NIGER DELTA UNIVERSITY

WILBERFOCE ISLAND, BAYELSA STATE.

35th INAUGURAL LECTURE

Titled:

NANO, NANO, NANO

By
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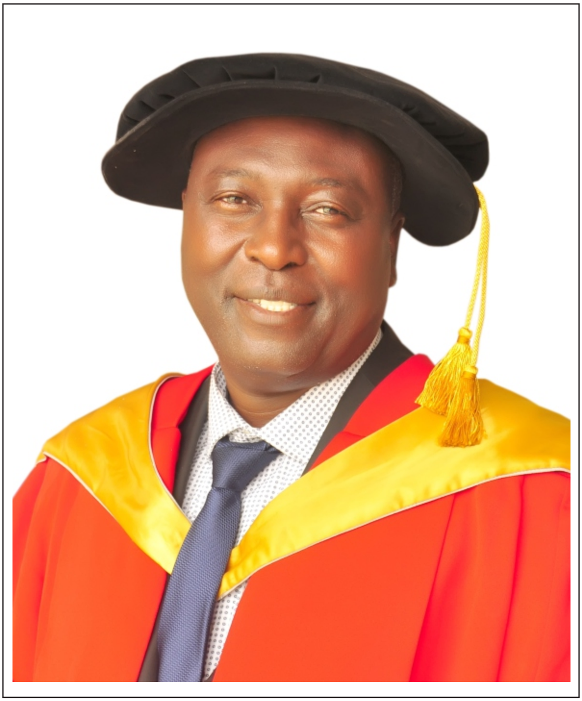


Prof Ezekiel Dixon Dikio ***(PhD, FRSC)***

Professor of Physical Chemistry.

DEDICATION

The Messages of the Three Angels

(Rev 14:6 KJV)
And I saw another angel fly in the midst of heaven, having the everlasting gospel to preach unto them that dwell on the earth, and to every nation, and kindred, and tongue, and people,
(Rev 14:7 KJV)
Saying with a loud voice, Fear God, and give glory to him; for the hour of his judgment is come: and worship him that made heaven, and earth, and the sea, and the fountains of waters.
(Rev 14:8 KJV)
And there followed another angel, saying, Babylon is fallen, is fallen, that great city, because she made all nations drink of the wine of the wrath of her fornication.
(Rev 14:9 KJV)
And the third angel followed them, saying with a loud voice, If any man worship the beast and his image, and receive *his* mark in his forehead, or in his hand,
(Rev 14:10 KJV)
The same shall drink of the wine of the wrath of God, which is poured out without mixture into the cup of his indignation; and he shall be tormented with fire and brimstone in the presence of the holy angels, and in the presence of the Lamb:
(Rev 14:11 KJV)
And the smoke of their torment ascendeth up for ever and ever: and they have no rest day nor night, who worship the beast and his image, and whosoever receiveth the mark of his name.

TABLE OF CONTENT

PROTOCOL

The Vice Chancellor,
The Deputy Vice Chancellor (Administration).
The Deputy Vice Chancellor (Academic).
Registrar
University Librarian
Provost, College of Health Sciences
Members of the University Governing Council here present
Dean Faculty of Science
Deans of other Faculties/ Directors of Institutes and Centres
Distinguished Professors and Scholars
Heads of Departments
Other Academic and Administrative Staff
Royal Majesties, Highnesses and other Traditional Rulers
Staff and Students of Niger Delta University
Academic and Non-academic Colleagues
Distinguished Guests
Ladies and Gentlemen

INTRODUCTION

It is with gratitude and a deep sense of humility that I stand before you all today the 20thDay of March 2019 to deliver this inaugural lecture to this University. This is a beautiful day and a blessed month. So, it is a lucky and blessed month for me. I believe that all of us here present are blessed you will agree with me Mr Vice Chancellor, Sir.

To be elevated to the privileged position of a Full Professor is by the Grace of God. It is therefore a duty for me to defend the action of the Niger Delta University authorities and academic peers who adjudged my humble contributions to scholarship worthy of recognition. An inaugural lecture allows the individual an occasion to define his new standing and outline his goals for the future.

For the academician, the inaugural lecture enable the professorial entrant to publicly review his field of expertise, present his academic credentials and relate his contributions in the field to the needs and challenges of the society at large.

Chemistry

Chemistry as one of the science subjects can be tricky and hard, but there are tremendous benefits and rewards, because, in scientific research, we unravel the mysteries of the universe around us. And please note, that unravelling the mysteries of the universe around us, is aim of the game.

One notable and exciting item we study in science and Physical chemistry, in particular, is energy. “Energy is anything that is imperceptible and yet drives everything around us – from our bodies to our mobile phones to our cars to all the stars in the universe – but you cannot create or destroy energy.

Understanding Chemistry

As experts in chemistry, there is a lot about chemistry that we just do not understand yet. We do not understand solids that well, and we do not understand liquids that well either, or the range of things that can happen when one meets the other. Chemistry has always been a fascinating subject from the days of the alchemy. The quest for riches without much toil was the driving force. People toiled to find gold in difficult terrain, travelled and worked from sun-up till sun-down, as we know, Mister Vice Chancellor. But the alchemy wanted a short cut. Alchemy was a tradition practised throughout Egypt and Euroasia aimed to purity, mature and perfect objects. Common aims among others were:

i. The transmutation of base metals into noble ones like gold.
ii. The creation of an elixir of immortality
iii. The creation of a panaceas able to cure any disease and
iv. The development of an alkahest, a universal solvent.

A Chemist

A scientist who does his research and experiments on the properties of chemical substances is called a Chemist we are no more called Alchemist. Chemists determine the quantity and the properties of chemical compounds in innumerable situations. Many industries benefit from the ideas and chemical compounds produced by research in the chemical sciences. Chemists also engage in research to improve the quality of established chemical products and employs advanced computer programmes in establishing new technologies. A chemist may be hired to work with simple forms of matter to influence a greater understanding of the chemical itself, uncover the elements of unaccustomed substances or create utterlydifferent chemical compounds for use in a diversity of applications.

This hardness, trickiness, lack of proper understanding, native doctor likeness and toiling in the laboratory, lead a 17th Century Alchemists to state that, "Chemists are a strange class of mortals, impelled by an almost insane impulse to seek their pleasures amid smoke and vapour, soot and flame, poisons and poverty." This has not changed much, Mr VC, you will notice that I am strange but not insane. Prof Wankasi, a Chemist who works on "Sorption" is also strange, you will agree with me, Mr VC.

The experiments, reactions, and discoveries in chemistry were scintillating, several metals, metalloids, and non-metals were discovered. A number of processes were promulgated, nothing much until John Dalton, discovered the atom. Like you all know, an atom is the smallest constituent unit of ordinary matter. The diameter of an atom ranges from 0.1 to 0.5 nm. This is the rebirth of nano. From this point we go nanonanonano all the way.

NANO NANO NANO

Nano is derived from the Greek nanos and Latin nanusrepresentingor characterizing dwarf. Nano is a prefix.

When the measurementof an object is in the order or range 1.0 x 10^{-9} or 0.000000001 of a meter, it is nano.

In simple terms, when you divide a meter one billion times, one part of that division, which the ordinary eye cannot see, even with the aid of our glasses but with, instruments such as, a scanning electron microscope (SEM), a transmission electron microscope (TEM), is the size we are talking about.

Nano has been with us all along. Prominent usage of this prefix are nanomaterial, nanotechnology, nanoscience, nanochemistry, nanoresearch and so on.

There are so several nanoscurrently,

NANO RICE.

Vialone Nano Rice is an Italian rice which has been grown in Italy since 1937. It was developed by crossing Vialone rice with a variety called Nano because of the plant's low height. Its high amylose content allows it to keep its shape and absorb lots of liquids during cooking.

Fig 1. Italian vialonenano rice

NANO BEANS

Coco Nano Beans is a member of the legume/pulses species which are sown at early spring. Following traditional and ancient cultivation methods, the bean plants are removed from the soil by a separating process. Sowing and harvesting are hand-made.It is not a simple common bean: it's the right and balanced product for the refined and careful consumer. Coco Nano beans are included in the Mediterranean diet and they are recommended by oncologists and nutritionists for their beneficial effects on health.

Fig 2. Coco Nano beans

NANO GARI NANO MOIMOI

Mr VC, I went in search of nanogari and nano moimoi, not available. They are yet to be officially registered and introduced in Italy. Once they are introduced to Italy, we will have nanogari and nano moimoi.

NANO CAR

In 2016,three scientists won Noble Prize in chemistry for their developing the worlds smallest machine. The car is 1000 times smaller than the human hair. A nanocar is about eight square nanometers. The width of a human hair is about 8,000 square nanometers. Thus, about a billion nanocars would fit in that space.

The nanocar is a molecule designed in 2005 at Rice University a group of scientists. The molecule consists of an H shaped Chassis with fullerene group attached at the four corners to act as wheels.

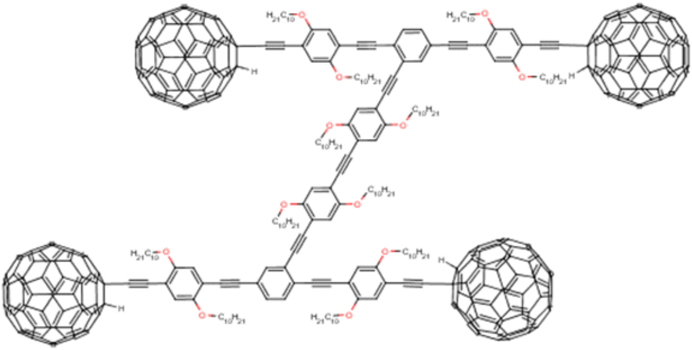


Fig 3. Nano car molecular arrangement

NANO CAR RACE

Car racing is an important race. The formula One car racing, you will recall. To determine which car is the fastest, the American Chemical Society conducted the first Nano car racing. In nanocar race, the world's smallest cars race along tracks thinner than a human hair. Six teams worked to build cars that could race each other on a track.

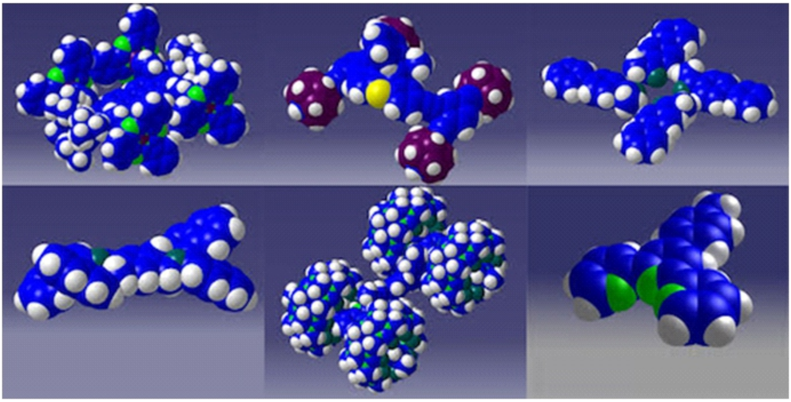


Fig 4. Molecular Nano Cars

The nanocars drive along a 100-nanometer track. The driving is done by applying a positive or negative electrical charge to effectively "push" or "pull" the nanocar is then given a direction. One nanocar was built by a professor of physics and astronomy.

Another nanocar was built by, an associate professor of chemistry and biochemistry, It had more than 100 atoms (644, in fact), and was operated on a gold surface.

