by Reactive Evaporation: Effects of Doping on the Electrical and Optical Properties*" **Lawrence Munguti**, R. J. Musembi, W. K. Njoroge, University of Nairobi, Nairobi Kenya; Kenyatta University, Nairobi, Kenya |
| 13.50-14.10 | *"Stability Monitoring of $Sn_xSe_y$/ZnO:Sn solar cells prepared by resistive evaporation"* **Peter Kinyua,** R. J. Musembi, M. Munji, University of Nairobi, Nairobi Kenya; Kenyatta University, Nairobi, Kenya |
| 14.10-14.30 | *"Electrical and optical properties of TiO2:Nb TCO thin films Prepared by Spray Pyrolysis"* **Victor Odari,** J.M. Mageto, C. M. Maghanga, M. Mwamburi, G. A. Niklasson and C. G. Granqvist, Moi University, Physics Department, Eldoret, Kenya, Department of Engineering Sciences, Uppsala University, Uppsala, Sweden |
| 14.30-14.50 | *"The effect of Al doping on the electrical and optical properties of tin oxide thin films"* **Calvince N. Odhiambo,** R. J. Musembi, . M. Mwamburi. University of Nairobi, Nairobi Kenya |
| 14.50- 15.05 | *"Eta Solar Cells*" **Robinson J. Musembi**, Department of Physics, University of Nairobi, Nairobi Kenya. |
| 15.05-15.20 | *Design Principles of Organic Materials for Solar Cell Applications (Side Chains Effects on Photovoltaic Response of Anthracene-Containing PPE-PPVs)* **Daniel. A. M. Egbe**, Johannes Kepler University Linz, Linz Austria |
| 15.20-15.40 | **Closing Ceremony:**<br>Handing of attestations of participation , group photo, etc |

# Material Science and Energy Research at the Department of Physics, University of Nairobi, Kenya

Sebastian Waita, Justus Simiyu, Robinson J. Musembi, Alex. Agacho, Thomas Nyang'onda , James Wafula , Silas Mureramanzi, Francis Nyongesa, Julius Mwabora and Bernard Aduda.

*Department of Physics, University of Nairobi, P.O BOX 30197-00100, NAIROBI, KENYA*

Email: swaita@yuonbi.ac.ke

Energy is the main driver in any economy because almost everything is directly or indirectly related to energy. Energy determines to a large extend the prices of goods, commodities , services and hence the cost of living in a country. Provision of adequate and affordable energy for any economy is therefore very critical. Material research on the other hand provides information which helps to determine the best applications for a certain material type. This scenario provides the rationale for the Condensed Matter Group based at the Department of Physics, University of Nairobi, to be focused on material science and energy (specifically renewable energy) research. The research interests spans across key areas such as the development of low cost dye sensitized solar cells, modeling of dye sensitized solar cells, extremely thin absorber (ETA) solar cells, cadmium-based photovoltaic solar cells, nanotechnology for energy conversion and other applications, water purification research. New and upcoming research areas include energy generation through hydrogen, biomass and wind. To facilitate the research, the laboratory is equipped with the latest research equipment which include: solar simulator, Shimadzu Double Spectrophotometer, Potentiostat, Edwards Vaccum Coating System, Spin Coater, Electropheric Deposition system, Raman Spectroscopy Equipment, Programmable Furnace. Its resource based in terms of personnel as well as equipment has made the Department a regional centre; attracting postgraduate students from the region as well as from other Universities within the country. For instance, in the last two years, over fifteen postgraduate students from other Universities in Kenya and neighbouring countries have been hosted in the Department for varying durations. As part of our social responsibility, the group organizes training for solar photovoltaic installers regularly. Since inception of the training last year, over eighty solar photovoltaic installer technicians have been trained. The group has established and maintained active research collaborations with at least seven different institutions in different countries across the continents.

**Key words**: material science, dye sensitized solar cells, eta solar cells, photovoltaic, renewable energy

# EPIXSOLAR

Steve Biko Omolo

*Mokongeni Drive, P.O. Box 00200-35003, Nairobi, Kenya,* ***tel:*** *+254 725 490 330, +254 735 785 377, email: epixsolar@gmail.com, website: www.epixsolar.kbo.co.ke*

## General Information

Charles Fritts was the first person to construct a solar cell, back in 1880. He intended to trap the solar energy for lighting. His prototype only utilized 1% of the solar energy, but the discovery was a remedy to the energy demand across the world. The photovoltaic systems are accredited for the fact that they do  not use fuel, and that their modules lasts for up to 40 years upon installation. However, the PV systems help in reducing $CO_2$ emissions, promoting national energy independence, and creating high tech jobs. Venturing in to the PV industry means financial liberty for the imminent project pioneers and even business personnel.

## Institution Information

**COMPANY BACKGROUND:** Epixsolar started as a bridge to the gap in the renewable energy sector arising from the inaccessibility of some areas and logistical constraints experienced by providers, therefore leaving millions unable to access cheaper alternative energy source. Efficiency in delivery and quality of products and services has established a relationship of satisfaction to both the customers and the company. Due to its networks, Epixsolar continues to provide low cost and affordable renewable energy solution hence giving it leverage over its direct and indirect competitors.

**CURRENT ACTIVITIES:** Epixsolar provides quality and affordable lighting solutions of international standards with partnerships with reputable suppliers.  Provision of solar water heating products, water pumps and photovoltaic (PV) panels is also undertaken to both household and corporate clients.

**MAJOR PRODUCTS AND SERVICES:** Solar lamps (various brands), mobile charging accessories, solar water pumps (shufflow) and photovoltaic (PV) panels, converters, charge controllers and solar batteries. Epixsolar maintains its products after sale in case of breakage or technical malfunctions and supports feedback from its customers as part of its warranty on each product.

**MAJOR MARKETS:** Nairobi area (Mathare slum, Kibera, Makongeni, Westlands, Embakasi, Kitengela, Donholm), Meru, Busia, Isiolo, Kisumu, Siaya and Masai mara (Narok).

**TARGETS:** Epixsolar projects and aims to expand into the regional markets and venture into wind power and biofuel (bagasse, biogas) and inject the renewable energy into the national grid.

