FEDERAL UNIVERSITY OF TECHNOLOGY MINNA

PHYSICS IN A SUSTAINABLE SOCIETY: NOW AND FUTURE PERSPECTIVES

By

PROFESSOR UNO ESSANG UNO
B.Sc (Unical), M.Sc, PhD (Uniabuja), FNIP, FICA
Professor of Physics

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INTRODUCTION

1.1.1. Courtesy

The Vice-Chancellor, it is with the highest sense of appreciation to God, you (Sir), and the entire university community that I present my inaugural lecture today. I thank my wife (Mrs. Uno), children, colleagues, spiritual leaders, students and friends for their immense support through this academic journey. I acknowledge the entire guest and all who have come to grace this occasion. I thank you all.

1.1.2. Preamble

In the beginning, God said, 'Let there be light,' and there was light (Gen1:1). Aside the religious interpretation, this was the first Physics act of the Creator, bringing the laws and principle of Physics in the conversion of sound to light energy. That leads us to the definition of Physics as the element of nature - study of matter in relation to the environment. This matter interacts with itself and the environment to yield different variable concepts as the field, energy, work and power among others. However, conditions, laws, mechanisms, and principles guide the different outcomes that ensue from the interaction of matter.

God gave human knowledge and proclaimed that "be fruitful, and multiply, and replenish the earth and subdue it" (Genesis 1:28).The lecture is not to bore the audience with scientific jargons, rather to bring hope to our country-Nigeria and Africa to understand the role of physics in addressing unemployment, economy, and nation-building in general.

Where are we as a nation? The **National Bureau of Statistics** (**NBS**) recently released the "2019 **Poverty** and Inequality in **Nigeria**" report, which highlights that 40 **percent** of the total **population**, or almost 83 million people, live below the country's **poverty line** of 137,430 naira ($381.75) per year. Figure 1 briefly presents the World Bank's report on the poverty rate in some selected countries (World Bank, 2018). The position of Nigeria among the committee of nations is not surprising. Figure 2 presents the unemployment rate from 1999-2019.

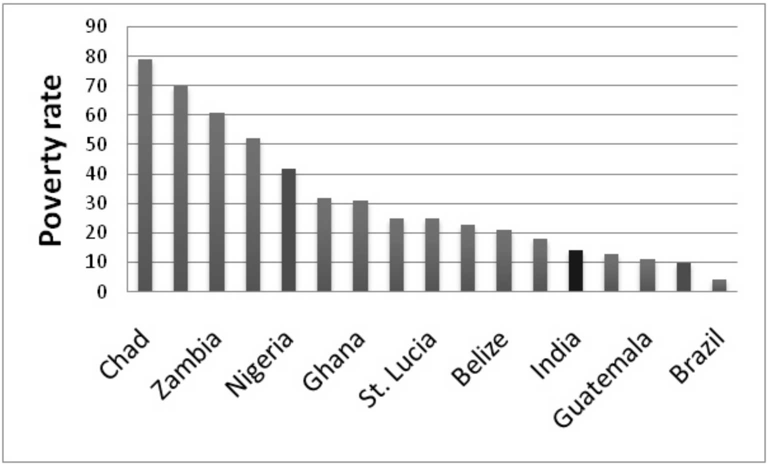


Figure 1: Poverty rate in selected countries of the world (World Bank, 2018)

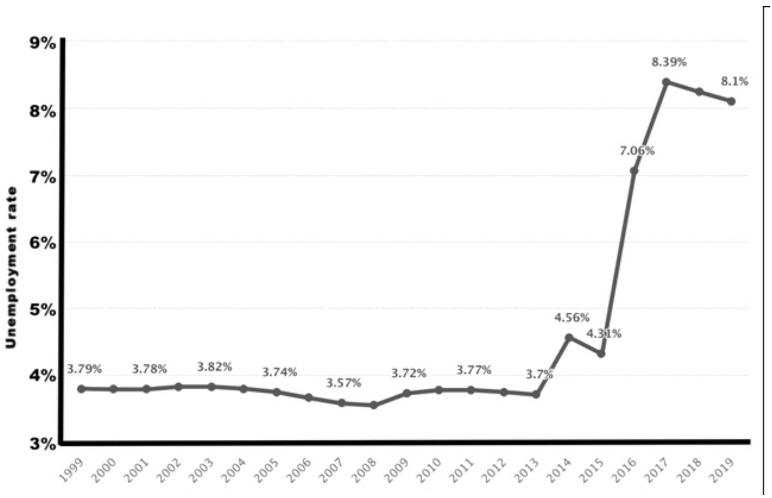


Figure 2: The unemployment rate in Nigeria (O'Neill, 2021)

The alarming unemployment rate and the unwinding of old and new industries have crashed the nation's Gross Domestic Product (GDP) or household final consumption expenditure (HFCE) per capita. In developed countries, the GDP is driven by the synergy between the academic and industry (i.e., "town and gown"). A typical example is presented in Figure 3, where most prominent pharmaceutical companies have a significant university base. These companies' successes improve on the company, university, and the nation's economy at large. In other words, this inaugural lecture is the inestimable treasure that can lift the country to fortune if the findings are being implemented by all relevant stakeholders.

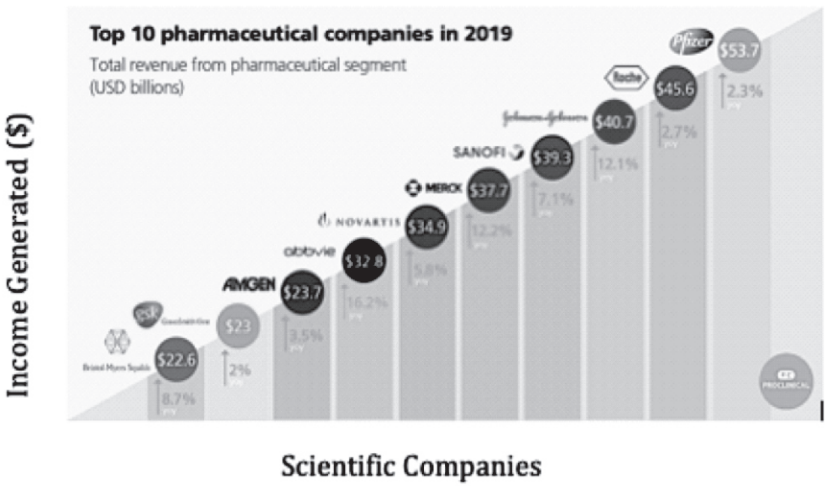


Figure 3: Successes of scientific companies and their impact on the nation's economy (Ellis, 2019)

Mr. Vice-Chancellor,it is based on the aforementioned above that this lecture is designed to take us through my contributions(electromagnetism, soil physics, and material synthesis) and the potentials it has to activate the interest of 'town' to invest in the 'gown'. At the end of the lecture, I intend to show that Africa's solution lies in the cooperation of its scientists, engineers, technologists and financial investors.

1.2 Physics: The journey so far

Mr. Vice-Chancellor, it is my pleasure to shed light on the beautiful concept of solid-state physics and how it relates to the present and future. It is the study of rigid matter, or solids, through quantum mechanics, crystallography, electromagnetism, and metallurgy. It is the largest branch of condensed matter physics.

Kindly note the four keywords in the definition, i.e., **quantum mechanics, crystallography, electromagnetism, and metallurgy**. Quantum mechanics is a fundamental branch of physics concerned with processes involving atoms and photons systems. Crystallography, on the other hand, is the experimental science of determining the arrangement of atoms in the crystalline solids. Electromagnetism is a branch of physics that describes the physical interaction between electrically charged particles. Metallurgy is a domain of materials science and engineering that studies the physical and chemical behavior of metallic elements, their inter-metallic compounds, and their mixtures, called alloys.

In this academic journey, my research work was in electromagnetism, soil physics, and material synthesis. This concept is because the past, present and the future of science and technology rest on how much these fields are explored. My principal objective is to see how many theories can be translated into a more practicable and sustainable concept to move the black race to its enviable height.