NANO POLICE CARS

Tata Nano, the world's cheapest car, has just become the world's cheapest police cruiser.

Fig 5. Tata nano police car

NANO FLASK

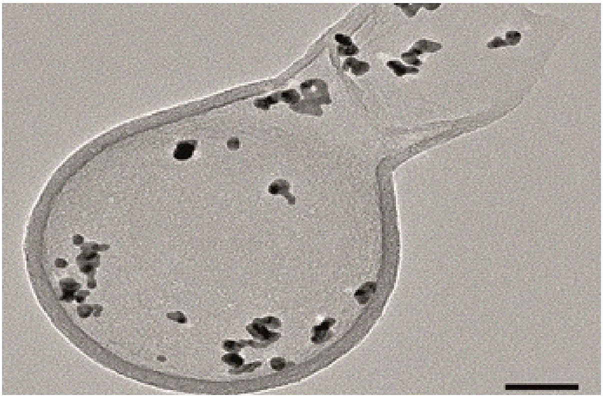


Fig 6. Nano flask

Using self-assembling nanospheres clusters, researchers have created chemical reactions 100 times faster than in solution and opened the door for advancing drug delivery.

When a single layer of nano-particles is coated onto a surface, they self-assemble into a crystalline structure known as a cluster. Known as “nanoflasks” these arrangements are exceedingly susceptible to light, assembling under UV light and dissembling under normal light. A feature that would be very useful in drug delivery, where a patient could take a drug that could be then activated at a later time.

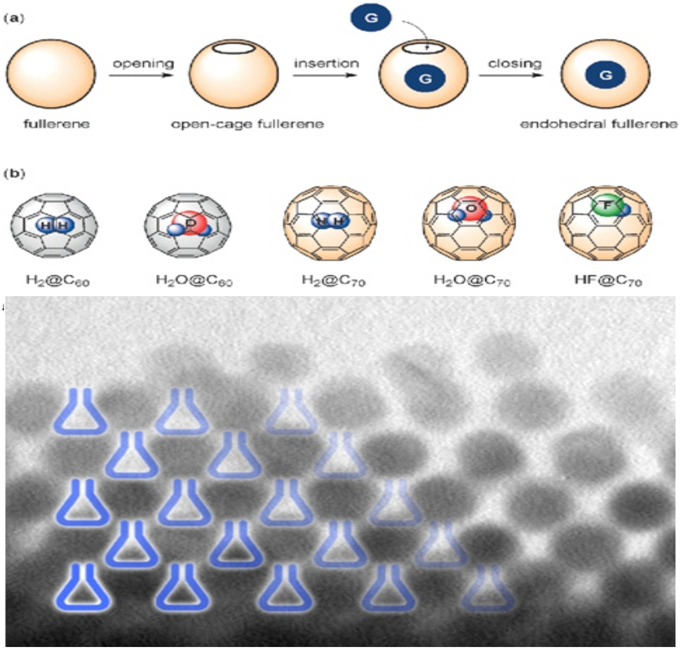


Fig 7. Nano flask

NANO BIOLOGY

Delft University of Technology also recognisedas TU Delft, as the largest and oldest Dutch public technological university, is located in Delft, Netherlands. It counts as one of the best universities for engineering and technology worldwide. It has started a new degree, BSc Nanobiology.

BSc Nanobiology

Nanobiology is the study of the complexity of living systems. It employs the methods and principles of physics to do this in a quantitative way. It is a relatively new area of research that bridges the borders between Physics, Nanophysics, biology and medical research. The course is suitable for students with a strong interest in both physics and biology.

NANO SOAP

Fig 8. Nano soap

NANO HOUSE

French researchers from an institution called Femto-ST Institute have used micro robots to compile the world's smallest house, which stands just 0.015 millimetres high.The tiny house, which has a trajectory of0.02 millimetres by 0.01 millimetres, is around half a million times smaller than a regular two-storey house. Sitting on the top of an optical fibre the house hasa traditional gabled roof, four windows, a door, chimney and walls made of an ultra-thin silica membrane that is just 0.0012 millimetres thick.

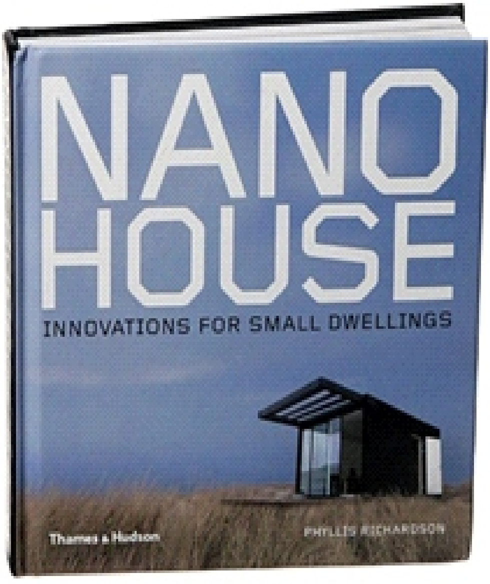


Fig 9. Nano House

NANO BIBLE

Israel's Nano-Sized Microchip Bible Nominated For Guiness Book Of Records Nano-sized New Testament Bible has been recommended for the Guinness Book of Records as the World's Tiniest Bible. The microchip containing the entire miniaturized New Testament is being marketed as a stylish accessory.

The tiny tome, which is less than a fifth of an inch square, can be mounted on a necklace but you'll need a special microscope to read it. The Jerusalem-based nano Bible establishmentsaid it builta chip smaller than five by five millimeters, which contains the original Greek version of the New Testament (Textus Receptus, or “received text” in Latin).

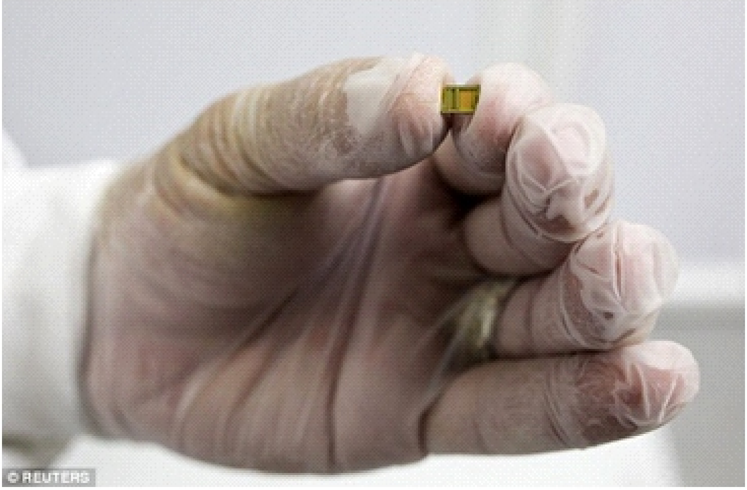


Fig 10. Nano New Testament Bible

NANO AGE

The following technologicaltransformation. Raymond Kurzweil, an established inventor of the Nanotech Era is of the opinion that this should begin between 2025 and 2050 bringing an end to the existing information age which is believed to have commenced in 1990. Humankind is at the verge of the single greatest innovation in the history of science and technology. Emerging is a Nano Transformation that will be at least as transformative as the Industrial Revolution (perhaps much more so), but packed into just a few years.

Beyond the existing nanotech applications, maturemolecular manufacturing or molecular nanotechnology will empower us to manifest our dreams (or nightmares). We are at the steps of a period where we will have the ability to build molecules out of atoms mechanochemically, and to use these molecular building blocks to construct virtually any substance or device we can conceive of. This most powerful technology of all will radically transform and extend the capabilities of practically every area of human endeavour by exploring the ultimate limits of fabrication. The Nano Age iscommencing, as an exponential escalation into a vastly distinctive world. Nanotechnology will turn out to be the grandest powerful gizmo the human species has ever used. With nanotechnology, we will factually pattern the world of tomorrow into whatever we soappeal.

Fig 11. Nano Age

NANO MANUFACTURING

Nanomanufacturing is both the production of nanoscaled materials, which can be powders or fluids, and the manufacturing of parts "bottom up" from nanoscaled materials or "top down" in smallest steps for high precision, used in several technologies such as laser ablation, etching and others. Nanomanufacturing differs from molecular manufacturing, which is the manufacture of complex, nanoscale structures by means of nonbiological mechanosynthesis (and subsequent assembly).

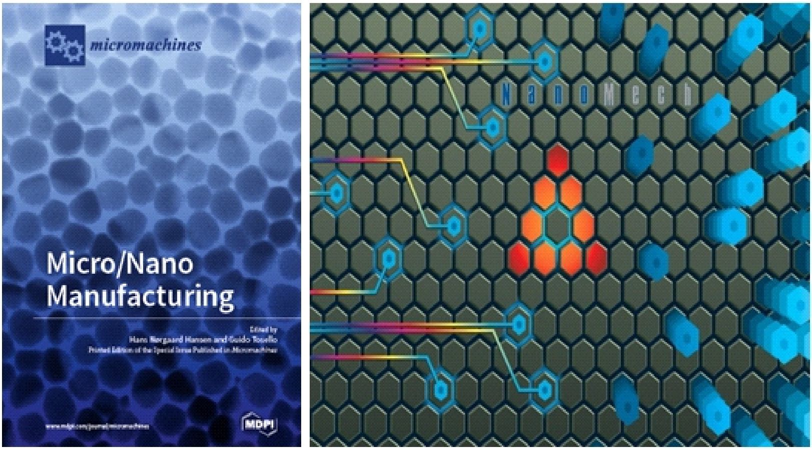


Fig 12. Nano Manufacturing guide book.

NANO ROCKET

Tiny machines like nanorockets are ideal candidates for drug delivery in the human body. Chemists at Radboud University now demonstrate the first complete movement regulation of a nanorocket, by providing temperature responsive brakes. An interesting feature for practical applications, since temperature sensitivity enables the rocket to stop in diseased tissues where temperatures are higher. *Nature Chemistry* publishes their results on December 12. The soft nanosystems that the bio-organic chemists at Radboud University work with self assemble, which means that they spontaneously form functional units.

This allows the nanorockets to change shape, making them ideal candidates for containing cargo like medicine. 'Our biggest challenge is to provide our nanorockets with various functionalities', says Daniela Wilson, head of Radboud University's Bio-organic chemistry department and Nanomedicine theme leader 'We now demonstrate the first molecularly built brake system, enabling the rockets to start and stop at desired locations.'

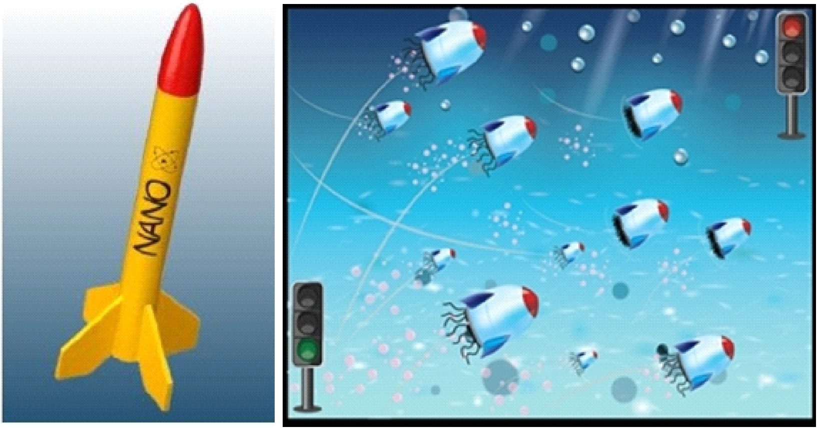


Fig 13. Nano Rocket design

NANO FLYING

The fly nono is a single seat seaplane designed by Aki Suokas in 2011. The aircraft is made from carbon fibre. It has 4.8-meter wing span. The aircraft has a single seat, a single electric engine, an open cockpit, without a windshield and no wheels. The aircraft wing can be removed for storage or ground transportation.