# Solar Energy Conversion to Electricity (Solar Photovoltaic)

Steve Biko Omolo

*Mokongeni Drive, P.O. Box 00200-35003, Nairobi, Kenya*

*Email: epixsolar@gmail.com*

Solar power is a conversion of sunlight in to electricity using a concentrated solar power (CSP), or using photovoltaic (PV). As a self-declared ambassador of solar power in Kenya, my interest settles for solar energy conversion to electricity using the solar photovoltaic. I am the CEO of the Epixsolar Company in Kenya. Epixsolar is a small company that purchases solar lighting equipment, and other electricity-powered appliances from major distributors, and then supplies them to the isolated regions in Kenya with no grid power supply. The company targets communities such as the nomads and low-income earners as the prospective customers. Additionally, Epixsolar Company strives to help Kenyans to cut down the huge electricity bills accrued from everyday use of the hydro-generated power. Kenya is a republic within the eastern Africa region. The region enjoys many sunshine days throughout the year. This paper explores the challenges facing solar power in Kenya.

**Key words**: Solar lighting equipment, electricity bills, prospective customers, low-income earners

## Current developments

The use of solar photovoltaic is fast growing, both at the domestic and commercial usage levels. In the European Photovoltaic Industry Association (EPIA), scientists anticipate a total global capacity of 60,638 MW of solar power by the end of 2013. Despite the little exposure, campaigns and media coverage, the use of solar power is fast gaining popularity. However, to achieve a consumption base for all this production, EPIXSOLAR opts to introduce the technology to the rural areas, the marginalized community, and the low-income earners, especially in Africa.

The less-privileged members of the society acknowledge the fact that kerosene prices are getting expensive. Thus, the enlightened populations replace the use of kerosene for lighting with the cheap solar powered gadgets. The enlightened few acknowledge that they have to sacrifice their resources to meet the installation costs of the solar equipment, after which, they enjoy an unlimited power supply with no running costs. Moreover, the BOXX help in distributing solar powered gadgets and the solar charging units inside Kenya.

## Energy Policies in Kenya: A major dilemma

Kenya as a republic is currently suffering from the widening gap between energy demand and the energy supply, especially for the electric power. Over the years, the dilemma is so factual, that the Kenyan Government merely considers population planning among other development planning with the hopes that the strategy would help reduce the impact of the dilemma to the population. However, as a growing economy, the Kenyan Government has raised awareness of its limitations, thus, encourages the private sectors help in developing and marketing the other renewable energy sources such as the solar power among others. Since Kenya is just a growing economy, it cannot deviate from such unlimited resources. Besides, Kenyans have to stop thinking that provision of energy is an exclusively government's responsibility.

**Challenges in marketing solar power**

The success behind marketing solar products solely relies on the ability of the technology to provide energy, which meets the end users, rather than on the willingness of the consumer to adopt end-users that would enable them to meet the capabilities of the sophisticated technologies. Furthermore, the technology does not contribute substantially towards meeting the National Energy demand, but it contributes towards satisfying specific individual's energy demands.

Kenya being a county where the majority lives below the poverty line, most people need demonstrations and free sample before they can welcome the idea of investing in Solar power. As a result, the solar powered products have no bargaining power in the market. On the other side, promoters for the solar powered gadgets cannot afford to offer free sample becuase these gadgets are costly. For example, a solar powered mobile phone charger would cost KShs 1000 (about $12), but the marginalized communities, or the low-income earners would not be able to raise the amount. Yet, they would easily pay up the cost of charging their phones.

The campaigns aimed at promoting the solar powered gadgets do not pull large crowds. The populations have a common notion that the gadgets are intended for capturing or squandering their financial resources. This is attributed to the fact that most persons are not educated, thus suffering from extreme ignorance. Such people cannot just comprehend how such small gadgets would power their radios or television sets. Therefore, the promoters have to go through the difficult work of enlightening and educating them about their power needs before advertising the solar products to them.

**Lessons learnt**

Kenya has the potential to utilize solar energy; if and only the experts outlay a perfect marketing strategy for the solar powered appliances and the solar charging units. Otherwise, the technology would dwell under-utilized, and the low-income people would not enjoy the affordable solar technology.

# The Synthesis of Jugloneas a Fine Chemical in Super-Critical Carbon Dioxide

Najya Muhammed [1] and David Worrall[2]

[1]*Pwani University, P.O Box 195 - 80108 Kilifi. Kenya,*

[2]*Loughborough University, Ashby Road, LE11 3TU, Leicester. UK.*

*Email: najy21@hotmail.com*

Chemical (thermal) oxidations are performed with aggressive oxidants that produce large amounts of toxic waste in comparison to photo-oxidation in the production of fine chemicals. Juglone is a fine chemical and has alleopathic effects (inhibits growth of plants) as well as it is used as a preservative in non-alcoholic drinks and, as a result, is quite expensive. Photo-oxidation conversion of 1,5-dihydroxynaphthalene to Juglone was followed using super critical carbon dioxide (sc$CO_2$) as a solvent. Methylene Blue was used as sensitizers in the formation of Juglone in both Sc$CO_2$ and in conventional solvents and showed that the concentration of the sensitizer only affects the rate of the reaction slightly as it is used up in the catalytic form. The production of Juglone was monitored *in situ* using UV-visible spectrophotometer for the photooxygenation process. It was found that a relatively higher amount of Juglone was produced in sc$CO_2$ condition in comparison to the conventional methanol solvent.