1.2.1 Research in Electromagnetism

Electromagnetism involves studying the electromagnetic force, a type of physical interaction that occurs between electrically charged particles (Figures 4a & b).In describing electromagnetism, Maxwell's equations are considered. Maxwell's equations are a set of partial differential, integral, or phasor equations that, together with the Lorentz force law, form the foundation of classical electrodynamics, classical optics, and electric circuits. Maxwell's equations include four salient laws i.e., Gauss, Ampere, Coulomb, and Faraday(shown equation 1-4 below)

$$\nabla . E = \frac{\rho}{\varepsilon_0} \tag{1}$$

$$\nabla \times E = -\frac{\partial B}{\partial t} \tag{2}$$

$$\nabla \times B = \mu_0 J + \mu_0 \varepsilon_0 \frac{\partial E}{\partial t} \tag{3}$$

$$\nabla . B = 0 \tag{4}$$

Equation 1 explains how charges produce electric field. Equation 2 shows how changing magnetic flux changes electric field. Equation 3 shows how electric current and changing electric flux produces magnetic field. Equation 4 shows that there are no magnetic charges or magnetic field lines. The interaction between charged particles in the electromagnetic field is presented in Figure 4.

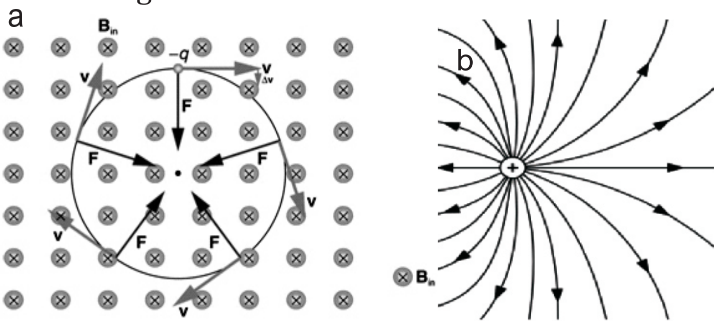


Figure 4: Interaction between electrically charged particles (Lumenlearning, 2020)

The application of Maxwell's equations can be found in the following devices i.e., MRI scanners in hospitals, magnetic tape, computers, antenna, GSM jammer (Uno *et al.,* 2013a), etc.
The research focus has been to examine the loop antenna and seek ways to optimize its efficiency. A loop antenna is a radio antenna consisting of a loop or coil of wire, tubing, or other electrical conductors usually fed by a balanced source or feeding a balanced load. The drawbacks of loop antennas include low efficiency (for small loop antennas), which restricts it to mainly receiving antennas at lower frequencies; small loop antennas have a very low value of radiation resistance that engender power loss heat, due to flow of current with high levels. Hence large loop antennas are preferred over smaller ones. The loop antenna is referred to as an electromagnetic device.
To improve on the loop antenna, the modification would come from its first principle (Maxwell's Equation). Like any transmitting antenna, smaller antennas are less efficient radiators than larger antennas. The list of transmitting Antenna is shown in Table 1.
Transmitters are necessary parts of many electronic devices that communicate by radio, such as cell phones, wireless computer networks,Bluetooth enabled devices, garage door openers, two-way radios in aircraft, ships, spacecraft, radar sets and navigational beacons (Plate 1).

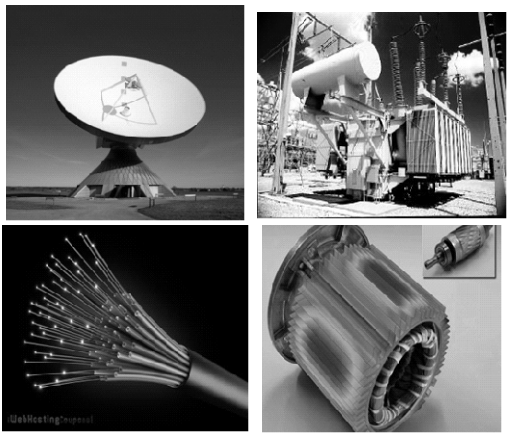


Plate 1: Industrial application of Maxwell's equations (Galušcák et al., 2008)

Table 1: Types of Antenna (Rowell and Lam, 2012)

Microstrip Antenna	Travelling Wave Antenna	Wire Antenna	Aperture Antenna
Rectangular Microstrip (Patch) Antenna	Helical Antenna	Half-Wave Dipole	Vivaldi Antenna
Planar Inverted-F Antenna (PIFA)	Yagi-Uda Antenna	Broadband Dipoles	Horn Antenna
	Spiral Antenna	Monopole Antenna	Slotted Waveguide Antenna
		Folded Dipole Antenna	Inverted-F Antenna
		Loop Antenna	Cavity-Backed Slot Antenna
		Cloverleaf Antenna	Slot Antenna
		Short Dipole Antenna	Telescopes
		Dipole Antenna	

Antenna technology has become a broad field that cuts across communication, astronomy, geophysics, geology, and medicine (Plate 2).

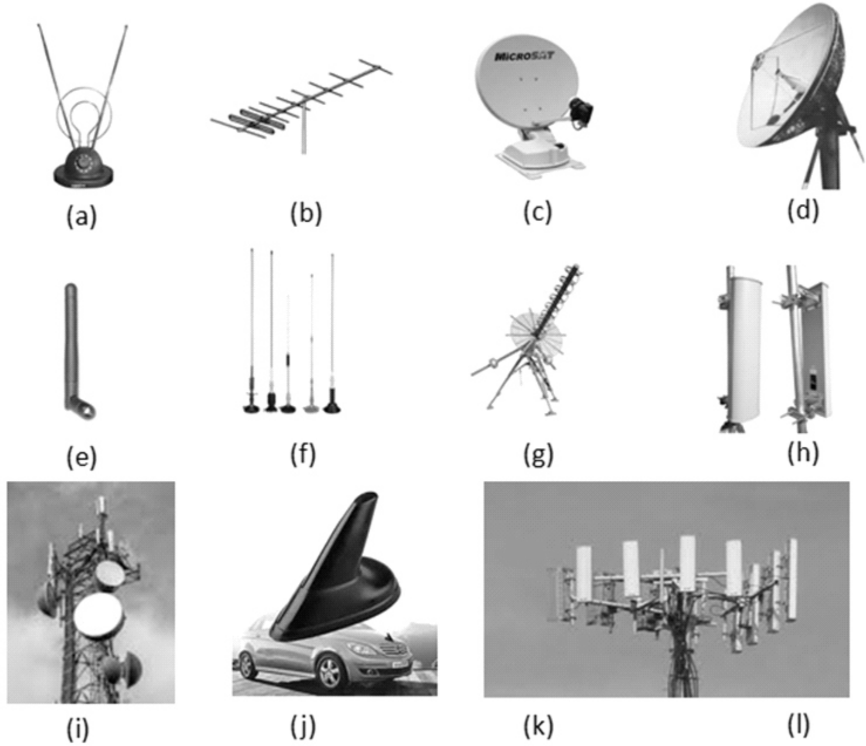


Plate 2: Types of antenna used in different spheres of life (Dhillon and Kumar, 2017)

(a) HDTV antenna used for indoor purposes (b)VHF television antenna (c) Offset Satellite Dish TV (d) Meter Compact Cassegrain Antenna (e) replacement Wireless Antenna (f) Wilson 12” Magnet Mount Antenna (g) HDTV Outdoor Antenna (h) Meraki Antenna (i) 2016 RT XM Antenna (j) car antenna (k) 30 Meter Tower Monopole Antenna

Small loops are "small" compared to their operating wavelength, typically between 5% and 30% of a wavelength in circumference, with transmitting loops tending to be closer to 30%. In other words, its optimization means that the loop antenna is made to operate at higher frequencies at a low signal-to-noise ratio.

1.2.1.1 My Contribution

The first step towards developing our model is to improve upon Maxwell's Equation.The mathematical imperfections of Maxwell's equations include Euler–Heisenberg Lagrangian (extremely strong fields), vacuum polarization (extremely short distances), and quantum entanglement (Ravndal, 1997; Blinder, 2003; Valle *et al*., 2013).Maxwell's Equation was modified using the Schrodinger equation to find the allowed energy levels of its quantum mechanical systems, as presented in equations 8-11. The computational and analytical results have been scientifically reported to enhance low transmission of signals (Uno and Adelabu 2006; Uno *et al*., 2008; Uno *et al*., 2011;Uno *et al*., 2012). These solutions have provided a mathematical framework to aid smart antenna technology.