Fig 14. Nano single engine plane

NANO FROG

Fig 15. Nano frog

Nano FROG (Frequency Resolved Optical Gating by a nanometric object)

NANO FEEDING BOTTLE

Nano technology has been employed in the development of Nano-feeding bottle. This feeding bottle is designed to help protect babies with weak immunity from gems. through new Nano-poly technology, and cutting-edge science, this Nano-feeding bottle perfectly prevents secondary virus inflammation by controlling germs.

Fig 16. Nano feeding bottle.

NANO BATTERIES

Nanobatteries are fabricated batteries employing technology at the nanoscale, particles that measure less than 100 nanometers or 10^{-7}meters. Batteries that Nano in size can be brought together to function as a macro-battery such as within a nanopore batttery. Lithium-ion battery technology utilize constituents, such as cobalt-oxide or manganese oxide, with particles varying between 5 and 20 micrometers (5000 and 20000 nanometers - over 100 times nanoscale). It is anticipated that nano-engineering will improve countless number of the shortcomings of present battery technology, such as volume enlargement and power density

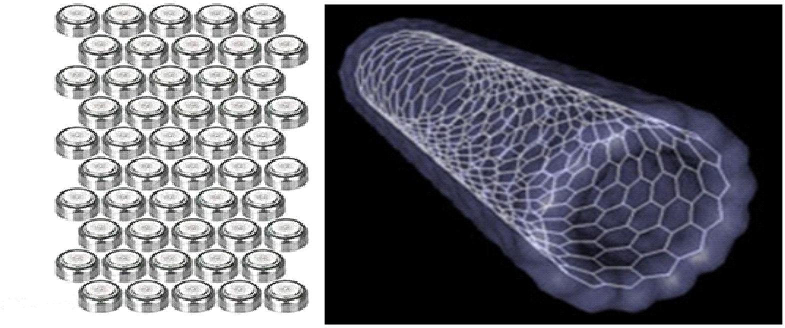


Fig 17. Nano Batteries. Nano sized bendable battery

NANO EGG

Researchers at Rice University's Laboratory for Nanophotonics (LANP) have reported the "nanoegg," this is their most recent addition to their ultra-small category, light-focusing particles. Nanoeggs are asymmetric specks of matter whose conspicuousoptical properties can be exploitedfor molecular imaging, medical diagnostics, chemical sensing.

Nanoeggsrange from about 20 times tinierthan a red blood cell, and they can be tuned to focus light on small regions of space. Individual nanoeggs interacts with more light - about five times the number of wavelengths - than their nanoshell cousins, and their asymmetric structure also allows them to focus more energy on a particular spot. Like nanoshells, nanoeggs have a spherical, non-conducting core that's covered with a thin metal shell. But where the casing on a nanoshell has a uniform thickness - like the peel covering an orange - the nanoegg's covering is thicker on one side than the other - in much the same way that a hard-boiled egg white is thick in some places and thin in others.

Fig 18. Nano egg

NANO TALES

Nano tale is a book that contains nano stories by a few authors, depicting life, motivation and inspiration. Nanotale is a small story written in limited words with a strong message. The figure of speech used by the writers is at it best. Irony, rhetoric, sarcasm, pun, satire are some of the essential tools of a nano tale. The words are limited, but the message is loud and clear.

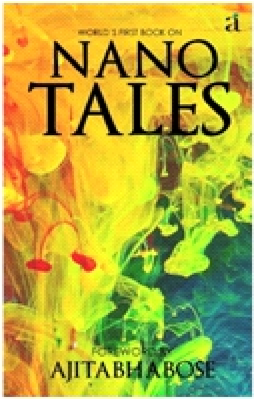


Fig 19. A book of Nano tales

NANO WEAPONS OF MASS DESTRUCTION (WMD)

The power of the individual has developed as biotechnology in recent years. In the past, countries or rogue organization, needed a lot of money, and special skills to create weapons of mass destruction (WMD). Now, it takes just one person, the internet, and a small cheap lab.

Instead of "Weapons of Mass Destruction (WMD)", we are faced with "Weapons of Mass Extinction (WME)".

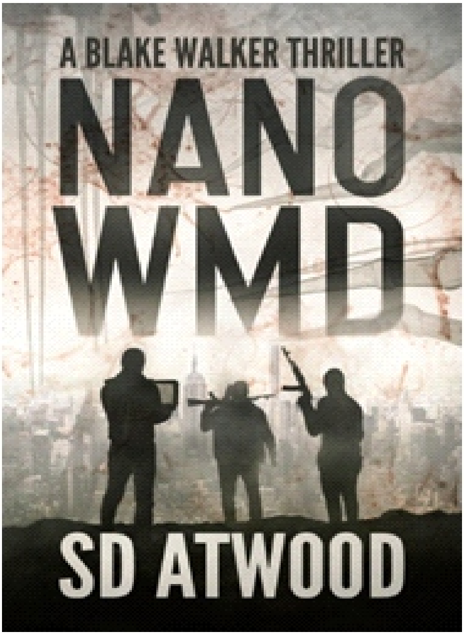


Fig20. A book of nano weapons of mass destruction

NANO BEER

As a nano brewery, Peat explained, their batches are much smaller than those of other breweries in town, with batches of beer ranging from 20 to 40 gallons. Theseassociates have made arrangementsto have eight taps and offer a rotation of beers of all different varieties and flavors. The beer won't be dispensed at other restaurants, remaining exclusive to Barrister's, Peat said.

NANO BREW

• CLEVELAND •

NANO ROBOT

A Nanorobot is a tiny machine invented to perform a specific task repeatedly aimed at high precision at nanoscale dimensions, specifically, dimensions of a few nanometers (nm) or less, where 1 nm = 10^{-9} meter. Nanorobots have prospective applications in the assembly and maintenance of sophisticated systems.

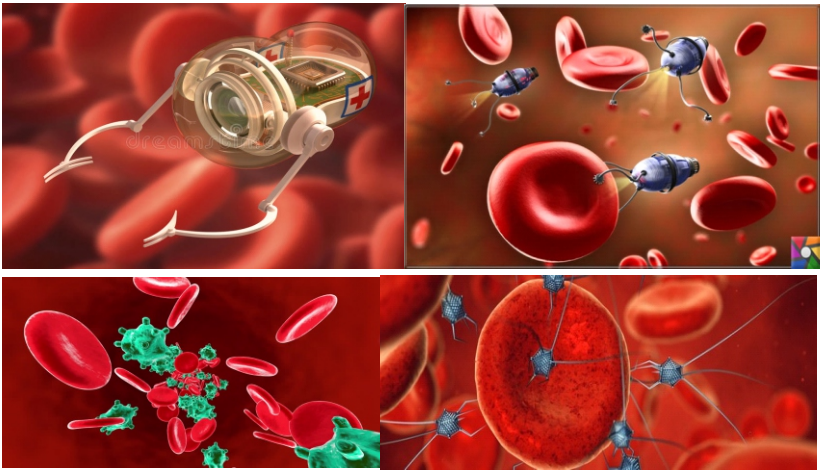


Fig 21. Design and conceptualization of nano robots as disease battling agents

NANO LOANS

NanoCredit is a development-oriented non-banking financial institution which is successfully based in the Georgian financial market since 2013 year. We offer excellent customer service to private individuals and enterprises. In last several years NanoCredit has established it's name as true trustworthy and the most stable financial company in the georgian market with good reputation within customers. In our operations with private and business clients, we focus on small and medium-sized business units, as we are convinced that these businesses create market value and is the most stable source of our company. By offering simple and accessible credit and fixed income promissory notes we help our customers to raise their business and growth their personal finances. In our company, we have the following core principles: we value transparency in our communication with customers, we do not promote consumer lending and we provide services which are based both on an understanding of each client's situation and on sound financial analysis.

NANO FINANCE

Nano Finance system gives the poorest of the poor participants an opportunity to have access to that could provide the individual interest free loans of not more than the equivalent of 20 USD to support their livelihoods, emergency needs, school fees for their children and health care for their family. Based on mutual trust, coordinators in the specific communities, chosen by women in the program from among themselves, manage the distribution and collection of the loans. The payment plan gives each woman a full year to pay back the loan in full. In this system, the participating women understand that the sustainability of the system is in their hands. The directors, the women participating feel theproprietorship of the system and they work together with communaltrust and understanding. In this way, we interpret this to mean, "Women helping women through Nano Finance."

Small is the New Big: Nanos will Rule the Future

Nanotechnology promises too much to ignore it completely. It seems inevitable that it will live up to its potential one day, so the best we can do is plan and prepare carefully for a future that will contain nanorobots. It may very well turn out that the biggest discovery in human history is also the smallest.

NANO RESEARCH

Our research in Nano Material has focused mainly in the synthesis, characterization and applications of carbon nanotubes, graphene, helical carbon, graphene oxide, reduced graphene oxide and heteroatom graphene. These are allotropes of carbon.

The element Carbon

Fig 22. The element Carbon

The date carbon was discovered is not known. The name is derived from the Latin “Carbo” Charcoal. Carbon is the 15th most abundant element in the Earth's crust. And the fourth most abundant element in the universe by mass. Carbon is a fantastically important element, this is because there are far more molecules that contain carbon than any other element. Without carbon, we could not exit. Carbon is one of the very few elements that has given rise to a whole branch of chemistry – organic chemistry. Carbon forms different allotropes, these are charcoal, diamond, graphite etc.

In the last 20 years, carbon gained pole position, more prominence, in the new forms that were discovered. These are fullerenes, C60 and C70, Carbon Nanotubes (Single-, Multi-, Double- Wall Carbon nanotubes, (SWCNT, MWCNT, DWCNT) respectively.

Carbon Nano Fibres (CNF)

Carbon has a valency that is a major distinguishing trait which enables it to form various allotropes. Diamond and graphite are the well-known allotrope of carbon. In the last few decades a large number of allotropes and variants of carbon have been discovered; some of them are carbon filaments/fibers (discovered in 1889), fullerenes (discovered in 1985), carbon nanotubes (discovered in 1991), graphene (discovered in 2004), etc. Carbon can be tailored into the above said allotropes, particularly those in the nanometer range, by changing the synthesis methodology.

The graphene sheet is the basic building block for these carbon nanovariants. In 1889, Hughes and co-workers reported the growth of carbon filamentsfor the first time. Extensive analysis carried out from that time by R.T.K. Baker et al. starting from 1972 focused on the growth of carbon filaments. Thesefilaments are shaped like solid-cored fiber with cylindrical structures were named as carbon fibers (Cfs).