**Keywords**: Juglone, Super Critical Carbon Dioxide; photooxygenation; green chemistry; photochemistry.

# Effect of sputtering power on structural and optoelectronic properties of $CuAl_XB_{1-X}Se_2$ thin films for photovoltaic application

Charles K. Wangati

*Department of Technical and Applied Physics, Technical University of Kenya, P.O. box 52428-00200 Nairobi, Kenya. Tel. +254(020)343672, 2249974, 2251300, Website: www.kenyapolytechnic.ac.ke*

**Ph D. Proposal**: This study intends to fabricate and characterize $CuAl_xB_{1-x}$ $Se_2$ thin film. The compound is based on I-III-VI family of chalcopyrite which has generated a lot of interest as an absorber material for solar cells due to their high absorption coefficient. Further, the chalcopyrites are applied as sensors and light emitting diodes. Solar cell has the potential of being the main drive to economic prosperity as it is one of the most promising sources of cheap, environmentally friendly and renewable energy. The global average power demand is expected to reach 28TW by 2050, which is only a fraction of solar energy that reaches the earth surface ($1.2 \times 10^5$TW) at any time. Although this viable and enormous source of energy reaches the Earth from the Sun, the current solar energy production is still low due to conversion inefficiencies that make it necessary to focus research towards solar cells. The current solar energy market is dominated by crystalline silicon technology which is generally expensive and has attained an efficiency of about 24.7% and is approaching a theoretical maximum of 30%. In order to reduce cost, focus is shifting towards thin film based I-III-VI family chalcopyrite compounds where cheaper $CuIn_xGa_{1-x}$ $Se_2$ semiconductor is reported to have attained an efficiency of approximately 20 %. The progress made on $CuIn_xGa_{1-x}$ $Se_2$ as an absorber material has acted as an impetus for the proposed research work. This study is based on $CuAl_xB_{1-x}$ $Se_2$ compound where aluminium and boron substitute the toxic and rare indium as well as gallium, respectively. The research procedure involves deposition of CuAlB compound precursor by DC magnetron sputtering of $CuAl_{0.7}B_{0.3}$ alloy target. The precursor films are made to react with selenium through RF magnetron sputtering of selenium metal target. The deposition is done using Edwards Auto 360 RF and DC magnetron vacuum system where deposition power is varied at controlled intervals. Characterization of the resulting thin film based on structural and optoelectronic properties is done using XRD, XPS, AFM, SEM, UV-Visible-IR Spectrometer, four point probe and illuminated I-V set up. The experimental results will be compared with the data theoretically generated by Quantum Espresso simulation based on Density Functional Theory (DFT). The outcome of this research will increase fundamental science and engineering based on structural and optoelectronic properties of $CuAl_xB_{1-x}$ $Se_2$ compound as solar absorber material among other optoelectronic devices. In general the study will contribute towards achieving greater efficiency in production of “green” energy.

# Transparent and Conducting $TiO_2:Nb$ Thin Films Prepared by Spray Pyrolysis Technique

Maxwell J. Mageto[1]*, C.M. Maghanga[3], M. Mwamburi[2], B.V. Odari[1]

1. Department of Physics, Masinde Muliro University of Science and Technology, P.O. Box 190, 50100, Kakamega, Kenya.
2. Department of Physics, Moi University, P.O. Box 1125, Eldoret, Kenya.
3. Department of Physics, Kabarak University, P.O. Box 3270, Nakuru, Kenya.
jmmageto@yahoo.com

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*Email: jmmageto@yahoo.com*

To date, only sputtering and pulsed laser deposition (PLD) techniques have been employed successfully to fabricate highly conducting and transparent $TiO_2$:Nb (TNO) films. In this article, we demonstrate that transparent and conducting $TiO_2:Nb$ films can be made by the spray pyrolysis technique. The films were deposited on Corning 7059 glass substrates at $500 \pm 15^{\circ}C$ using an alcoholic precursor solution consisting of titanium (IV) isopropoxide and $NbCl_5$. The influence of increasing Nb concentration on the electrical, optical and structural properties was investigated. The minimum resistivity, $3.36 \times 10^{-3}$ Ω cm, for $Ti_{1-x}Nb_xO_2$ film (x = 0.15) was obtained after 1 hour post deposition annealing in hydrogen atmosphere at 500°C. The x-ray diffraction of hydrogen annealed films showed a polycrystalline anatase (004)-oriented phase without any second phases. The optical band gap for undoped and doped films lay in the range 3.38 – 3.47 eV. Using dispersion analysis, optical constants were determined from spectro-photometric measurements for films on glass.

**Keywords:** Spray pyrolysis; tin oxide; Nb doping; thin film

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## PUBLICATIONS OF MAXWELL J. MAGETO

1. Benjamin.V.Odari, **Maxwell Mageto**, Robinson Musembi, Henrick Othieno, Francis Gaitho and
Valentine Muramba, (2013), "Optical And Electrical Properties Of Pd Doped $Sno_2$ Thin Films Deposited By Spray Pyrolysis," Australian Journal of Basic and Applied Sciences, Vol. 7 issue 2 Pg 89-98, 2013 (ISSN 1991-8178)

2. **Maxwell J. Mageto**, V. Muramba, M. Mwamburi, (2013), "Preparation and Characterization of Transparent and Conducting Aluminum doped Tin Oxide thin films prepared by Spray Pyrolysis Technique", East African Journal of Engineering, Science and Technology, Vol. 1 Issue No. 2 April, pp.30 – 39 (ISSN 2219-8598)

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5. **Maxwell J. Mageto**, C.M. Maghanga, M. Mwamburi, (2012) " The Lorentz Oscillator model simulations illustrating a broad maximum in the bulk reflectance for frequencies just above the resonance frequency", The African Review of Physics, Vol. 7 : 0011, 95 – 105 (ISSN 2223-6589)

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10. **Maxwell J. Mageto**, C.M. Maghanga, M. Mwamburi, (2012), "Optical and Electrical Properties of $TiO_2$:Nb Prepared by spray Pyrolysis technique", SPIE International conference, August 12 – 16, 2012, San Diego, Calfornia USA

11. S. Kioko, C.M. Maghanga, **M. Mageto**, M. Mwamburi, (2012) "The effect of temperature on the output characteristics of mono crystalline solar cells using LBIC and LBIV techniques", Moi University International Conference, Eldoret, Kenya, 11$^{th}$ July 2012.