$$E_{rt} + \left[\frac{\hbar^2}{2m}|\mathrm{B_r} - eA|^2 + |B_z + V_o e|^2 - \left(\left|B_z - E_o e\left(\frac{a^2}{r} - r\right)\right|^2 - |B_z|\right) + 2E_o V_o e^2 + \beta e_r\right]E_r = \beta E_r e_r e^{-j\beta r}(sin\theta + cos\theta) \quad [5]$$

$$\frac{\partial}{\partial t}\left[(B_z + V_o e)E_r{}^2\right] - \frac{\partial}{\partial t}\left[\left(B_z + E_o e\left(\frac{a^2}{x} - x\right)\right)E_r{}^2\right] - \frac{1}{2}\frac{\partial B_z}{\partial t} = 0 \quad [6]$$

$$\frac{\hbar^2}{2m}E_r{}^2\frac{\partial}{\partial t}(\mathrm{B_r} - eA) = \beta B_r f_r e^{-j\beta r}(sin\theta + cos\theta) \quad [7]$$

$$\frac{\partial}{\partial t}E_z = \frac{\partial}{\partial t}E_z e_z e^{-j\beta r}(sin\theta + cos\theta) \quad [8]$$

$$2\left|B_z - E_o e\left(\frac{a^2}{r} - r\right)\right|E_r E_o e\left(\frac{a^2}{r^2} - 1\right) = \frac{j\beta}{8\pi}\left[\frac{E_r e_r}{r}(sin\theta + cos\theta) + \frac{2B_r f_r}{r}(sin\theta + cos\theta)\right]\beta e^{-j\beta r} \quad [9]$$

$$\frac{1}{8\pi}[\beta E_r(a,z)e_r + \beta B_r(a,z)f_r + E_z(a,z)e_z + B_z(a,z)f_z][cos\theta - sin\theta] = 0 \quad [10]$$

$$\frac{1}{8\pi}\left[-\frac{2}{z}e^{-j\beta r}sin\theta(B_z(a,z)f_z + E_z(a,z)e_z) - \frac{2}{z}e^{-j\beta r}cos\theta(B_z(a,z)f_z + E_z(a,z)e_z)\right] = 0 \quad [11]$$

where a is the attenuation factors of the electrical fields; E_z is the electric fields generated by the polar difference; β is the frequency of exciting power; *j* is the antenna current; *r* represents the radius or horizontal component of the antenna; *z* represents the vertical component of the antenna; m represents the magnitude of the particulates; represents the electrical permeability; ξ represents the magnetic permeability; e_r is the spin factor which determines the electron spin along with the horizontal component; e_z is the spin factor which determines the electron spin along with the vertical component, V is the total potential in space or near earth surface, V_o is a constant on the surface of the charged air, E_o is the electric field, and x is the Dybe length.

Equation 5 shows that the directional transmission of signal requires an electric field that depends on time and the antenna's quantum states. This information is very important for Magnetic Resonance Imaging (MRI) machines. Equation 6 shows that no magnetic charge is expected to emerge at quantum states. Equation 7 shows that changing magnetic flux refines the value of the magnetic fields. Equation 8 shows that the changing electrical fluxes are dependent on the directional transmission lines. Equation 9 defines the reference terms for the coexistence of electric and magnetic fields in light. This concept is the framework of the smart antenna technology. Equation 10 shows that in some way, the electric and magnetic fields compete in light. Equation 11 shows the directional implication of the directional competing orders of the electric and magnetic fields.
Aside the loop antenna calculations that birthed our mathematical framework, the solutions is also very useful to the smart antenna technology because it enhances its functionality beyond entertainment (DVB-H, Cellular LTE MBMS broadcast/unicast services, dual and tri-band MIMO Wi-Fi, Bluetooth and potentially IoT wireless standards), Smartphone or Tablet (2G GSM; 3G WCDMA/HSPA+; 4G LTE/LTE-A cellular standards, plus Wi-Fi; Bluetooth; and GPS/GNSS for location services), laptops (dual band MIMO Wi-Fi, Bluetooth, GPS/GNSS and cellular 3G WCDMA and 4G LTE), Internet of Things

(IoT/M2M Antenna), automobile (multi-standard Sharkfin antenna system capable of supporting MIMO LTE-A, Wi-Fi V2X, GPS, DAB and DVB-H). For example, scientists have recently initiated the idea of integrating a small antenna into an electronic chip. This idea is possible if electromagnetic waves are generated not only from the acceleration of electrons but also from aphenomenon called symmetry breaking of the electric field in space within the radiating system (Sinha and Amaratunga, 2015). The symmetry breaking may be insignificant if the increasing vertical component ratio initiates electron deceleration. This result is due to the distortion of the atomic angular momentum distribution in the plane perpendicular to the electric field and initial alignment (Hilborn, 1995). However, when the angle between the initial alignment and the external electric field is π/4 as predicted by Auzinsh *et al.* (2006), the symmetry breaking becomes significant. This concept forms some of the cardinal working principles of the smart antenna technology illustrated in Plate 3.

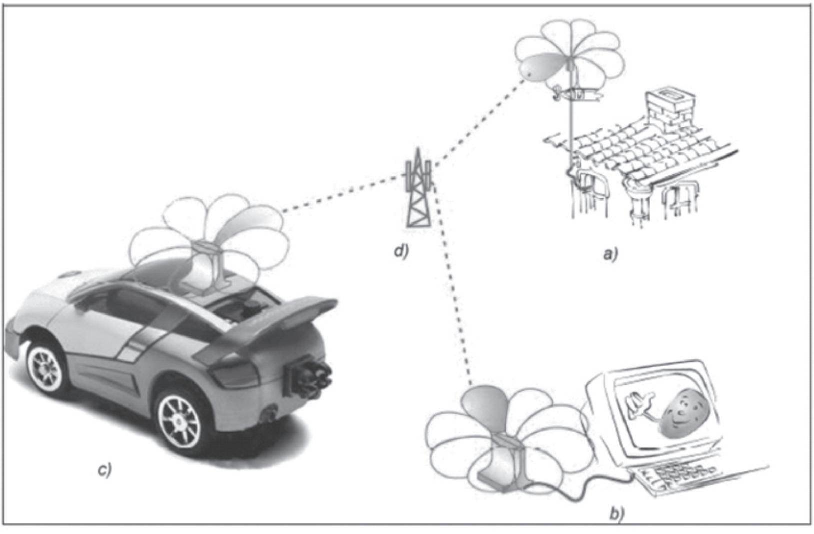


Plate 3: Smart antenna technology (Ascor, 2019)

Beyond the smart antenna technology, our research findings show that the antenna's potentials have not been fully explored. We have been working on how the regular antenna (loop antenna) can be improved to meet-up with our proposed concept-'intra cloud technology'. Below in Figure 5 are the proposed gains we have calculated at the lowest range of 0 to 5 meters. The transmitting loop at the proposed position is expected to exhibit useful sharp nulls in the azimuth pattern. This result is a major advantage when incorporating the loop antenna into the proposed 'intra cloud technology.' The loops were theoretically built to reduce radiation losses i.e., common to the transmitting loop antenna. Also, the angle of elevation can account for the loss that transforms into heat in the conductor. This revelation is futuristic to the combination of the old and new technology of antenna. Already, Rasool *et al.*(2014) used the system design of an array of antennas with half a wave and a loop antenna to show the application of antenna technology to mobile communication.

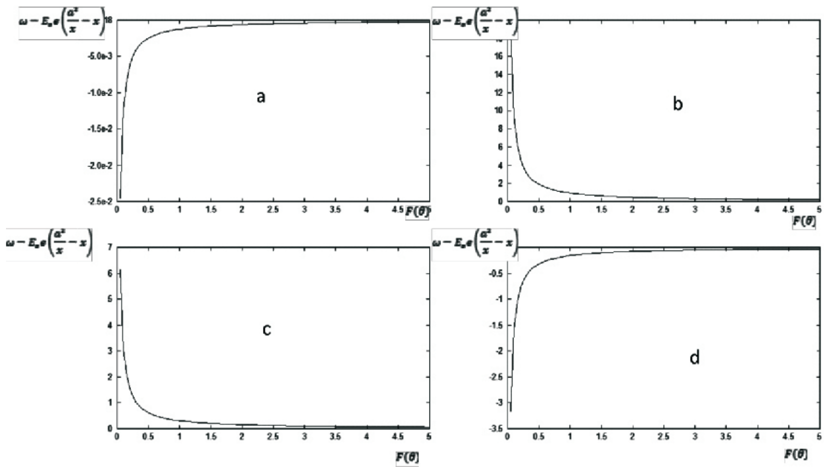


Figure (5a): The standing waves when the phase angle is 30^{o} and functional phase ratio ranges from 0 to 5. (4b): when the phase angle is

60° and functional phase ratio ranges from 0 to 5. (4c): when the phase angle is 120° and functional phase ratio ranges from 0 to 5. (4d): when the phase angle is 150° and functional phase ratio ranges from 0 to 5. (Uno *et al.,* 2012).