Depending on thethickness and length, CFs can be categorized into carbon nanofibers (CNFs) and carbon microfibers (CMFs). CNFs holdthe ensuingmicrostructural configuration, i.e., (i) platelet CNFs, where graphite sheets are perpendicular to the fiber axis, (ii) herringbone CNFs, where graphite sheets are inclined at an angle with respect to the fiber axis, and (iii) tubular CNFs, also named carbon nanotubes, where graphite sheets are parallel to the fiber axis. From their morphological point of view, CFs can take various shapes such as planar, branched, twisted, spiral, coiled, helical, etc. as shown in Fig 1. (Raghubanshi and Dikio)

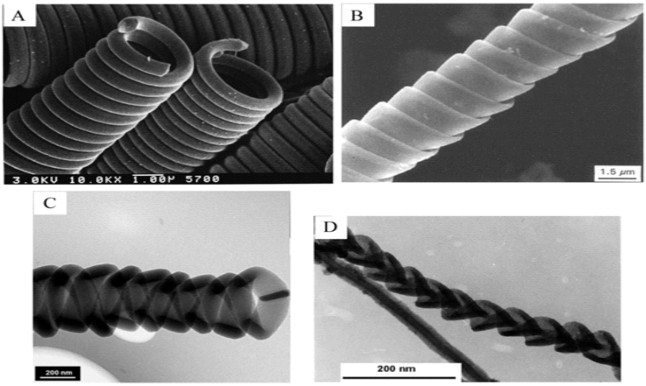


Fig 23. Various morphologies of carbon fibers. (A) double-

helix regular circular carbon; (B) regularly ribbon-like flat coiled carbon fibres; (C) Intertwined carbon fibers with symmetrical growth mode and centrally located Cu catalyst particle; (D) nanobraids (together with a carbon nanofiber)

Helical carbon fibers

Helical carbon fibers(HCFs) are very fascinating materials of carbon, composed of fibers with "helical" morphology. Their three-dimensional helical/spiral structure is the fundamental structure in nature like great maelstrom of the cosmos, the α-helix of proteins, double helix of deoxynucleic acid (DNA), screw dislocation in solids, electric waves, growth of vine plants, screw dislocation in solids, etc. The helical morphologies of carbon fiber (CF) were called as double/single-helix CF, micro/nano coiled CF, circular/flat coiled CF, spiral CF, helical CF, twisted CFs, etc., by several workers, depending on their morphologies.

In this review, we will use the notation HCFs for these various types of helical morphologies of carbon. Kuzuya et al. categorized the HCFs into helical carbon nanofibers (HCNFs) and helical carbon microfibers (HCMFs), according to the coil diameter. Typical fiber diameter, coil diameters and coil length in HCNFs are 50-200 nm, 50-1000 nm, and 0.3-3 µm, respectively; and in HCMFs are 0.3-1 µm, 1-10 µm, and 1-10 mm, respectively.

HCFs have attracted much interest due to their interesting helical structures, unique prperties, and potential applications. Their properties include high: chemical stability, surface area, elasticity, mechanical strength, and good thermal and electrical conductivity. HCFs have shown excellent electron field emission characteristics and wide band absorption of electromagnetic waves. Because of their unique morphology and properties, HCFs have been proposed for potential applications in polymer additives, supercapacitor electrodes, catalysts, catalyst supports, hydrogen adsorption, generator or detector of magnetic field, an electrical inductors, micro/nano spring, sensors, nanodevices etc.

There was a report in 1953 by Davis et al. concerning the vapor growth of two thin carbon fibersscrewedtogether in the form of a rope. Since then, a handfulresearchers have also reported the growth of HCFs from the vapor phase in their experiments.From that time on, detailed and pioneering works on the synthesis of HCFs were first introduced by Motojima et al. Furthermore, several research groups have utilizedchemical vapor deposition (CVD) to cultivateHCFs via catalytic decomposition of hydrocarbons, usingmany different metal catalysts. Till date, wide-rangingresearch endeavours have been done on the synthesis and mass production of HCFs. In these research work, the catalysts employed were usually selected from transition metal particles such as Ni, Fe, Co, Cu and also from their mixture as well as alloys. These transition metal nanoparticles operateas nucleation centers for the developmentof CFs and catalyze the decomposition of the carbon source. The catalytic activity or capability of carbon deposition and condensation, however, is not the same for all metals.

During the last decade, HCFs-based materials such as metal particles decorated HCFs, composites of HCFs have also been extensively synthesized and studied for their potential applications in the fields of electrocatalyst catalyst for hydrogen storage materials sensors, electromagnetic wave absorbers, etc. The synthesis, properties and possible potential applications of HCFs have been reviewed by some researchers. The aim of this review article is to elaborate the brief history and recent advancement on the synthesis of HCFs and related materials. We briefly cover the synthesis methodology and the effect of experimental parameters on the growth of HCFs.

Publication/s

- Himanshu Raghubanshi, **Ezekiel Dixon Dikio**. *Nanomaterial*.**2015,** 5(2), 937 – 968**.**
- Himanshu Raghubanshi, **Ezekiel Dixon Dikio,** Eliazer Bobby Naidoo. *J. Ind. Eng. Chem.* 2016, **44, 23 – 42**

CARBON NANOTUBES

Carbon nanotubes are allotropes of carbon which form cylindrical carbon molecules and have novel properties that make them potentially useful in a wide variety of applications in nanotechnology, electronic, optic and other fields of material science. Nanotubes are members of the fullerene structural family. Their names are derived from their long hollow structure with the walls formed by a one-atom-thick sheet of carbon called graphene. The chemical bond in nanotubes are composed entirely of sp^2 bonds similar to those of graphite. These bonds which are stronger than the sp^3 bonds found in alkanes and diamonds provide nanotubes with their unique strength.

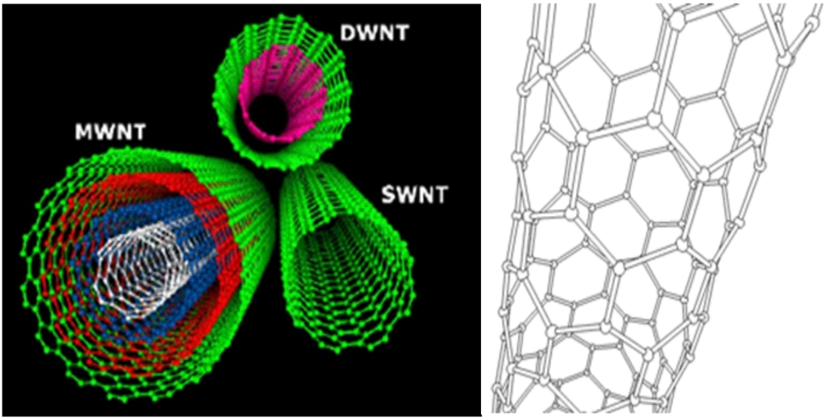


Fig 24. Images of carbon nanotubes. Single wall nanotube (SWNT), Double wall nanotube (DWNT) and Multi wall nanotube (DWNT).

We have lived with carbon nanomaterial from time immemorial. From the day man started fire, when wood or any other material burnt, nanomaterials were produced.

Synthesis Process

Several method have been employed for the synthesis of carbon nanotubes. These are the electric arc discharge, laser evaporation/ablation, nebulizer spray pyrolysis and catalytic chemical vapour deposition (CCVD) to mention a few. In our laboratory, we use the CCVD method only in all our synthesis.

Characterization techniques

Synthesized carbon nanomaterials are characterized using

Raman spectroscopy, Fourier transform infrared(FTIR), Scanning electron microscope (SEM), Transmission electron microscope (TEM), Thermogravimetric analysis (TGA), X-ray diffraction spectroscopy [XRD] andEnergy dispersive spectroscopy (EDS). Here in VUT, we have Fourier infrared spectroscopy, Thermogravimetric analysis and X-ray diffraction spectroscopy.

Catalyst

The synthesis of CNT usually involve the use of a metal catalyst of some form. The role of the catalyst is crucial to get high activity and special selectivity towards CNTs formation. Most of CNTs synthesis techniques require the introduction of catalyst in form of a gas particulates or as a solid support. The selection of a metallic catalyst may affect the growth and morphology of the nanotubes. Carbon nanotubes have been synthesized using dispersed magnetic fluids, instead of conventional metallic catalyst particles. Application of magnetic fluid of surfactant-coated magnetic nanoparticles by spin coating method on Si substrates resulted in successful growth of dense and aligned CNs. Moreover, mixing the magnetic fluid in PVA renders a viscosity to the solution, provides uniform particles distribution without accumulation and enables the control of the nanoparticle density on the substrate.

Carbon Source

Several substances have been employed as carbon source during synthesis of carbon nanotubes. A carbon source is a substance that could easily release its carbon atoms in the presence or absence of a catalyst. Substances used as carbon source are methane, acetylene, benzene and ethanol. Other sources are hexachlorobenzene and tetrachloroethylene to mention a few.

In our research work, the carbon source has been made constant, by using only acetylene. This is to enable us monitor the other parameters in the study more effectively.

Support Material

Catalyst support materials are usually solids with a high surface area which the catalyst can affix. This is because the activity of the heterogeneous catalyst occurs at the surface of the atoms. The catalyst is therefore distributed over the surface of the support. On the other hand, the support which may be inert, may also participate in the catalytic reaction process. In our research, we have employed the impregnation method. Here, in this method, a suspension of the solid support is treated with a solution of the metal catalyst salt then activated under conditions that will convert the pre-catalyst to a more active state.

In the co-precipitation method, an acidic solution of the support material, eg, aluminium oxide and precatalyst are treated with a base to precipitate the mixed hydroxide which is then calcined in a furnace.

My own contribution

My research has focused on the synthesis, characterization and application of carbon nanotubes and graphene on the one hand and the kinetic and thermodynamic study of reactions and mixtures. In this inaugural lecture, I will present only the synthesis, characterization of carbon nanotubes and graphene which are new carbon materials.

We started by taking kerosene, diesel and candle wax, substances formed from remains of ancient organic matter. These we burnt under controlled laboratory conditions and collected the material that were produced. The scanning and transmission electron microscopy study show the grainy material are produced when these obtained as carbon nanoparticles. These carbon nanoparticles are harmful to health.

These results were published in international journals.

Kerosene:

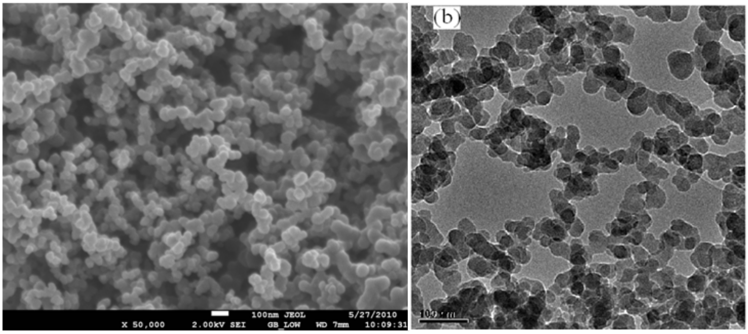


Fig 25. SEM of kerosene particles after combustion

Diesel:

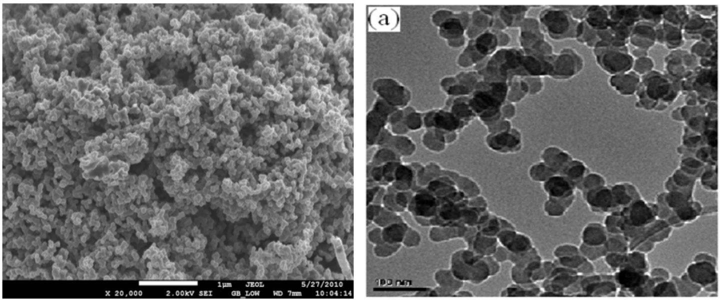


Fig 26. SEM images of diesel particles after combustion

Candle Wax:

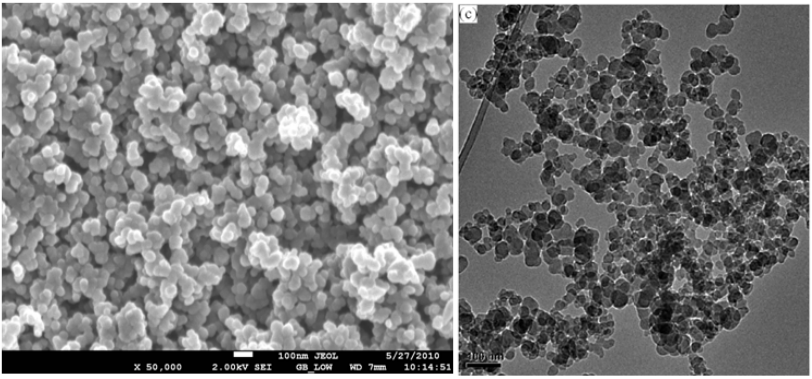


Fig 27. SEM images of candle wax particles after combustion

The results obtained gave insight into the nature of these materials. We could now understand the acute environmental pollution and health hazards that results from the burning of these items.