## Optical and Electrical Properties of Pd Doped $SnO_2$ Thin Films Deposited by Spray Pyrolysis

Benjamin Victor Odari[a*], Maxwell Joel Mageto[a], Robinson Juma Musembi[b], Herick Othieno[c], Francis Gaitho[a] and Valentine Muramba[a]

[a]*Department of Physics, Masinde Muliro University of Science and Technology, P.O Box 190, 50100, Kakamega, Kenya*

[b]*Department of Physics, University of Nairobi, P.O Box 30197-00100, Nairobi, Kenya*

[c]*Department of Physics, Maseno University, P.O Box Private Bag, Maseno, Kenya*

Thin films of $SnO_2$: Pd were deposited on glass substrate at $450^0$C using an alcoholic precursor solution consisting of Tin (IV) Chloride ($SnCl_4.5H_2O$) and Palladium Chloride ($PdCl_2$). The influence of increasing Pd concentration on the electrical and optical properties was investigated. The minimum resistivity of $5.14 \times 10^{-2}$ Ωcm for 3.68at% Pd film was obtained. The optical properties were studied in the UV/VIS/NIR region. The optical band gap for undoped $SnO_2$ films lies at 3.93 eV and Palladium doped films lay in the range 3.86 – 3.99 eV. Using dispersion analysis with Drude and Kim terms, optical constants were determined from spectro-photometric measurements for films on glass. The film thickness was determined through analysis using the SCOUT software and was found to be in the range of 140 – 223 nm.

**Keywords** Spray pyrolysis; tin oxide; Pd doping; Electrical; Optical.

## An Investigation on the Output Stability and Properties of Photovoltaic PEC Cells Using Semiconductor Thin Films of CdX ( X = S, Se, Te) Electrophoretically Deposited on $TiO_2$ Substrate.

Silas Mureramanzi,

*Department of Physics, University of Nairobi, Nairobi Kenya*

Solar energy is potentially one of the most important sources of inexhaustible renewable and clean energy. Even if the efficiency of sunlight energy conversion to electricity reaches values as high as 24% for a solid state silicon solar cell, the requirement of single – crystal silicon of high purity makes these solar cells quite expensive. Intense research aimed at finding low cost solar cells has been undertaken since more than two decades.

The conversion of light energy into electrical and/or chemical energy by means of photosensitive electrochemical cells (PECs), based on the junction between an appropriate semiconductor and a "redox electrolyte" provides a cheap and flexible route for trapping solar energy.

We are investigating chalcogenide – based photovoltaic PEC cells in which cadmium sulfide (CdS), selenide (CdSe) or telluride (CdTe) in contact with appropriate redox electrolyte assume the role of photoanodes while a platinum cathode (counter electrode) is immersed in the same electrolyte. After numerous investigations, it was realized that these semiconductor electrodes are stabilized in aqueous electrolyte by using sulfide/polysulfide ($S^{2-}/S^{2-}_2$), selenide/polyselenide ($Se^{2-}/Se^{2-}_2$, telluride/polytelluride ($Te^{2-}/Te^{2-}_2$), couples in the solution. We have observed that the output power characteristics of the PEC cells are quite stable in the presence of these redox couples.

The general objective of our research is to achieve the conversion of solar energy to electrical energy by means of photovoltaic PEC cells using semiconductor thin films of CdS, CdSe, CdTe electrophoretically deposited on $TiO_2$ substrate at various current densities. We expect to improve the power conversion efficiency by choosing properly the photoelectrode/electrolyte combinations and redox couples. We are also investigating the effects of surface treatment on cell performance.

Using a *CdS / 1 M, NaOH , $Na_2S$, S/Pt* photovoltaic PEC cell a power conversion efficiency of about 0.5% was obtained. Single crystals of n- CdSe and n – CdTe in polysulfide or polyselenide electrolytes show a power conversion efficiency of about 8%. There is a wide range of power conversion efficiency depending on the semiconductor – electrolyte combination and illumination intensity. Therefore there is room for improvement.

**Keywords:** PEC cells, photovoltaics, electrophoresis, $TiO_2$ substrate

## Solar Cells with PbS Extremely Thin Absorber (ETA) Based on Novel ETA Concept

Robinson .J. Musembi, Bernard .O. Aduda, J.M. Mwabora

*Department of Physics, University of Nairobi, P.O. Box 30197 – 00100 Nairobi Kenya*

A new highly structured $In(OH)_xS_y$/PbS/PEDOT:PSS solar cell has been developed based on the novel eta concept, and characterized by photovoltage spectroscopy, X-ray photoelectron spectroscopy, scanning electron spectroscopy, photovoltaic response and quantum efficiency spectroscopy. In this system, $In(OH)_xS_y$, PbS and PEDOT: PSS serve as electron conductor, light photon absorber material and hole conductor respectively. The electron conductor and absorber layer were prepared by chemical bath deposition, while the hole conductor was prepared by spin coating technique. The band gap of as prepared $In(OH)_xS_y$ has been found to vary with pH of the solution; furthermore the bandgap of PbS can be engineered to make it suitable as absorber material. At present, a solar cell device has been realized with efficiency up to over 1%, $J_{sc}$ =11.7 mA/cm$^2$ and $V_{oc}$=3.0 V.

**Keywords**: Extremely thin absorber, solar cell, PbS, photovoltage spectroscopy

## Characterization of Snx/ZnO: Sn p-n Junction for Solar Cell Applications

Lawrence Munguti, Robinson Musembi, K. Njoroge

*Department of Physics, University of Nairobi, P.O. Box 30197 – 00100 Nairobi Kenya*

In this study, tin selenide was prepared at different ratios using tin and selenium pellets in glass tube filled with argon and then heated up to 350°C, also, tin doped zinc oxide was prepared using tin pellets and zinc granules in a similar procedure followed when preparing tin selenide. The resulting materials were cut into ingots, respectively, and used in preparing thin films by resistive evaporation. The evaporation was done using Edwards auto 306 coating unit. The chamber pressure was maintained at 5.0 x $10^{-5}$ mbars during the film deposition. Thin films of tin-selenide and those of tin doped zinc oxide were characterized for optical properties and sheet resistance. The optical measurements were done using UV-VIS-NIR spectrophotometer Solid State 3700 DUV in the visible range (380-750nm) and the transmittance spectra data obtained was analyzed using the SCOUT software. The transmittance for zinc oxide ranged between 75% to 90% and that of tin selenide was below 60% with their band gap energies obtained as 2.95 eV and 1.40 eV, respectively. The electrical characterization measurements were carried out using a four point probe at room temperature (25°C) to obtain the sheet resistivity. The value of resistivity for tin selenide was 20.10 cm while that of tin doped zinc oxide was found to be 24.30 cm at 4% doping concentration. The SnSe/ZnO:Sn p-n junction solar cell was also fabricated by double depositing the optimized films on a microscope glass slide. The current voltage (1- V) characterization of the p-n junction diode was done using a solar cell simulator. and the data obtained was used to calculate solar cell parameters; open circuit voltage Voc= 0.5716 V, FF = 0.6654 and the short circuit current Jsc = l.0799 mA/cm$^2$ .The resulting solar cell efficiency of 0.41 % was higher than that obtained by previous study using ZnO of 0.117%.