1.2.1.2 Summary of Findings

A mathematical model was developed by improving Maxwell equation in order to optimize loop antenna to operate at high efficiency and low signal-to-noise ratio. The concept of intra-cloud technology was proposed. The advantage of these findings is that it enables rural settlers in Nigeria and other developing countries to connect ceaselessly to the world via an 'intra cloud technology" revealed in 2012 (Uno *et al*., 2012) to enable free information sharing(Harald, 2017) such as in communities ravaged by insecurity for transmission of information to each other and to security apparatus/organizations. It is recommended that industries, and government agencies should take advantage of these findings as it has financial prospects, as well as job provision for the teeming youth.

1.2.2 Research in Soil Physics

Soil physics deals with physical soil components' dynamics and their phases as solids, liquids, and gases. The thermal transmissions in solid, liquid, and gaseous phases are considered before treating complex soil systems. Its application can be found in agriculture, construction, and geology. My research focus on soil Physics was on soil compaction and its impact on physical parameters. The first scenario in soil is to determine the thermal impact of varying soil compaction. Kirkham and Power (1972) gave the one-dimensional thermal conductive Equation as listed below:

$$T(z,t) = T_O + A\,exp\left(\frac{-z}{d}\right) sin\left(\omega t - \frac{z}{d} + \beta\right) \tag{12}$$

Where A is amplitude, ω is circular frequency, β is initial phase, T(z,t) is the soil temperature at time (t), z is the soil depth, To is the average soil temperature (^{o}C), d is the damping depth (m).

1.2.2.1 My contribution

It was discovered that the validity of equation [12] do not hold for some soil sample mixture because of the variability of complex soil systems in different geological terrains. For example, we considered a unique soil sample in Minna which comprised 62±1% sand, 28±4% clay, 6±1% silt, 0.6±0.2% organic carbon,1.5±0.5% organic matter. The analysis was carried out at the Soil Science laboratory of the Federal University of Technology, Minna. Excerpt of the daily temperature variation with bulk density and moisture content is shown in Table 2. After which we started experimenting to get the best thermal conductive Equation for Minna and other parts of Nigeria's north-central region (Uno and Adelabu 2006; Uno *et al.,* 2008; Uno *et al*, 2011; Uno *et al*., 2013b). Finally, we arrived at the Equation 13 (called the temperature deviation model) using computational simulations (freemats). This model applied salient parameters such as soil particle density and soil bulk density.

$$\Delta T = A_0 e^{-\rho_s/\rho_b} \sin\left(-\frac{\rho_s}{\rho_b} - \frac{\pi}{2}\right) \qquad (13)$$

ρ_s= soil particle density which is an approximately 2.66gcm^{-3} by Gupta *et al.*(2011), ρ_b = soil bulk density. ΔT= temperature deviation, A_0 is the annual amplitude of the surface soil temperature.

Table 2: Daily Temperature Variation with Bulk Density and Moisture Content(Uno et al., 2012a)

Time (24hr)	Tpvc 1 (^{0}C)	Tpvc 2 (^{0}C)	Tpvc 3 (^{0}C)	Tpvc 4 (^{0}C)	BD (kg m-³)	MC (%)	TMax (^{0}C)
8:00	28·00	29·00	28·00	29·00	1.42	11.1	47
9:00	32·50	32·00	32·00	31·00			
10:00	38·00	37·50	37·50	36·50	1.51	18.2	46.5
11:00	41·00	40·00	40·50	39·50			
12:00	43·00	42·50	42·50	41·50	1.54	10.1	46
13:00	44·50	43·50	43·50	43·00			
14:00	46·00	45·50	45·50	44·00	1.66	7.4	45.5
15:00	47·00	46·50	46·00	45·50			
16:00	46·50	46·50	46·00	45·50	1.75	15	46
17:00	44·50	44·50	42·50	44·00			

Equation [13] worked perfectly with soil samples in parts of northern Nigeria (Uno *et al.*, 2011; Uno *et al.*, 2013b). An excerpt from the validation is shown in Figure 6A-D. The scattered plot reveals that the temperature deviation trend in northern Nigeria is (positive) parabolic. The study implies that the annual amplitude of the surface soil temperature can be related to the soil heat flux; hence, it is possible to analyze the complex soil system with this model. The temperature deviation curve model has been applied in geological studies (Kuforiji *et al.* 2017; Akinpelu *et al.*, 2017; Emetere *et al.*, 2017). For example, we have been able to use the method to determine hydrocarbon deposition in Lagos State offshore as shown in Plate 4.

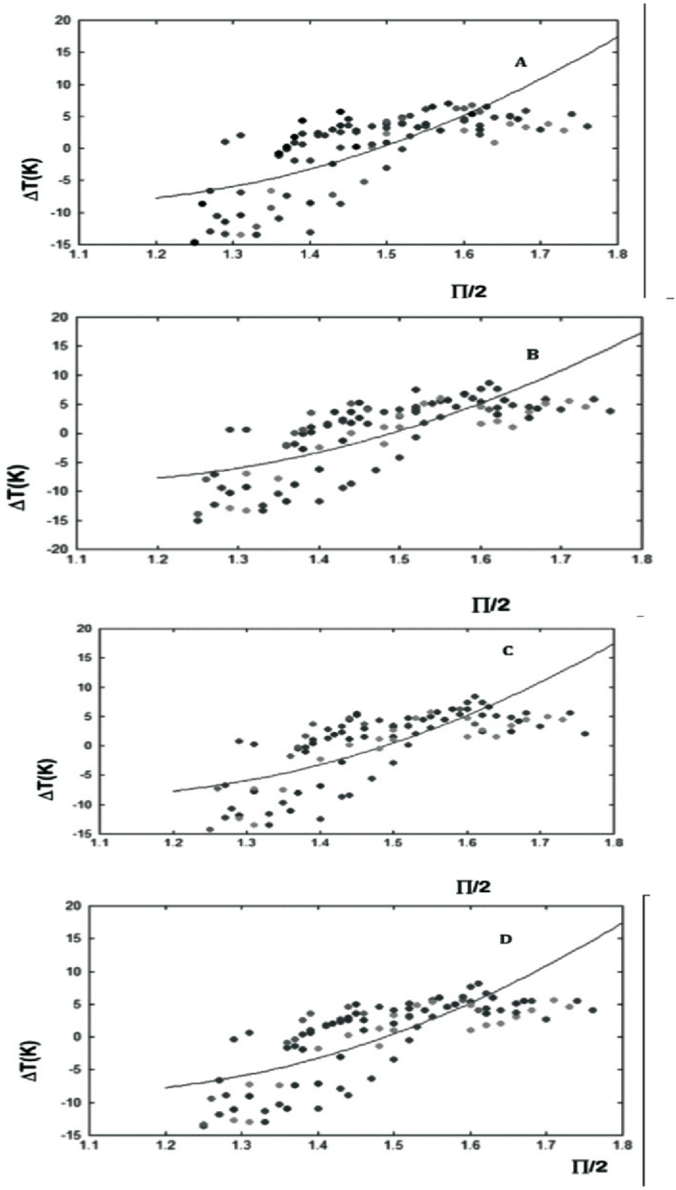


Figure 6: Temperature deviation curve for soil sample(Uno et al., 2012a; Uno et al., 2012b)

Interestingly, over ten years, soil samples of four northern states were used, and most samples were collected in the rural areas (Uno 2008a, 2008b). The highest annual amplitude of the surface soil temperatures over the north is high. This discovery could assist the government in exploring geothermal energy production in Nigeria. Our plan is to collaborate with our colleagues in geology and geophysics to analyze large datasets over locations in northern Nigeria.

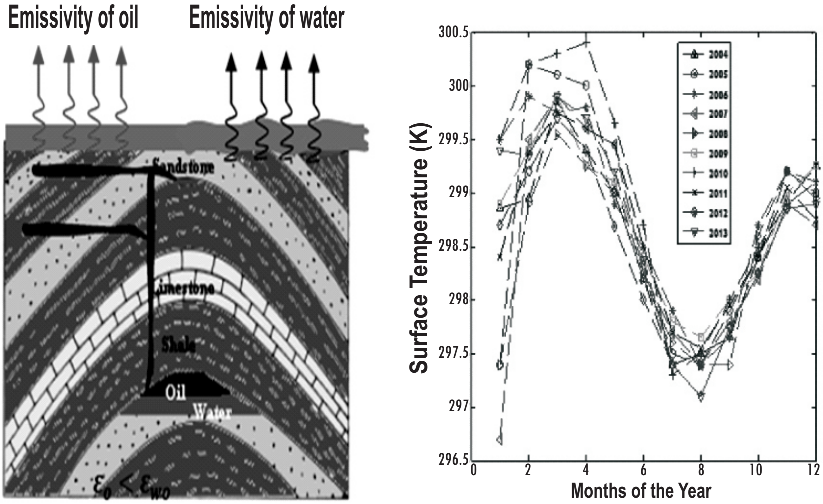


Plate 4: determination of hydrocarbon deposits in offshore of Lagos State (Emetere *et al.,* 2017)

Geothermal energy is the heat from the Earth. It is clean and sustainable (Plate 5). Global geothermal power capacity is expected to reach 14.5–17.6 GW by 2020 (Yasmin, 2015). However, the estimated potential of geothermal energy in Nigeria is 9,383 MW if it is explored (Abraham & Nkitman, 2017). However, if more physics theories are committed to this course in Nigeria, we may expect more than estimated. My research cluster and I hope to unravel the physics of the geothermal energy prospects in Nigeria. A picture of an existing geothermal energy station is shown below in Plate 5 & 6.