Publications

- FT Thema, MJ Moloto, **ED Dikio**, NN Nyangiwe, L Kotsedi, M. Maaza, M. Khenfouch. Synthesis and characterization of graphene thin films by chemical exfoliation and intercalation of graphite oxide. *J. Chem.***2013,DOI:10.1155/2013/150536.**
- **E. D. Dikio**, Synthesis and characterization of carbon nanotubes by catalytic decomposition of acetylene with Fe/Co/MgO, Co/Zn/Al and $(C_5H_7O_2)_3Mn/Al$ as catalysts. *Technical Proceedings of the Nano Science and*

Technology Institute, 2012, 1, 121 – 124. **ISBN 978-1-4665-6274-5.**

- Abdullahi M. Farah, Ntaote D. Shooto, Force T. Thema, Johannes S. Modise and **Ezekiel D. Dikio**. Fabrication of Prussian blue/Multiwall carbon nanotubes modified glassy carbon electrode for electrochemical detection of hydrogen peroxide. *Int. J. Electrochem. Sci.* **2012,7(5), 4302 – 4313.**
- **Ezekiel Dixon Dikio**, Morphological characterization of soot from the atmospheric combustion of kerosene fuel. *E. J. Chem.* **2011** 8(3) 1068 – 1073.
- **Ezekiel Dixon Dikio**, A comparative study of carbon nanotubes synthesized from Co/Zn/Al and Fe/Ni/Al catalyst. *E. J. Chem.* **2011,** 8(3) 1014 – 1021.
- David N. Shooto**, Ezekiel Dixon Dikio**, Morphological characterization of soot from the combustion of candle wax. *Int. J. Electrochem. Sci.* **2011,** 6(5), 1269 – 1276
- **Ezekiel Dixon Dikio** and NolukhanyoBixa. Carbon nanotubes synthesis by catalytic decomposition of ethyne using Fe/Ni catalyst on aluminium oxide. *Int. J. Appl. Chem.* **2011,** 7(2) 35 – 42.
- **Ezekiel Dixon Dikio**, Force T. Thema, Charity W. Dikio and Fanyana M. Mtunzi. Synthesis of carbon nanotubes by catalytic

decomposition of ethyne using Co-Zn-Al catalyst. *Int. J. Nanotech. Appl.***2010**, 4, 117 – 124.

The synthesis of carbon nanotubes requires four important starting material, a carbon source, a catalyst, a catalyst support and an appropriate heating system.

Carbon Source: Acetylene

Catalyst: Cobalt

Catalyst Support: Calcium Carbonate, Aluminium Oxide and Magnesium Oxide

Heating System: Cylindrical Furnace, Catalytic Chemical vapour deposition method

The catalyst: for our catalyst, we choose Cobalt Metal as our main catalyst and combined this with other metals to form what we call a binary metal system.

Table 1.

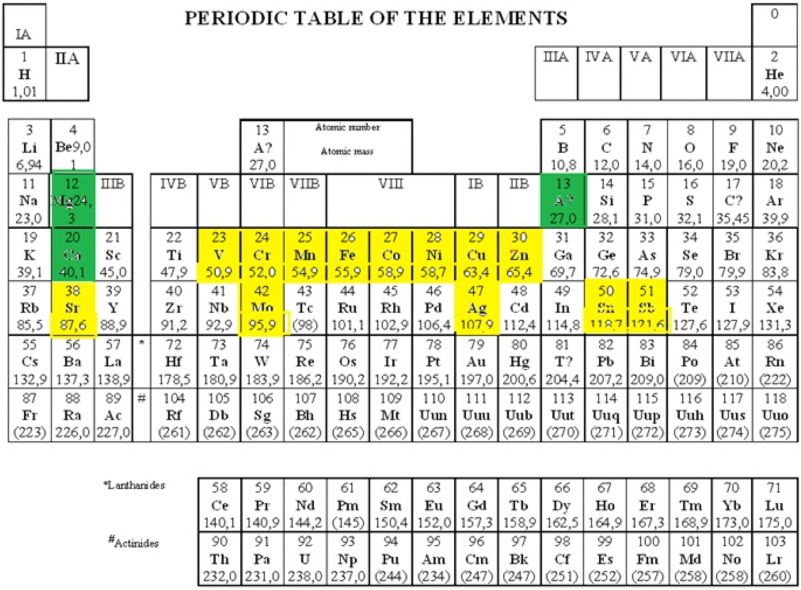
Carbon Source	**Support Material**	**Binary Catalyst System**
Acetylene	$CaCO_3$, MgO, Al_2O_3	Co/Zn
X	X	Co/Ni
X	X	Co/Fe
X	X	Co/Cu
X	X	Co/Cr
X	X	Co/Mn
X	X	Co/Mo
X	X	Co/Ag
X	X	Co/Sn
X	X	Co/Sb
X	X	Co/Sr

Co/Zn, Co/Ni, Co/Cu, Co/Fe, Co/Mn, Co/Cr, Co/Mo, Co/Ag, Co/Sn, Co/Sb, Co/Sr

We are walking through the periodic table. We are only hindered by the availability of these metals and their cost.

The results we have obtained are impressive. The presence or absence of a metal results in a number of changes. Book publishers who have looked at these results in our publications have invited me to write a book chapter on synthesis and characterization of carbon nanotubes with these catalyst combinations. This is important because it provides a ready data-base for researchers.

Table 2. Periodic table

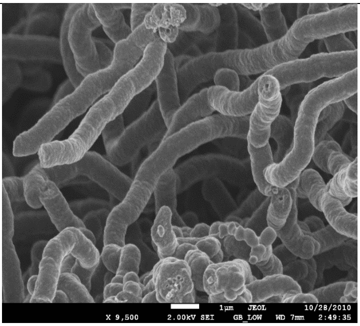
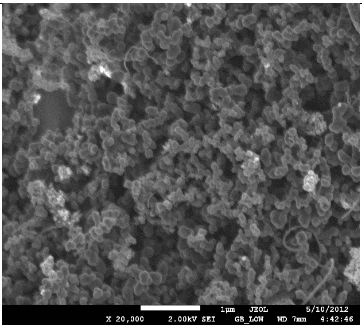
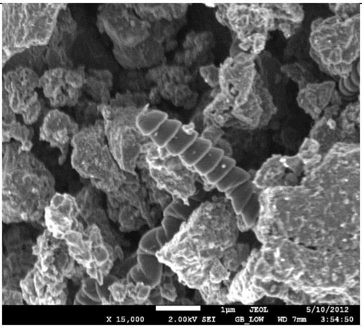


PERIODIC TABLE OF THE ELEMENTS

IA																		0
1 H 1,01	IIA												IIIA	IVA	VA	VIA	VIIA	2 He 4,00
3 Li 6,94	4 Be9,0 1					13 A? 27,0	Atomic number Atomic mass						5 B 10,8	6 C 12,0	7 N 14,0	8 O 16,0	9 F 19,0	10 Ne 20,2
11 Na 23,0	12 Mg24, 3	IIIB		IVB	VB	VIB	VIIB	VIII			IB	IIB	13 A? 27,0	14 Si 28,1	15 P 31,0	16 S 32,1	17 C? 35,45	18 Ar 39,9
19 K 39,1	20 Ca 40,1	21 Sc 45,0		22 Ti 47,9	23 V 50,9	24 Cr 52,0	25 Mn 54,9	26 Fe 55,9	27 Co 58,9	28 Ni 58,7	29 Cu 63,4	30 Zn 65,4	31 Ga 69,7	32 Ge 72,6	33 As 74,9	34 Se 79,0	35 Br 79,9	36 Kr 83,8
37 Rb 85,5	38 Sr 87,6	39 Y 88,9		40 Zr 91,2	41 Nb 92,9	42 Mo 95,9	43 Tc (98)	44 Ru 101,1	45 Rh 102,9	46 Pd 106,4	47 Ag 107,9	48 Cd 112,4	49 In 114,8	50 Sn 118,7	51 Sb 121,6	52 Te 127,6	53 I 127,9	54 Xe 131,3
55 Cs 132,9	56 Ba 137,3	57 La 138,9	*	72 Hf 178,5	73 Ta 180,9	74 W 183,9	75 Re 186,2	76 Os 190,2	77 Ir 192,2	78 Pt 195,1	79 Au 197,0	80 Hg 200,6	81 T? 204,4	82 Pb 207,2	83 Bi 209,0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226,0	89 Ac 227,0	#	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 Uun (267)	111 Uuu (268)	112 Uub (269)	113 Uut (270)	114 Uuq (271)	115 Uup (272)	116 Uuh (273)	117 Uus (274)	118 Uuo (275)

*Lanthanides	58 Ce 140,1	59 Pr 140,9	60 Nd 144,2	61 Pm (145)	62 Sm 150,4	63 Eu 152,0	64 Gd 157,3	65 Tb 158,9	66 Dy 162,5	67 Ho 164,9	68 Er 167,3	69 Tm 168,9	70 Yb 173,0	71 Lu 175,0
#Actinides	90 Th 232,0	91 Pa 231,0	92 U 238,0	93 Np 237,0	94 Pu (244)	95 Am (234)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (258)	103 Lr (260)

Table 3. Table of catalyst and SEM of synthesized CNT

Catalyst	Configuration	SEM Image
Co/Zn/Al_2O_3		
Co/Ni/MgO		
Co/Mo/MgO		

Acetylacetone catalyst

We have used unusual catalyst also in our research work. The organometallic compound 2,4-pentanedione also called acetylacetone.

Acetylacetones are organic compounds that exist in two tautomeric forms that interconvert.

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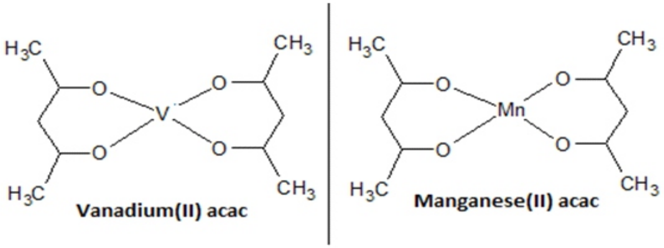
Structure.