**Keywords:** p-n junction, solar cells, tin selenide

# ZnO:Sn deposition by reactive evaporation: Effects of Sn doping on the electrical and optical properties.

L. K. Munguti,[a,]* R. J. Musembi,[b] W. K. Njoroge[a]

[a] *Kenyatta University, P.O. Box 43844 Nairobi-Kenya*

[b] *University of Nairobi P.O. BOX 30197 Nairobi-Kenya*

**Email: mungutimunlak@yahoo.com*

Tin doped zinc oxide thin films were deposited by reactive evaporation under various tin doping levels ranging from 1% to 8%. The deposition was done using Edwards Auto 306 coating unit at room temperature (25°C) and 5.0 x $10^{-5}$ mbar of chamber pressure. The optical transmittance spectra was obtained using UV-Vis-NIR spectrophotometer 3700 DUV in the visible wavelength 380-750nm. The doped films showed high transmittance >75% although slightly lower than that of undoped films. The band gap ranged from 2.95-3.95eV with the lowest value been attained at 4% tin doping. For the electrical characterization, sheet resistivity was carried using the four point probe at room temperature (25°C). The sheet resistivity ranged from 24.3-26.7Ωcm although it decreased with increase in doping concentration.

**Keywords:** Zinc oxide; Doping effects; Optical properties; Band gap.

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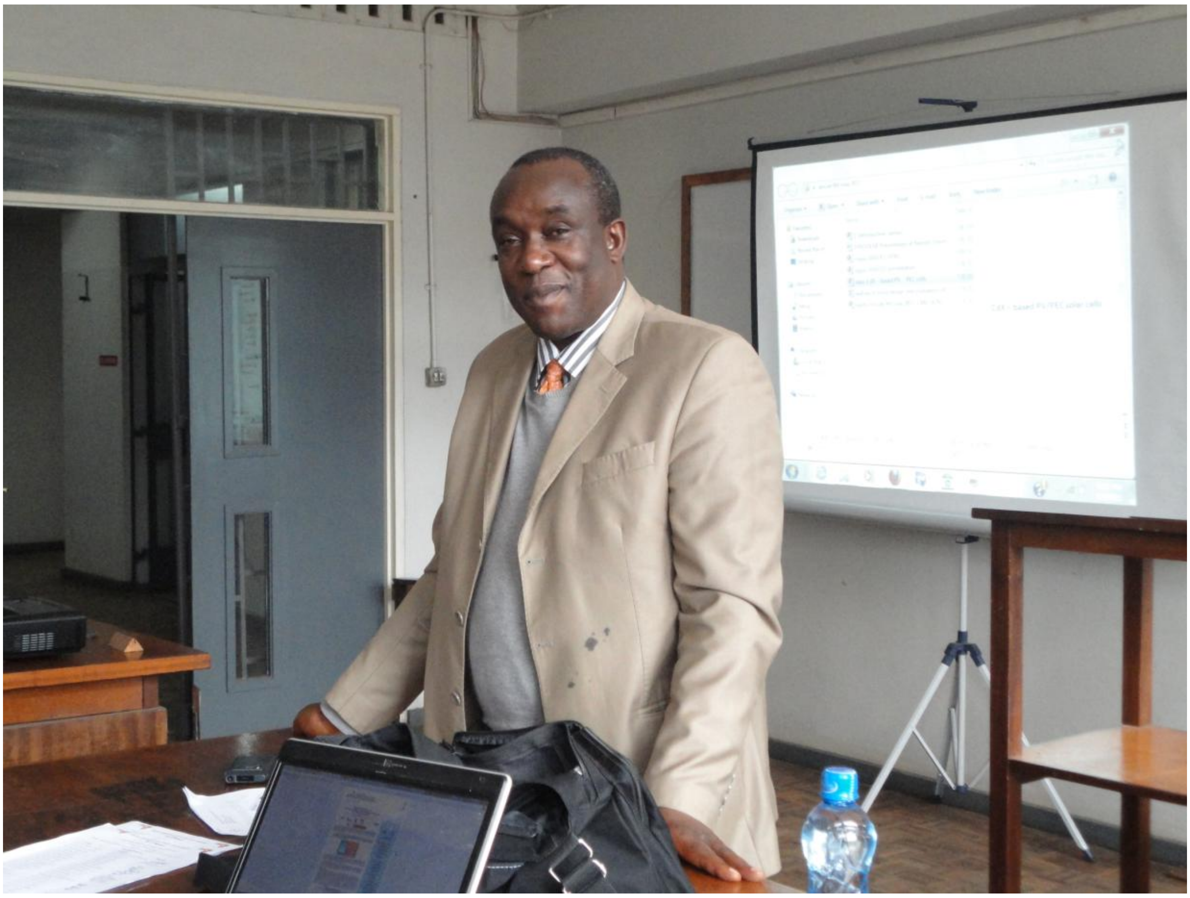
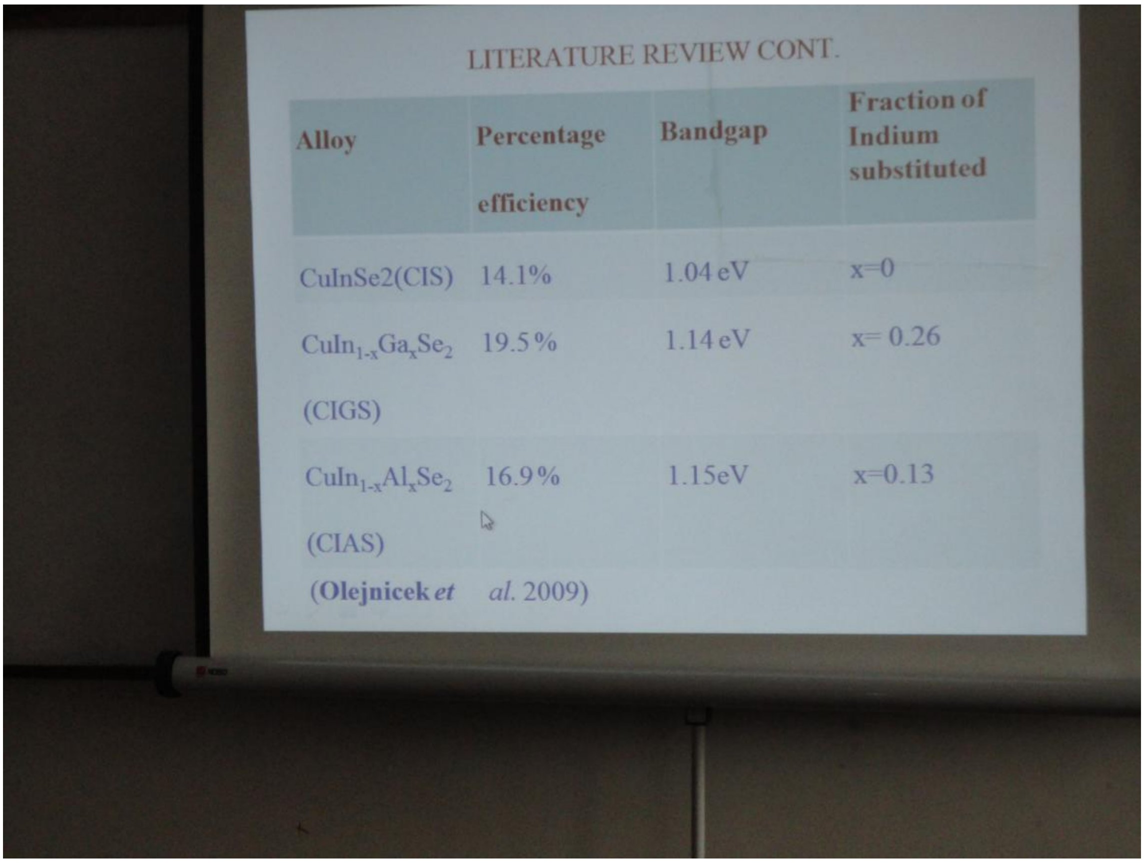
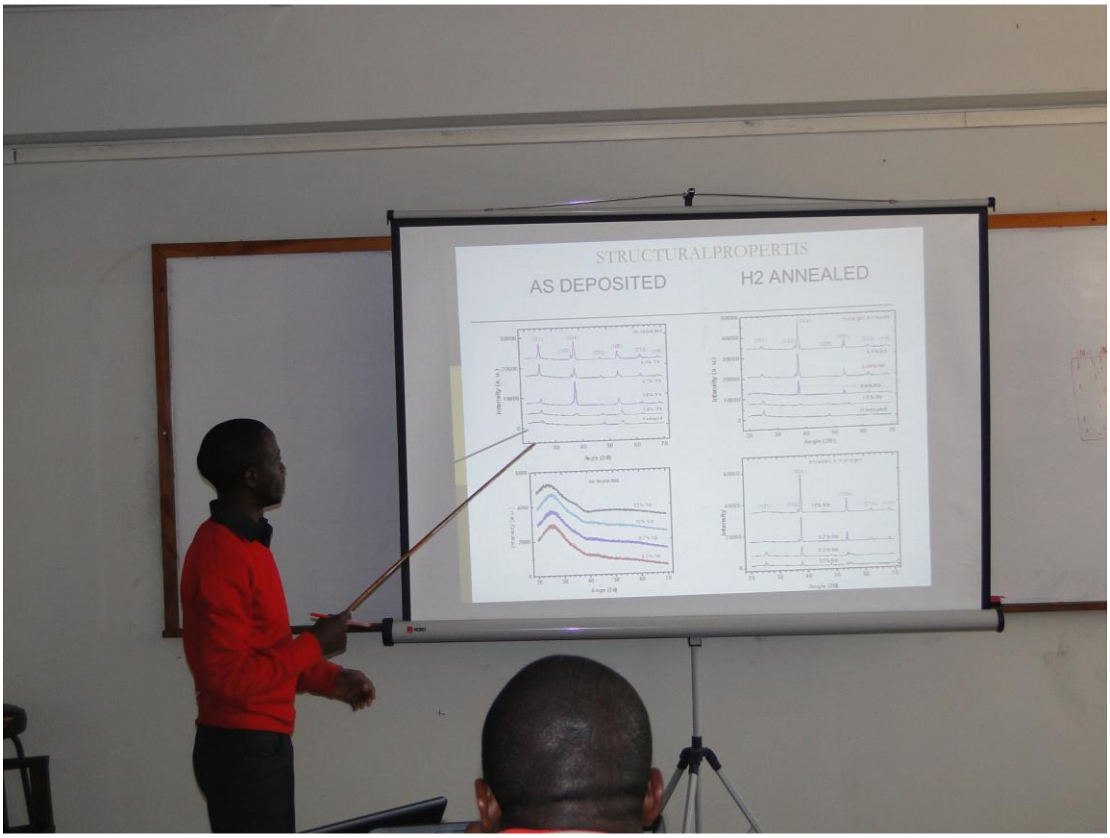



LITERATURE REVIEW CONT.
Alloy
Percentage efficiency
Bandgap
Fraction of Indium substituted
CuInSe2(CIS)
14.1%
1.04 eV
x=0
$CuIn_{1-x}Ga_xSe_2$ (CIGS)
19.5%
1.14 eV
x= 0.26
$CuIn_{1-x}Al_xSe_2$ (CIAS)
16.9%
1.15eV
x=0.13
(Olejnicek et al. 2009)