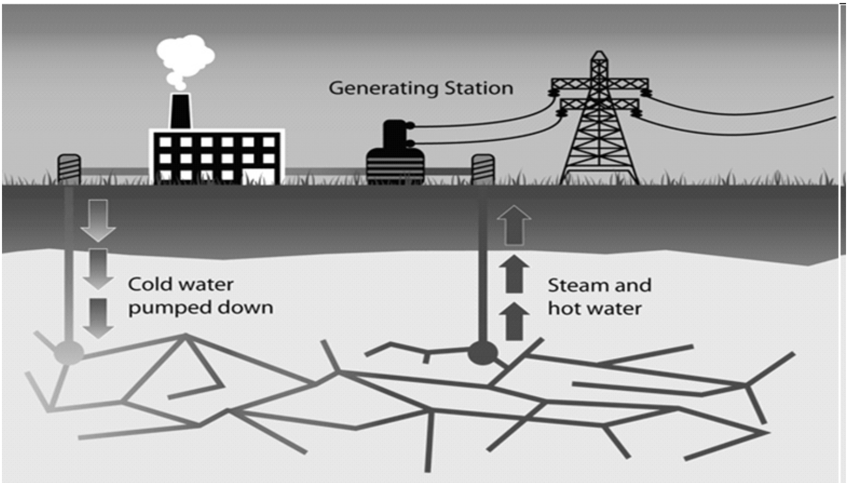


Plate 5: Energy generation from geothermal sources (Carbonneutral, 2017)


Plate 6: Prototype of the proposed geothermal energy station (Greenworld, 2017)

1.2.2.2 Summary of Findings

A new model has been developed to estimate thermal transport across complex soil profiles. This model has found high demand in agriculture, construction, and geothermal energy. It is recommended that two and three-dimensional temperature deviation models should be developed to solve geological problems such as earthquake prediction models etc.

1.2.3 Research in Materials Science

We have been involved in materials science research which is geared at providing solutions to societal needs in the area of energy harvesting/storage, semiconductor materials for electronics and optoelectronics devices. The issue of energy has become a global challenge due to growing population, improved technology and unclean source of energy. A typical outlook of the global energy generation is presented in Figure 7.The Sustainable Development Goal 7 (SDG-7) elaborates on sustainable and clean energy. Solar energy is referred to as clean energy because its source is renewable, and it does not emit greenhouse gases. The device used for converting solar irradiance to electricity is known as the photovoltaic (PV) module. The PV module is an array of solar cells that are referred to as solid-state device. Most of the solid-state cells are semiconductor.

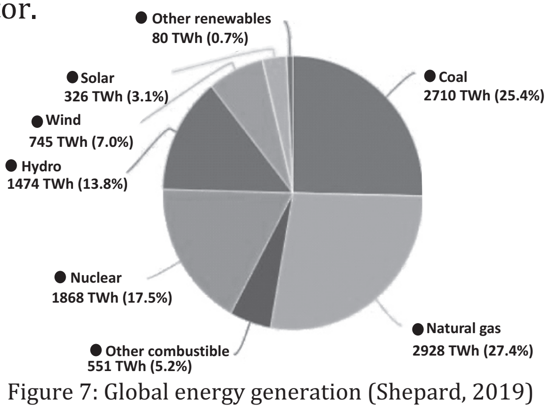


Figure 7: Global energy generation (Shepard, 2019)

1.2.3.1 My Contribution

Mr Vice-Chancellor; for over a decade, my team and I had worked on both theory and experimental studies of semiconductors (Uno and Adelabu 2005; Uno and Adelabu 2006; Uno and Adelabu 2009; Uno *et al.*, 2011; Uno *et al.*, 2012; Uno *et al.*, 2014). We considered the effect of electron-hole recombination in disordered GaAs-Ga_{1-x}ALAs multi-quantum well structure (Figure 8), using an analytical method based on the rate equations (Uno et al., 2012).

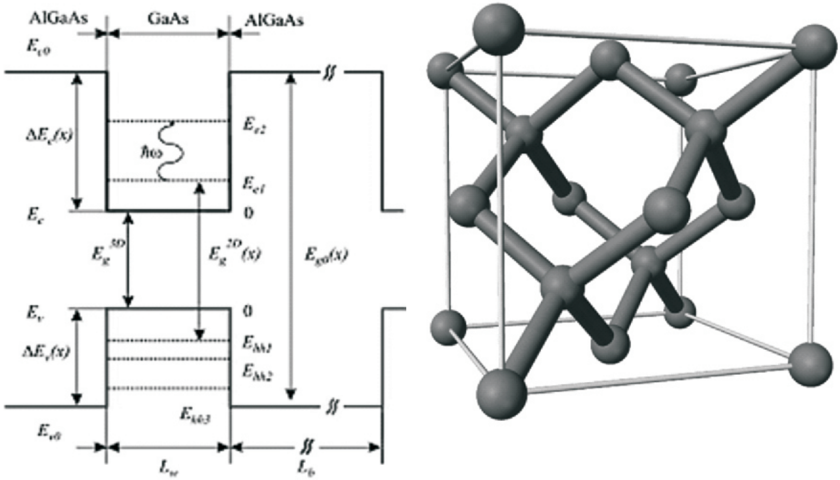


Figure 8: GaAs-Ga_{1-x}ALAs multi-quantum well structure (Demyanenko et al., 2017)

This was achieved by using unique assumptions to synchronize experimental results. The assumptions were:

1. The disorder in the quantum well of *GaAs-*Ga_{1-x}*ALAs* is caused by their alloy composition and imperfect interfaces, which makes it create a set of localized states than trap photo-generated charge carriers. The carriers are captured after photo-generation.
2. The carriers can either recombine or perform a photo-assisted hopping transition to other localized states. The probabilities depend exponentially on the distance involved.

The rate of recombination with a localized hole at a rate is (Uno et al., 2012),

$$\Gamma_\sigma(R) \approx \tau_o^{-1} \exp\left(-\frac{2R}{\alpha}\right) \quad (14)$$

Where α is the absorption coefficient, R is the recombination rate, τ_o depends on the partic τ_o ar recombination mechanism. In the case of radioactive recombination, τ_o is of the order of the exciton radioactive lifetime.

3. The rate for a charge carrier to perform a non-radioactive hopping transition from an occupied state i to an empty localized state j over a distance r_{ij} is determined by the Miller and Elihu (1960).

$$\Gamma_{ij} = V_o \exp\left[-\frac{2r_{ij}}{\alpha} - \frac{\xi_j - \xi_I + |\xi_j - \xi_I|}{2KT}\right. \quad (15)$$

Where ξ_j and ξ_I are the energies of states j and i respectively and V_o is the attempt- to –escape- frequency of the $10^{12} s^{-1}$

4. Applying the approach of Marshall (2000), one divides the energy range where the localized states are distributed into a set of m energy slices with a given width and formulates the rate equation for carrier densities in those energy slices. The time of the carrier concentration n_k in slice number k is determined by the Equation

$$\frac{dn_k}{dt} = \sum_{\substack{j=i \\ j \neq k}}^{m} \left(n_j \Gamma_{j\to k} - n_k \Gamma_{k\to}\right) - n_k \Gamma_\sigma \quad (16)$$

Where $\Gamma_{j\to k}$ denotes the rate of a charge carrier transition from a state in slice 'i' to a state in slice 'j' and Γ_σ is the recombination rate.