Vanadium(II) acac

Manganese(II) acac

Fig 28. Structures of metal acetylacetonates employed in CNT synthesis

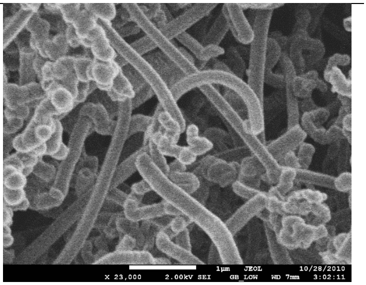
We incorporated a metal in the structure and used this as a catalyst for the synthesis of carbon nanotubes.

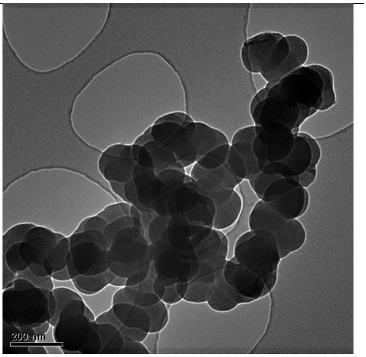
Table 4. **Organic Catalyst and Support Materials**

Carbon Source	**Support Material**	**Organometallic Catalyst System**	
Acetylene	$CaCO_3$, MgO, Al_2O_3	$(C_5H_7O_2)_2V$	
X	X	$(C_5H_7O_2)_2Mn$	
X	X	$(C_5H_7O_2)_2X$	

These organometallic substances have high catalytic properties. The point here is this, could this initiate the formation of carbon nanotubes? If so, what kind of carbon nanotubes could be formed?

Table 5. **Carbon Nanotube from Organic Catalyst**

Catalyst		SEM image
$V(C_5H_7O_2)2$		

$Mn(C_5H_7O_2)_2$ or $Mn(C_5H7O_2)_3$		

The results obtained in these studies are published in international journals.

Carbon nanotubes could be functionalized or Doped.
A carbon nanotube is functionalised when reactive sites are introduced in the carbon nanotube system. And a carbon nanotube is doped when another atom, a foreign atom is introduced into the carbon-carbon chain structure.

Doping, the methodical incorporationof other atom to replace carbon in the hexagonal graphitic plane of the CNT structure, can be achievedduring synthesis or post-synthesis.

When the general properties such as, physical, thermal, mechanical, electronic and chemical properties of CNTs are deliberately tuned or adjusted to suit the particular purpose for which they are intended to be used in a process, the term doping is employed.

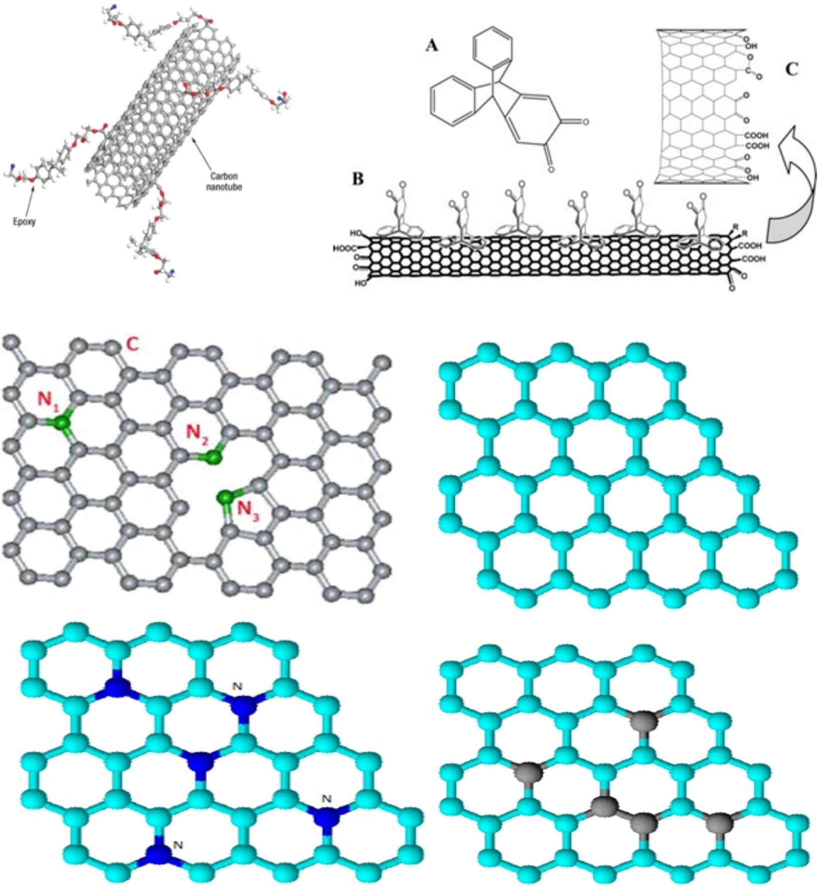
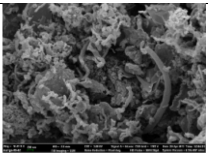
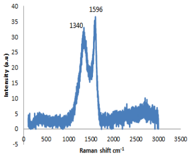
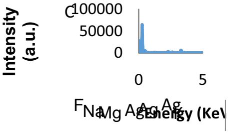
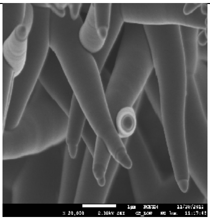
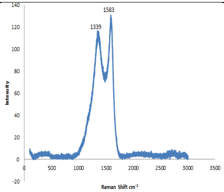
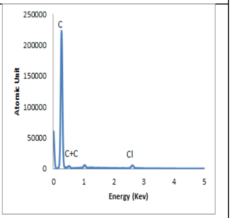
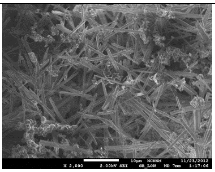
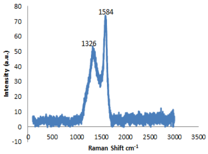
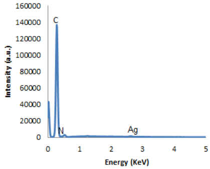
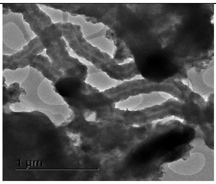
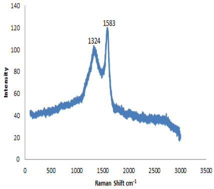
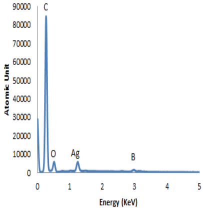


Fig 29. Structures of functionalized CNT

Doping and functionalization introduces a foreign atom or molecule into the organised system of the carbon nanotube that disrupts the structure and modifies the properties of the end-product.

We carried out studies aimed at both doping and functionalization. We used Boron, Nitrogen, Fluorine and Chlorine as both functional and dope subjects. The results obtained here are published in international journals.

Table 6. Functionalized and doped Carbon Nanotubes

Dopant	SEM	Raman	EDS
Fluorine			
Chlorine			
Nitrogen			
Boron			

Adsorption studies

The batch adsorption experiments were conducted to study the effects of concentration, time and temperature of the synthesized Fluorine, chlorine, Nitrogen and Boron doped carbon nanotubes on lead and chromium ion.

A measured quantity of the chlorine doped carbon nanotubes (0.01 g) was weighed and placed in pre-cleaned test tubes. Five metal ion solutions with standard concentrations of 20, 40, 60, 80 and 100 mg/l were made from spectroscopic grade standards of Cr^{3+} (from $CrCl_3$), and 20 ml of each metal solution were added to each tube containing the carbon nanomaterials and equilibrated for 1 hour by shaking at 29°C. The resultant carbon nanomaterial suspensions were centrifuged for 5 min at 4000 rpm. The supernatants were analysed to determine the metal content.

In order to study the effect of time and temperature, this same experiment was repeated by equilibrating the chlorine doped carbon nanomaterials for each time intervals of 20, 30, 40, 50 and 60 min and at temperature interval of 25, 40, 60 and 80°C using a CompenstatGallenhamp water bath. In each case, the resultant carbon nanomaterial suspensions were centrifuged for 5 min at 4000 rpm and the supernatants were analysed to determine the metal content. The metal analysis was performed with AAS using a Buck Scientific Atomic Absorption/Emission spectrophotometer 200A (AAES). The controls of one of the metal solutions were run to detect any possible metal precipitation or contamination.

GRAPHENE

Enter graphene, a one atom thick material stronger than steel. Graphene, which is dubbed as the mother of all graphitic structures, is a single two dimensional carbon sheet with the same structure as an individual layer of graphite packed into a hexagonal pattern. The figure shows all forms of graphene in different structural patterns. As a one atom-thick planar sheet of sp^2 bonded carbon atom, graphene has received much attention in the recent years in materials science due to its unusual properties, such as a half-integer quantum hall effect, ballistic and extraordinary electron transport. Precisely, graphene based assemblies are also gaining attention because of their potential in designing electronic, sensing and energy conversion devices.

Graphene oxide (GO) synthesized from chemical oxidation of graphite provides a simple and convenient method to obtain exfoliated, two dimensional carbon sheets. Oxidation diminishes graphene's excellent conducting properties, so reduction of GO is desirable in order to partially restore its sp^2 network. Reduced graphene oxide (RGO) can be produced through chemical, sonolytic, microwave photo thermal, photo catalytic and electrochemical methods. Graphene oxide is a hydrophilic derivative of graphene to which biological micro molecules readily attach, with properties superior to those of amorphous carbon films commonly used in electron microscopy. Hydrophobic, graphene can be functionalized by a chemical process producing hydrophilic substrates to which molecules can also readily attach.

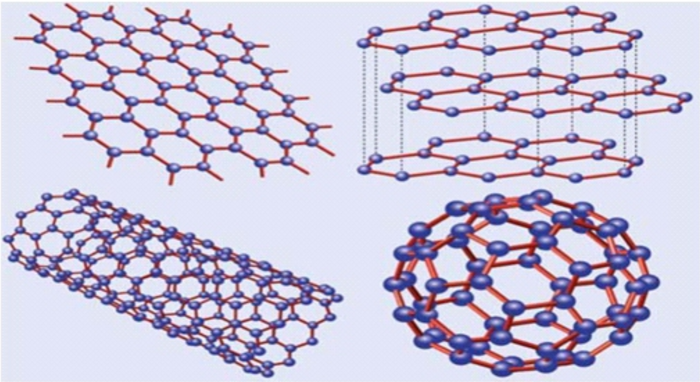


Fig 30. Images of graphene

Graphene Oxide

Graphite oxide (GO) has been continuously receiving significant attention in the scientific and industrial community as a reliable and scalable precursor of graphite.

The potential applications of GO have been reported in various studies, ranging fromGO has unrivalled mechanical, electrical and thermal properties. The potential applications of GO include: synthesis of reduced graphite oxide, high performance composites, macroscopic materials such as fibres, films and aerogels, biomedical field, sensors. GO is a nonconductive hydrophilic carbon material since it is heavily oxygenated, bears hydroxyl and epoxy functional groups on their basal plane, in addition to carbonyl and carboxyl groups located at the sheet edges. Due to the presence of oxygen functional groups the interlayer spacing in GO is higher than graphite. Generally, GO is prepared by the ultrasonic exfoliation of graphite oxide.Further reduction of GO produced graphene. The most popular methodology employed for synthesis of GO is the chemical oxidation of graphite. Chemical oxidation of graphite is a very effective strategy for large-scale manufacturing of graphite materials.