Introduction
Zinc Oxide is a II-IV semiconductor
Has wide direct band gap of 3.2 eV
High abundance
Non toxicity
Its resistivity decreases due to doping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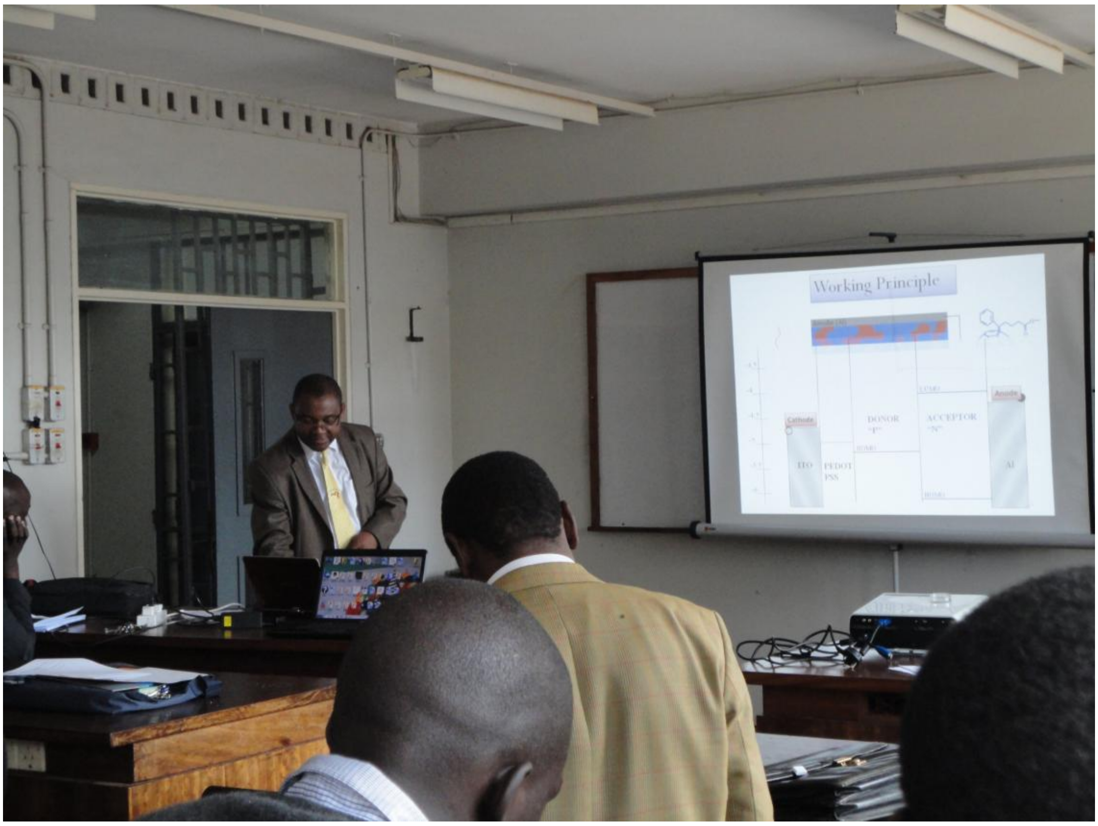
Working Principle
Cathode
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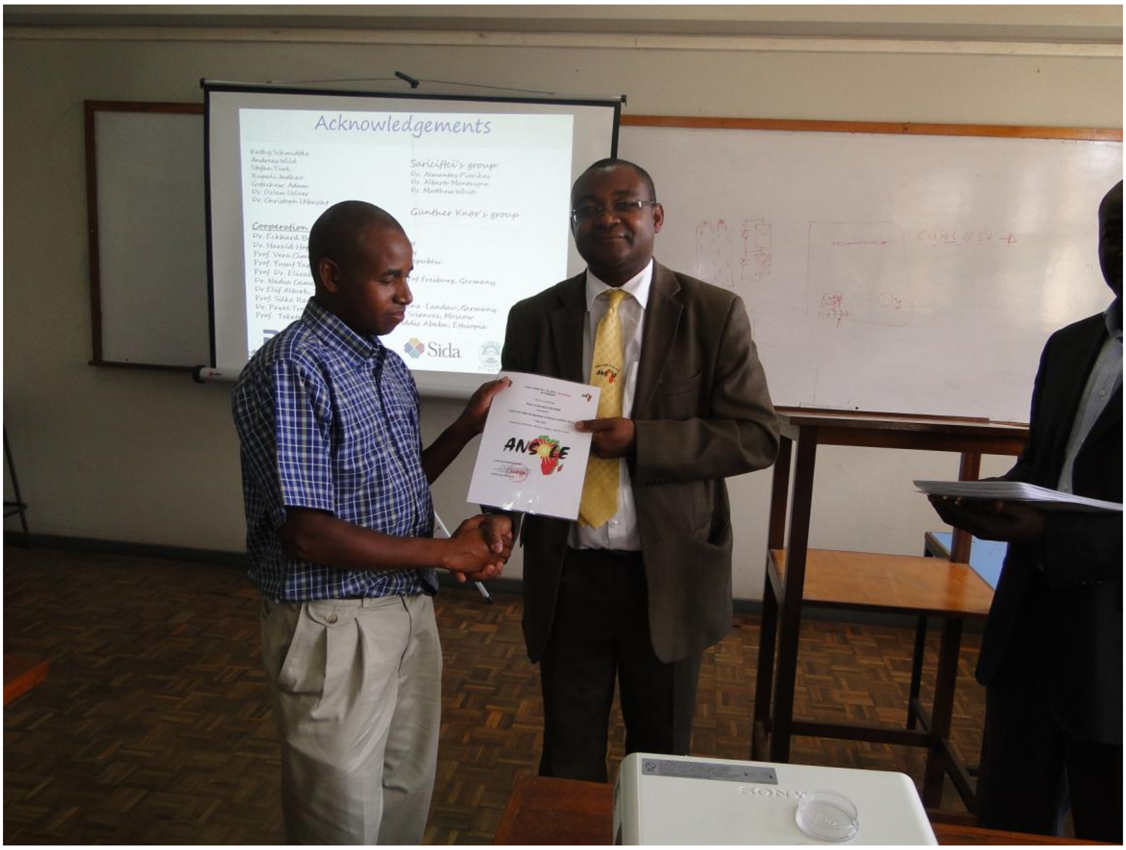
Günther Knor's group