5. Considering the transition rate $\tau_{k\downarrow}$ from the slice 'k' downward

in energy, since the transition occurs through energy loss hopping; only the tunnelling term remains in Equation 15. Therefore, one can write the downward transition rate as;

$$T_{k\downarrow} = V_o \exp\left(\frac{-2R_k}{\alpha}\right) \qquad (17)$$

Where R_k is the hopping distance determined by energy below E_k. In two-dimensional case it can be estimated as:

$$R_k = \left\{\pi \sum_{i=k}^{m}(d_j - n_i(t))\right\}^{\frac{-1}{2}} \quad (18)$$

Where d_j denotes the concentration of localized states in the energy 'j'. Using equation 4, we can derive the downward hopping rate $\Gamma_{j\to k}$ between two energy slices as a fraction of $T_{k\downarrow}$.
Therefore, the downward in energy transition rates between states in two energy slices ' k' and `j'.($E_k > E_j$ can be written in the form

$$T_{k\to j} = V_o \exp\left(\frac{-2R_k}{\alpha}\right) * \frac{d_j - n_i(t)}{\sum_{i=k}^{m}[d_j - n_i(t)]} \quad (19)$$

6. We can also calculate the transition rate for carriers between two slices 'j' and 'k' upward in energy can be derived from downward transition rate

$$T_{k\to j} = T_{k\to j}\frac{d_k - n_k(t)}{d_j - n_i(t)} \exp\left(\frac{\xi_k - \xi_j}{KT}\right) \qquad (20)$$

Hence, upward in energy transition, the expression becomes

$$T_{k\to j} = V_o \exp\left(\frac{-2R_k}{\alpha} - \frac{\xi_k - \xi_j}{KT}\right) * \frac{d_j - n_i(t)}{\sum_{i=k}^{m}[d_j - n_i(t)]} \quad (21)$$

7. If the concentration of charge carriers at time 't' is 'n', the recombination rate would be of the order $\Gamma_\sigma(n^{-1/2})$
The recombination rate in Equation [16] can be expressed as the product of the density of filled electron state n and the probability '$n\alpha^2$' from the filled hole state of a distance α from

filled electron state n;

$$\Gamma_\sigma \approx \tau_o^{-1} n(t)\alpha^2 \qquad (22)$$

Applying Equations (14)- (20) we obtain the luminescence spectrum as;

$$I(\hbar\omega, t) = \alpha \int_{-\infty}^{\infty} n^{(o)}(\hbar\omega + \xi, t) n^{(k)}(\xi, t) d\xi \quad (23)$$

Where $n^{(o)}(\xi, t)$ and $n^{(k)}(\xi, t)$ denote the densities of electron and holes, respectively.

The results show extreme broad distribution of the recombination time, which depends exponentially on the recombining excitons (Figures 9 and 10).

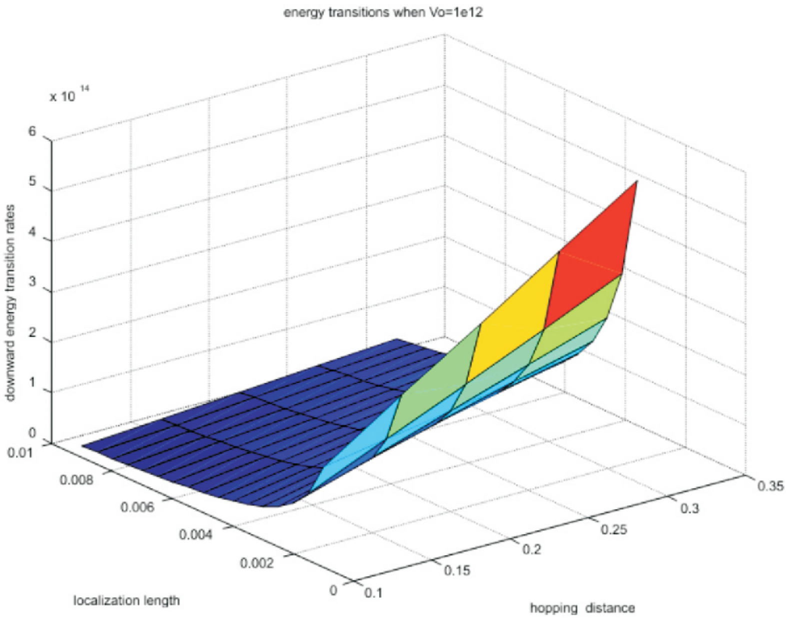


Figure 9: effects on the downward energy transition when V_o =1Hz and R>α in the second Taylors expansion (Uno et al., 2012c)

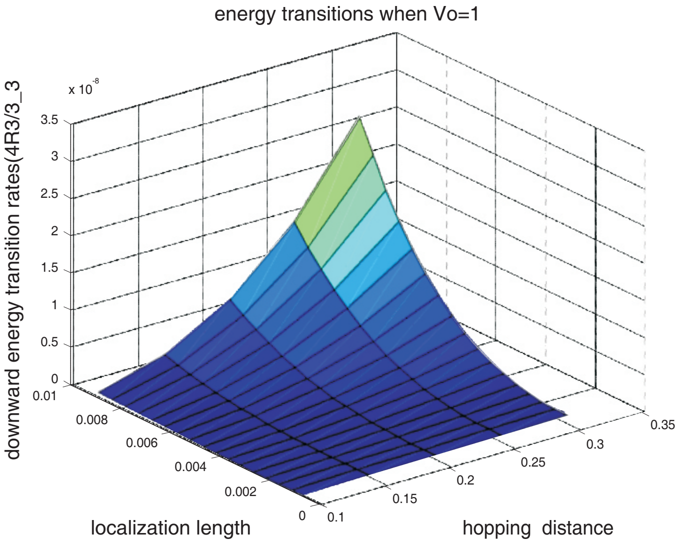


Figure 10: effects on the downward energy transition when V_o =1Hz and R>α in the fourth Taylors expansion(Uno et al., 2012c)

The energies at each localized state show an energy split between the electronic ground state and the ? rst-excited state of 0.0038eV. This salient result raised a fundamental question on the magnetic fields' influence in the superlattices of the material. We theoretically investigated the magnetic field effect on the electronic structure of doped GaAs quantum well and superlattices (Uno *et al.,* 2014).
The energy level investigation in a p-typed doped GaAs structure under the magnetic field was carried out theoretically using the effective mass for a uniform acceptor distribution. The structure was calculated by solving the Schrödinger and Poisson equations.

$$E_n^{hh}\Psi_n(z) = \left(\frac{-\hbar^2}{2m^*_{hh}}\frac{d^2}{dz^2} + V_H(z)\frac{e^2B^2}{2m^*_{hh}C^2}z^2\right)\Psi_{hh}(z) \qquad (24)$$

$$E_n^{lh}\Psi_n(z) = \left(\frac{-\hbar^2}{2m^*_{lh}}\frac{d^2}{dz^2} + V_H(z)\frac{e^2B^2}{2m^*_{lh}C^2}z^2\right)\Psi_{lh}(z) \qquad (25)$$

Where m^*_{hh} and m^*_{lh} are the heavy-hole and light-hole effective masses

Z is the direction perpendicular to the δ-doped layer

$V_H(z)$ is the effective Hartress potential

B is the magnetic field strength applied perpendicular to the growth direction

The effective Hartress potential $V_H(z)$ is obtained by solving Poisson equation;

The hole density is related to

$$P(z) = \sum_{j=2}^{2}\sum_{i=2}^{n}\frac{P_i}{\Psi_i^{j}(z)} \qquad (26)$$

$$\Rightarrow P(z) = \sum_{j=1}^{2}\frac{m_j^*}{\pi\hbar^2}\sum_{i=1}^{n}\frac{(E_F - E_i^{j})}{\Psi_i^{j}(z)} \qquad (27)$$

Where j labels the sub-bands (j=1for the hh band, j=2 for the lh band).

P_i the number of holes per unit area

Recall that this option was as a result of the energies at each localized state which shows an energy splitting between the electronic ground state and the ? rst excited state of 0.0038eV. Hence, it is very necessary to consider the basics of the energy levels, especially in a magnetic field.It is evident from the result that the magnetic field introduces valley splitting in electronic gas and further reduces dimension, leading to quantum well energy state. At this state, the degree of confinement and localization of electrons varies depending on the magnetic field (Figure 11).