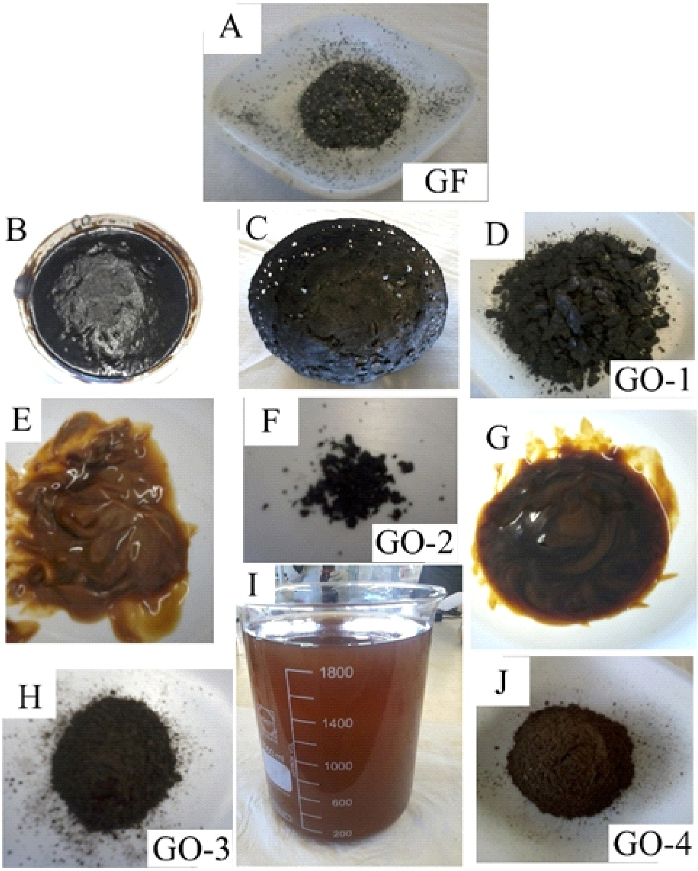


Fig 31. Preparation of graphene oxide

Fig. 31 shows the photograph of the as-prepared GOs at different stages. GFs of sizes 50 µm (Fig. 31A) were used as starting material for the synthesis of GOs. In GO-1, UG was also presented with GO. Hence, it makes a composite material of UG and GO. For study the drying method, GO-1 slurry (Fig. 31B) was dried at 60 °C under constant vacuum for 2 days. The dried material was very hard (Fig. 31C) and further grounded to obtain as-prepared GO-1 (Fig. 31D). In GO-2, GO was separated from UG. Here, GO-2 was further used without purification and washing process, for study the effect of metal impurities on the thermal stability of GO.

The unpurified GO slurry (Fig. 31E) was dried at 40 °C under constant vacuum for 3 days and further grounded to obtain the as-prepared GO-2 (Fig. 31F).In GO-3, GO were separated from UG and further purified and washed. The purified GO slurry (Fig. 1G) was freeze-dried for 2 days.

The dried sample was ground to obtain the as-prepared GO-3 (Fig. 31H).GO-4 was synthesized using Improved methods. The yellowish-brown suspension of GO is shown in Fig. 31I. The paste-like product was collected and freeze-dried for 2 days. The dried sample was ground and named as GO-4 (Fig. 31J). By comparing the drying method for GO among heating at certain temperature (40 °C, 60 °C) under constant vacuum and freeze drying. The freeze-drying method was found to be the best drying method for drying the GO slurry. The FTIR spectra were used to confirm the formation of GO from chemical treatment of GF. Fig. 5 shows the FTIR spectra of GF (A), GO-1 (B), GO-2 (C), GO-3 (D), and GO-4 (E) from 650-4000 cm^{-1}. For GF, no distinct peaks are detected,and nearly straight line is observed (Fig. 5A). The FTIR spectrum is consistent with the data reported in the literature for graphite. After the oxidation reaction, the FTIR spectra of GO entirely changed compared to that of GF.

The FTIR spectra identify the same functional groups in all GO samples: a broad band is observed between 3000-3700 cm^{-1} due to free and associated hydroxyl (O-H) stretching vibrations from COOH, C-OH, and H_2O; a strong band at 1716 (GO-1), 1710 (GO-2), 1713 (GO-3), 1728 (GO-4) cm^{-1} is most often related to the carbonyl (C=O) stretching vibrations of COOH groups situated at the edges of the oxidized graphite's a band at 1614 (GO-1), 1607 (GO-2), 1616 (GO-3), 1619 (GO-4) cm^{-1}might be related to not only the aromatic C=C from sp^2 bonds but also that of the OH bending vibration of adsorbed water molecules and structural OH groupsthe bands at 1372 (GO-1), 1414 (GO-2), 1393 (GO-3), 1384 (GO-4) cm^{-1}ascribed to the O-H deformation vibration of COOH group bands at 1041 (GO-1), 1028 (GO-2), 1031 (GO-3), 1041 (GO-4) due to vibration of alkoxy (C-O) group. GO-1 and GO-4 exhibit a band at 1216 and 1221 cm^{-1}, respectively due to epoxy (C-O) stretching vibration. GO-2 and GO-3 exhibit a band at 1148 and 1143 cm^{-1}, respectively due to phenolic hydroxyl group (C-OH) stretching. GO-1 and GO-4 exhibit a band at 975 and 974 cm^{-1}, respectively due to epoxy O-C vibration.

The absorption band at lower frequency side at 866 (GO-2) and 869 (GO-3) cm^{-1} appears due to the aromatic C-H bonds. The FTIR spectra confirm the formation of hydroxyl, carbonyl and epoxy groups during the oxidation process.Thermal stability of GOs could be directly demonstrated by the thermogravimetric analysis (TGA) curves (Fig. 2) since oxygen functional groups of GOs decomposed on heating. GF had a much higher thermal stability and remained unchanged (only 2% weight loss up to 900 °C). For GO-1 and GO-4 a typical three-step weight loss and for GO-2 and GO-3 a typical four-step weight loss appeared against the temperature increased, including the liberation of hydrate water and the decomposition of the functional groups. GOs started to decompose (weight loss of about 12-25%) from room temperature to 160 °C was ascribed to the removal of adsorbed water. TGA of the GOs showed major weight losses (20-30%) between 100 and 250 °C, which corresponds to CO, CO_2, and steam release from the most labile functional groups.

In between 200 to 900 °C a slower mass loss was observed in all GOs and can be attributed to the removal of more stable oxygen functionalities. By TGA, GO-1 and GO-2 had the smallest (39%) and highest (20%) weight losses, respectively; while GO-3 and GO-4 had similar weight losses (28-30%) at 900 °C. Apparently, GO-1 was more stable than the other GOs since it is a composite material of GO and unreacted graphite. The highest weight loss in GO-2 is owing to the presence of metal impurities.

Adsorption of Pb^{+2} on GOs

Effect of concentrations on the adsorption capacity

The adsorption isotherm of GOs toward Pb^{2+} is presented. It was found that the adsorption capacity of GO increased with increasing initial concentration of Pb^{2+}, which could be due to the presence of a wide variety of oxygen functional groups at the surface (results from FTIR analysis). The maximum adsorption of 120 mg/g took place at initial concentration of 60 mg/L Pb^{2+}.

The oxygen functional groups of GO has very high negative charge density which allow ion exchange with positively charged metal ions or organic molecules and hence removal is expected to be effective. The initial concentration dependent adsorption capacity probably due to the layered structure of GO which may assist in the adsorption of metal ions. It was also reported that the wrinkles nature of GO, might favours in the enhancement of the adsorption of Pb^{2+} over the surface of GO.

Effect of contact time on the adsorption and adsorption kinetics

The effect of the contact time on the adsorption capacity of GO for Pb^{2+} is presented in Fig. 8. It was observed that over 96% of the Pb^{2+} was adsorbed within 5 min. Thereafter, agitation of GO in presence of Pb^{2+} solution showed a nearly constant adsorption afterwards before reaching a plateau value after 10 min, with about more than 98% of total Pb^{2+} being removed.

This observation is consistent with previous report such as, Huang et al. investigated the adsorption of $Pb^{2+}$from aqueous solution on low-temperature exfoliated graphite nanosheets and about 85% of the Pb^{2+} was removed within the initial 5 min. The uptake of $Pb^{2+}$by graphene oxideinsideof the opening5 min of the reaction, is attributed to the large surface area, presence of various oxygen bonds, and encrustedconfiguration of GO. The presence of various oxygen functional groups makes the surface of GO is highly reactive. In latter stages, however, the rate of Pb^{2+} adsorption becomes nearly constant. Since initially, almost all the vacant bonding sites were filled with Pb^{2+}after which great decrease of the bonding sites on the surface, and in between the layer of GO; and the remaining bonding sites were difficult to be occupied due to repulsive forces between the Pb^{2+}.

To scrutinizethe processof adsorption, kinetic reaction models of pseudo-first-order, and pseudo-second-order models were investigated.The pseudo-second-order prototypecan be represented by the following linear form.

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{t}{q_e} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

where k_2 is the pseudo-second-order rate constant of adsorption ($g mg^{-1} min^{-1}$). The slope and intercept of the plot of t/q_t versus t were used to calculate the value of q_e and k_2. The adsorption data of Pb^{2+} at different time intervals were fit for a pseudo-second-order kinetic model (Fig. 9). From equation (1), the experimental adsorption capacity (q_{exp}) is estimated to about 18.32 mg/g, which is in good agreement with the calculated adsorption capacity (q_{cal}: 17.82 mg/g) for the pseudo-second-order kinetics. Additionally, correlation coefficient value ($R^2 = 0.999$) for pseudo-second-order was higher than pseudo-first-order ($R^2 = 0.153$) confirmed the GO can be well described by pseudo-second-order kinetic model (Fig. 9). This suggest that the adsorption may be the rate-limiting step involving valence forces through sharing or exchange of electrons between the adsorbent and the adsorbate.

Effect of temperature on the adsorption capacity

Fig. 10 presents the plot of adsorption capacity of GO at varying temperatures with optimum capacity of 17 mg/g occurring at 25 °C. The plot showed that further increase in temperature resulted in a slight decrease in adsorption. This behavior could be attributed to the weakening of the attractive forces between the polymer and Pb^{2+}.

Effect of concentration on the removal efficiency

Fig. 11 shows the effect of the initial concentration on the removal efficiency of GO for Pb^{2+}using a 0.01 g adsorbent dose. The removal efficiency of GOincreased with increasing initial concentration. At low initial solution concentration, the surface area and the availability of adsorption sites were high, and the adsorbate was easily adsorbed and removed. However, at higher initial solution concentration, the surface area and the availability of adsorption sites were still high and available for adsorption due to the many oxygen functional groups and layered configuration of GO, thus resulting in a slight increase in the removal efficiency of GO and further constant. This type of removal efficiency nature were also reported byremoval efficiency *ke* graph *ko* confirm.

Adsorption on graphene oxide

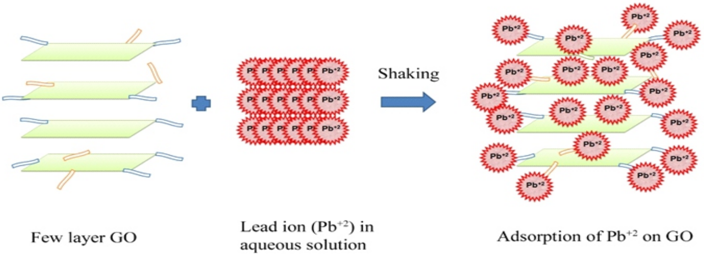


Fig 32 Mechanism of lead Adsorption.