Acknowledgements
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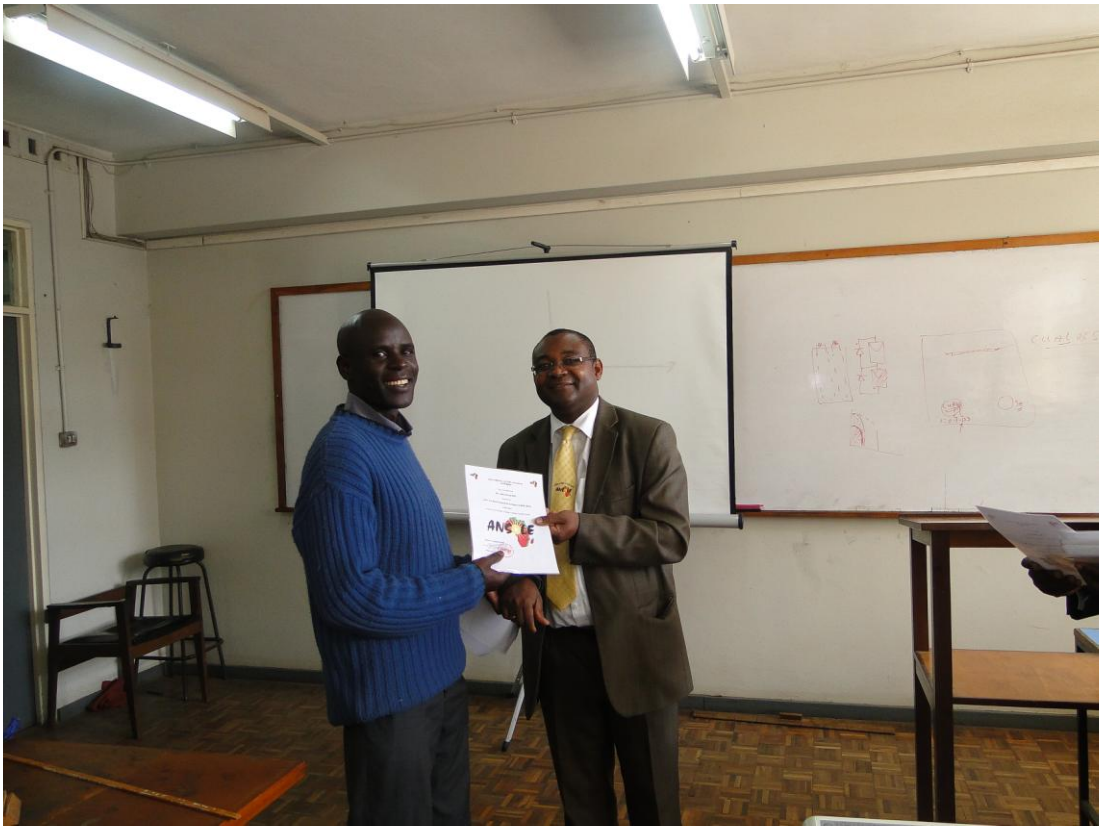

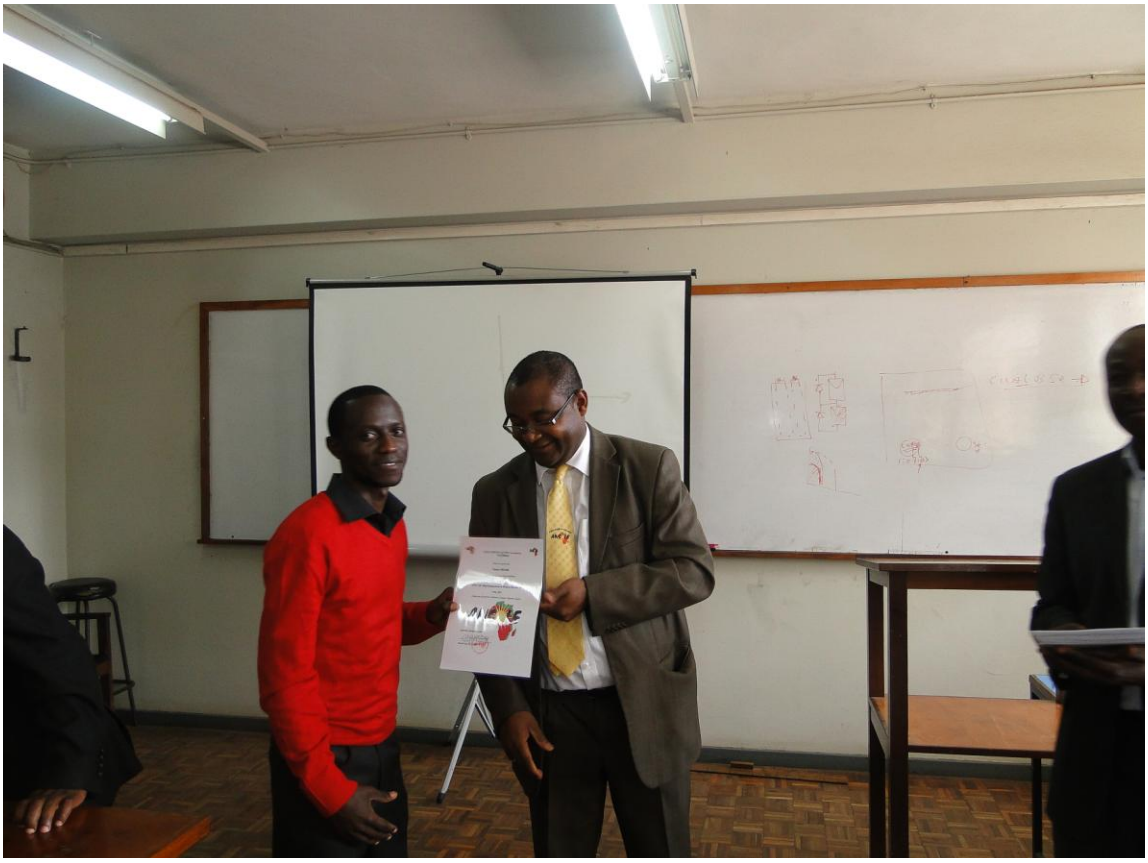


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