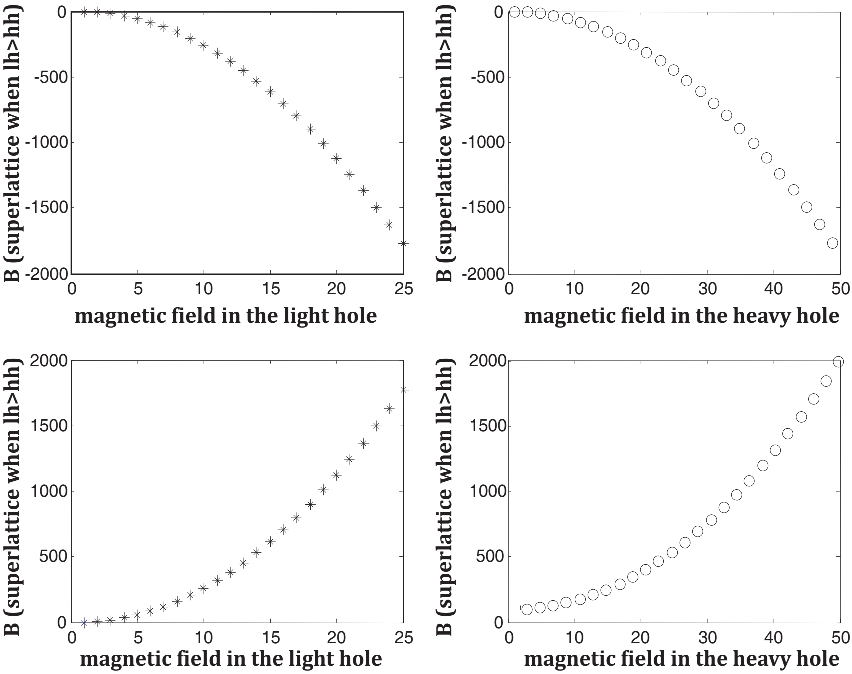


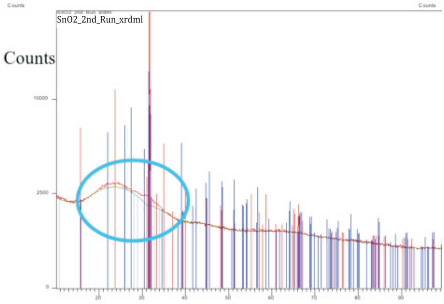
Figure 11: Magnetic influence on the GaAs sub-bands for both light and heavy holes(Uno et al., 2014c)

More so, the heavy-hole sub-bands contain more energy states than the light-holes sub-bands. The total population of heavy-holes increases with an increasing magnetic field as the number of field states changes (Figure 11 c&d). This observation led to the derivation of the differential Hartress potential that was used to investigate 24 sub-bands.

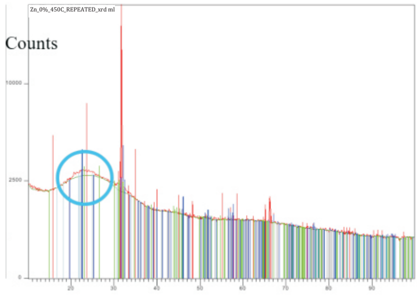
The idea of considering 24 sub-bands in doped GaAs led to our first experimental work on the crystalline grain size effects on the doped tin dioxide (SnO_2) with zinc (Zn).

Spray pyrolysis technique was used for the fabrication of the sample. The experiment was conducted in Sheda Science and Technology Complex (SHETSCO)Abuja. We considered a series of doped SnO_2 ($Sn_{(1-x)}Zn_xO_2$), deposited on the glass slide with different doping concentration values of 0.01-0.04 m. Zn on SnO_2. It was observed that the average grain size of the Zn doped SnO_2, compare to the average grain size of SnO_2 film, is increasing upon an increase in doping concentration (see an excerpt some of the results in Table 3 and Figures 12 a-e).

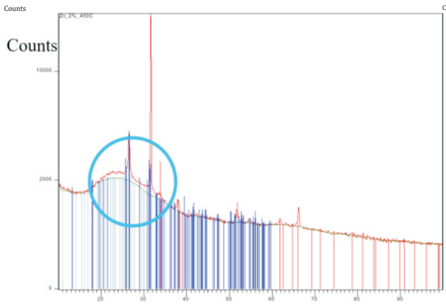
Wt. of Sn (g)	Wt. of Zn (g)	% of Zn	Vol. of Zn (ml)	Vol. of $SnCl_4$ (ml)
0.37	0.0037	1	0.476	10
0.37	0.0074	2	0.663	10
0.37	0.0111	3	1.401	10
0.37	0.0148	4	1.847	10



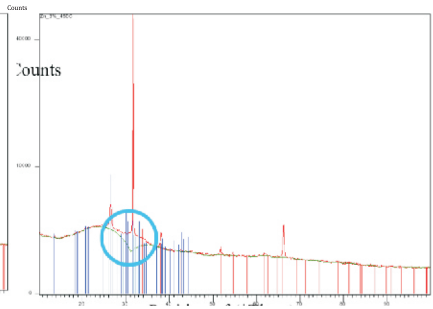
Position of (*Theta)
Figure 12a: X-ray diffraction stick pattern of pure tin dioxide thin film



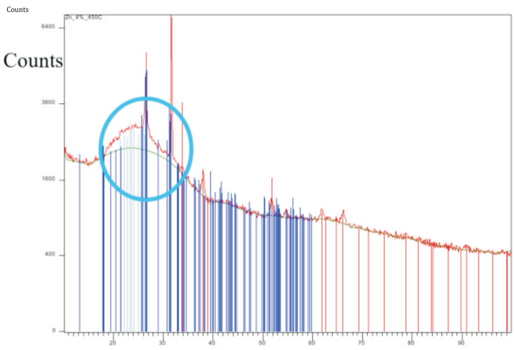
Position of (*Theta)
Figure 12b: X-ray diffraction stick pattern of doped tin dioxide thin film with 1% Zn



Position of (*Theta)
Figure 12c: X-ray diffraction stickpattern of doped tin dioxide thin film with 2% Zn



Position of (*Theta)
Figure 12d: X-ray diffraction stick pattern of doped tin dioxide thin film with 3% Zn



Position of (*Theta)
Figure 12e: X-ray diffraction stick pattern of doped tin dioxide thin film with 4% Zn (Uno et al., 2014b)

However, grain boundary theories were obeyed except for the 4 wt.% Zn on SnO_2 that showed a high doping incompatibility level. At 1 wt.% Zn on SnO_2 exhibited the characteristics of a homogenous and stable p-type semiconductor. At 3 wt.% Zn on SnO_2, the direction change in the orientation of two adjacent grains was shown to localize at a site equidistant to the grains.

These results were further confirmation of our theoretical predictions using the 24 sub-bands of theoretically doped GaAs. Curiously, we looked at the possibility of obtaining positional doping effects on the optical properties of doped tin dioxide (SnO2) with zinc (Zn). We foresee that this concept would be a fundamental breakthrough in the physical sciences (Figure 13).

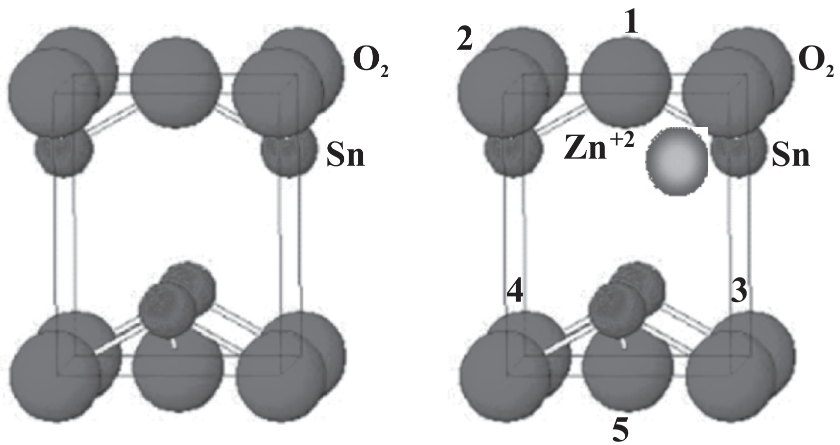


Figure 13: Logical positions of dopant within the tin oxide structure (Uno et al., 2014b)

The procedure was the same as the latter research. However, we investigated the optical properties of doped tin dioxide (SnO_2) with zinc (Zn). The average transmittance, reflectance intensity, and optical bandgap of the Zn doped SnO2 showed that the results gotten were due to the dopant affinity for any sites on the sample structure, which defines the properties of the doped samples (see few excerpts of the results in Figures 14-16).

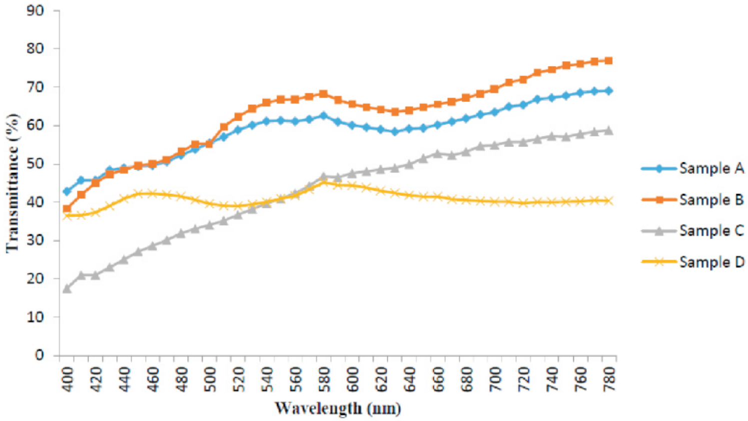


Figure 14: Transmittance spectra for Samples A, B, C and D (Uno et al., 2014b)

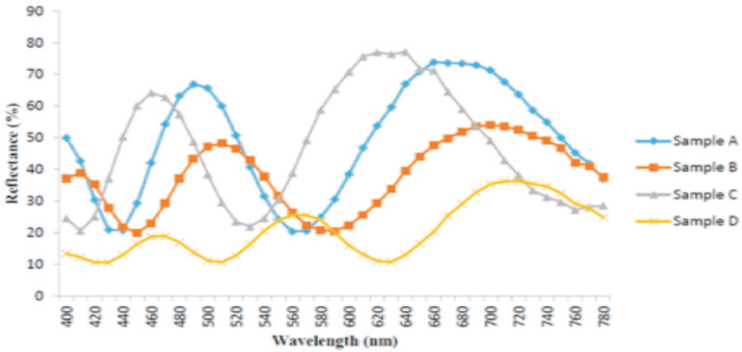


Figure 15:Reflectance spectra for Samples A, B, C and D (Uno et al., 2014b)

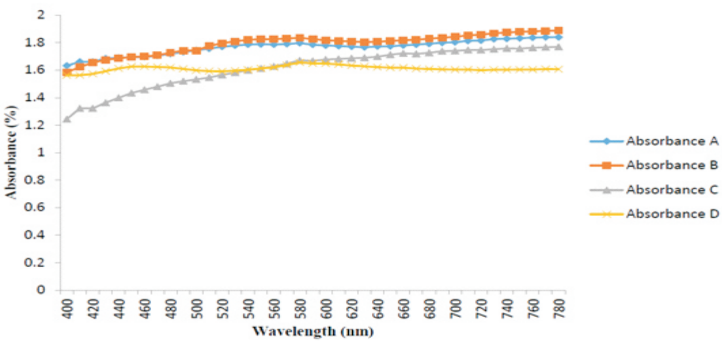


Figure 16:Absorption spectra for Samples A, B, C and D (Uno et al., 2014b)

We tried to mathematically express a formula that would incorporate the positional doping concept as:

$$E_g = \sum_{1}^{i} K_1 \frac{p_i}{d_i} - K_2 \qquad (28)$$

Where E_g is the optical band gap, p_i is the position, d_i is the d spacing, K_1 and K_2 are the energy-independent constant given as $K_1 \leq 1, K_2 > 1$ $\frac{K_1}{K_2} \leq 1$ Equation (28) showed accuracy with the samples. However, the validity of Equation (28) has not been proven for other doped metallic oxides. This result would be our focus in the coming years.We also worked on the structural and optical properties of compounds such as Tin Sulphur (SnS), and dye sensitized solar cell.

The aim of our contribution in semiconductors is because of its high financial prospects ascircuitry component or solar cell. If this project is funded, it could create jobs for the teeming youth and provide a good platform for academics to trigger product development. It is most exciting to know that the production of circuitry devices can be successfully domiciled in Nigeria, not only in China or other developed countries.

1.2.3.2 Summary of Findings

This finding is essential for the electronics and optoelectronics companies to produce long-lasting photovoltaic modules. Our calculations started with the energy levels in a hole-electron recombination process. The process was monitored under a magnetic field within twenty-four sub-band. The findings shows that the structural imperfections in semiconductor depends on the method of synthesis and material type. Based on the above, the structural and optical properties of selected semiconductors was studied experimentally. Salient discoveries were discovered such as the effect of positional doping on semiconductor material which is the main component of photovoltaic module. It was recommended that more focus should be channeled to lead-free semiconductor which is environmentally friendly.

1.4 Conclusion and Recommendations

Mr. Vice-Chancellor Sir, there is hope for a sustainable society if relevant mercenary is put in place to ensure that academic discoveries do not reside in shelves. The three major discoveries in my over twenty-five years research, i.e. intra cloud technology, geothermal energy prospects, and material synthesis, may just be an academic exercise if industrialization and commercialization issues are not resolved.

Allow me to conclude how rich our universities could be when 'gown' meets 'town'. The 100 wealthiest universities in the world all have links to synergy with the industry. For example, in 2018, Harvard University is worth $36 Billion, Yale University is worth $27.1 Billion, The University of Texas System is worth $26.5 Billion, Stanford University is worth$24.7 Billion, etc.

From my vantage point in promoting technological knowledge, I see a beautiful future for Nigeria. I see a rapid form of development that may be faster than projected if the government play their role to fund research radically.

Thank you all for listening

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Brief Profile of the Inaugural Lecturer

Prof Uno Essang Uno, who hails from Eyulor in Urue Offong Oruko Local Goverment Area of Akwa Ibom State, was born to the family of Essang Uno Abasiene Uno on 29th December, 1959.He attended Primary School at Government School Oruko and proceeded to Secondary Technical School Oyubia,Oron both in Akwa Ibom State. In search of and hunger for knowledge, he proceeded to the famous University of Calabar (as a young Malabite) 1982-1986, where he obtained B.Sc(Hons) degree in Physics. Between 1996 and 2006, he was at the University of Abuja where he obtained his M.Sc and PhD degrees in Solid State Physics respectively.

He started his humble career as a Store Keeper after his School Certificate with Federal Government College Enugu from 1979-1982. He had his NYSC between1986 and 1987 at the Federal Government College Kano. He started his teaching career with Kano State Government 1987-1989 and was posted to Senior Secondary Grammar School, Kazaure. He later had federal teaching appointment with Federal Ministry of Education deployed to Federal Government Girls' College Bwari, Abuja in 1989. He joined the services of the Federal University of Technology Minna in 2002 (on transfer of service) as an Assistant Lecturer and rose to the rank of Professor in 2015.
Professor Uno has held various positions and served in many committees in the Federal University of Technology Minna, which include among others: Examination Officer, Department

of Physics; Examination Officer, School of Science and Science Education; Deputy Chairman, University Board of Research and the Pioneer Coordinator of Electronic Based Examination in the University. The Centre he handled meritoriously for 11years from 2008-2019. He is the immediate past Head of Department of Physics and Member, University Governing Council. He was the Local Organizing Committee Chairman, 40th edition of Nigerian Institute of Physics and Member, NIP Council(2017-2018).

Prof Uno has contributed immensely to the growth and popularization of Science and Technology in Nigeria and beyond. To mention but a few:

(1) He is an International Board Member of Physics Olympiad (2006 till date)

(2) He is a Country Leader and International Board Member, International Junior Science Olympiad (IJSO). Excellent Organizer, through him Nigeria hosted IJSO 2010 which attracted 42 Countries to Nigeria.

(3) He is a Country Leader and International Board Member '' International Young Physicists Tournament'' (IYPT) (2006 till date)

(4) He is a Leader, Science Odyssey and Board Member Still-Learning Organization International.

(5) He is a Project/Quiz Master, Junior Engineers Technicians and Scientists (JETS')Nigeria.

(6) He is a Consultant and Passionate Organizer of Quiz and Science programmes to Federal Ministry of Education, Federal Ministry of Science and Technology, NAFDAC and WAEC.

(7) He is a Board Member and the Founder of Centre for the Gifted in Science.

Professor Uno has supervised over 60 undergraduate,45 Master's and 8 Doctoral Theses. He is a Fellow of Nigerian Institute of Physics ***FNIP*** and the Institute of Corporate Administration(***FICA***). He belongs to several other Professional Bodies. He has over 67 Scholarly Publications in reputable Books and Journals. He is the Author of the Book titled ''Winning Gold at the International Science Olympiads."

The Man, Professor Uno is hardworking, sincere and faithful. He is honest, friendly and sociable. He is firm and very stable; even under pressure, he attempts every assignment with zeal and determination. He is highly disciplined. He is the man with strong persuasion, sound principles with strategic programme. He is a man with selfless perspective, Ambassador of goodwill and an Advocate of good morals. He has travelled far and Wide. He is married and blessed with children and grandchildren.