Publication/s

- Himanshu Raghubanshi, Shalate M. Ngobeni, Adeniyi O. Osikoya, Ntaote David Shooto, Charity W. Dikio, Eliazer Bobby Naidoo **Ezekiel Dixon Dikio,** Rajiv K. Pandey, Rajiv Prakash. *J. Ind. Eng. Chem.* 2017,47, 169 – 178.
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Electrochemical Studies

Graphene's unique structure, excellent electronic properties, thermal and chemical stability have shown great promise applications in the field of electronic nanodevices, energy-storage materials, transparent conducting electrodes, chemical and biological sensors.

In our study, we have synthesized and characterized both PB and GO. PB was then deposited on graphene oxide (GO) to increase the stability of the PB film and take advantage of the unique properties of both GO and PB in an attempt to enhance and greatly broaden the application of GO and PB in sensor electrochemistry. The ability of the electrodes to detect hydrogen peroxide in a low potential with different pH ranges in phosphate buffer solution were also studied.

Electrochemical properties of bare-GC, GC-PB, GC-MWCNT-PB, GC-GO-PB, and GC-CTAB-PB electrodes were studied in 0.1M phosphate buffer solution at different pH values, recorded between -250 to 500 mV at scan rate of 100 mV/s.Electrochemical determinations of hydrogen peroxide using modified electrodes as a working electrode employed both cyclic and square wave voltammetry are presented.

METAL ORGANIC FRAMEWORKS

Metal-organic framework (MOF) materials are coordination networks of metal ions and organic ligands containing potential voids and functional groups, they are also known as metal-organic networks, or coordination polymers. The properties of MOFs depend on the particular metal and ligand used and the zero-dimensional (0D) or infinite one-dimensional (1D), two-dimensional (2D) or three-dimensional (3D) network structures these form as shown in figure 2.17. MOFs have versatile properties and may potentially have many industrial applications.

The specific micro-porosity of MOF materials have been one focus of interest, since guest molecules can become trapped or adsorbed inside the network voids. Adsorbed molecules can also change the material properties of the MOF. For instance, certain MOFs can be made electrically conductive by adsorption of certain molecules. Also, it has recently been shown that certain MOFs can trap and catalyze the decomposition of nerve agents like Soman. The possibility to tailor-make MOF materials with voids that can adsorb specific molecules opens up possibilities for MOF materials to be used as adsorbent in gas storage and gas separation.

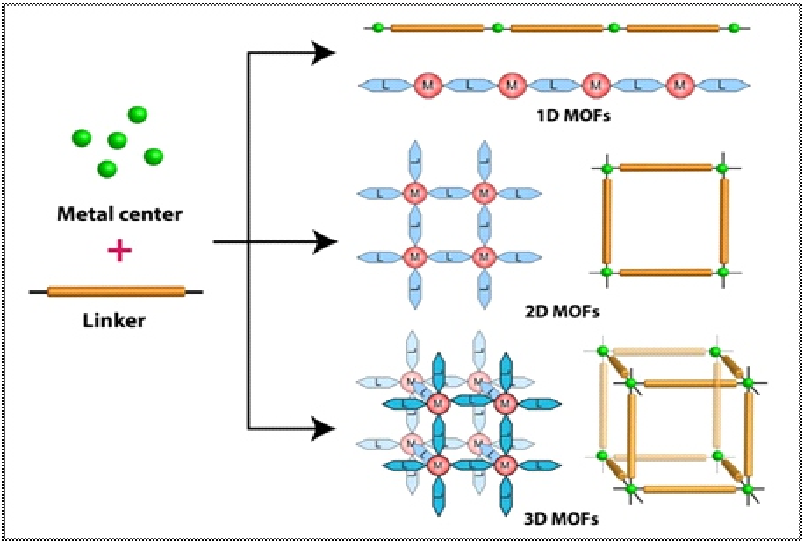

Fig 33. Synthesis of MOFs from metal centers and organic linkers to form 1D, 2D or 3D MOFs depending on degree of extension

Not only has these co-ordination polymeric materials attracted current research interest due to their unique attributes such as versatility, fascinating architecture and network topology also more importantly they are been applied in various fields including waste water treatment, gas storage and separation, heterogeneous catalysis, nonlinear optics, and drug delivery.

LAYERED DOUBLE HYDROXIDES (LDH)

Layered double hydroxides (LDHs), also known as anionic clays or hydrotalcite-like compounds, are an important class of ionic lamellar solids. The structure of LDHs consists of positively charged mixed metal hydroxide layers separated by charge-balancing anions and water molecules. These compounds have tempted both industrialist and academics due to their versatile applications. Their interlayer anions are exchangeable, giving rise to a rich intercalation chemistry. The guest species may be organic or inorganic, simple or complex. Intercalation of desired anionic guest is achieved by direct synthesis, ion-exchange, or by reconstruction of the layered structure when contacting the material calcined at 300-500 with solutions of anions. LDHs find use as catalysts and catalyst supports, adsorbents, anion scavengers, anion exchangers, polymer stabilizers and antacids LDHs comprise of an extensive class of materials that are very easy to synthesize in the laboratory, albeit not always as pure phases. This topic focuses on the way in which the physiochemical properties of the materials

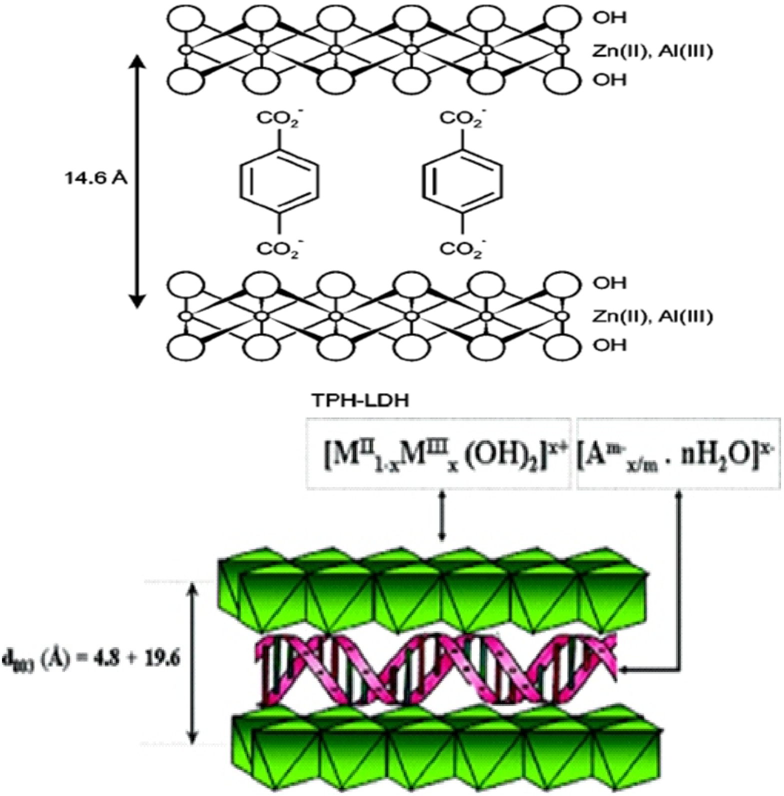

Fig 34. Layered Double Hydroxide (LDH).

such as phase purity, crystallinity and surface area are investigated. Some methods can be used to synthesize LDHs containing a wide range of constituent cations and anions.

Layered double hydroxides (LDHs) also constitute a family of lamellar compounds built by the stacking of brucite-type layers where a partial substitution of the divalent cations have taken place; the positive charge is thereof balanced by introducing some anions in the interlamellar region, where they coexist with water molecules.

Calcination at ca.500 degrees Celsius give rise to MgO-type, poorly crystallized, mixed oxides, which show high specific surface area values, high metallic dispersion and particle stability against sintering; for these reasons they have been widely applied as catalysts. however, another well-known property of LDHs is their ability to recover the original layered structure after being calcined at different temperatures and then exposed to air or immersed in a solution containing different anions carboxylate anions have been already intercalated in LDHs. different types of carboxylate anions, with one or two carboxylic functional groups and with aliphatic or aromatic hydrocarbon chains, have been intercalated. since the first synthesis reported by drezdzon, the complexity of the anions intercalated has increased; LDHs containing interlayer carboxylate anions have attracted considerable attention in recent years, as these materials have a number of interesting properties and potential applications in addition, studies have been carried out to gain information about the structure of the interlayer region where carboxylate anions are inserted.

The enthalpies of ion exchange of dicarboxylate anions and the kinetics and mechanism of the intercalation process are studied in summary, it has been found that the interlayer spacing of dicarboxylates varies linearly with the length of the chain for linear aliphatic dicarboxylates.

IONIC LIQUIDS

Ionic liquids are a class of compounds that evolved from traditional high temperature molten salts. They were observed as far as back the mid-19th century. The first ionic liquid (ethanol ammonium nitrate) was discovery in 1888 by S. Gabriel and J.Weiner.Ionic liquids aresubstantiallyused in manufacturingcompaniesand can be synthesized in different ways. Some of the synthetic methods include:

Ionic liquids usually known as room temperature ionic liquids are inorganic salts composed of entirely of ions. They are usually liquids or solids at room temperatures with melting points at or below 373K.As compared to regularly used liquids that are mainly structured of neutral molecules, ionic liquids are structured of ions. Various synonyms are used as descriptive names for ionic liquids i.e. non aqueous liquids, room temperature ionic liquids, molten salts, fused salts, ionic melts etc. As a new glass of upcoming solvents that is growing to substitute recently used solvents, they may have a greater potential in chemical analysis.

Ionic liquids have unique characteristics that render them to be of high importance in various divisions of research, development and industrial applications. Ionic liquids are a new class of compounds that has recently emerged as potential substitute for volatile organic solvents. Ionic liquids are used for various applications in industries. In chemical reactions they can act as acids, bases and ligands.

These room temperature liquids are widely used in industries due to their beneficial properties that make them much safer to work with. The use of solvents in scientific and engineering world is of outmost importance; due to the recently used solvents that do not meet the required specifications. The use of ionic liquids is growing gradually since they are non-toxic and safer to work with. Ionic liquids have drawn some sort of interest in the engineering and scientific world. With a rapid growth of research in chemistry, it has become evident that these new class of solvents in the near future are going to serve as a replacement to the recently used solvents. These room temperature liquids have shown great potential as better alternate solvents due to their beneficial properties such as solubility, miscibility and non-volatile behaviour.

SUSTAINABILITY, NANO CHEMISTRY AND DEVELOPMENT

The need to introduce human development needs and environmental protection is a challenge to scientist the world over. How could science and technology help in sustaining human developmental needs and environmental protection

On the 25th of September, 2015, countries in the world adopted a set of goals aimed at ending poverty, protect the planet and ensure prosperity for all as part of a NEW SUSTAINABLE DEVELOPMENT AGENDA. There are

17 goals aimed to transform the world in the next 15 years. These goals are set in 3 levels.

1. Things you can do from your couch
2. Things you can do at home
3. Things you can do outside your house

These 17 points are

1. No poverty
2. Zero hunger
3. Goodhealth and well-being
4. Quality education
5. Gender equality
6. Clean water and sanitation
7. Affordable and clean energy
8. Decent work and economic growth
9. Industry, innovation and infrastructure
10. Reduced inequalities
11. Sustainable cities and communities
12. Responsible consumption and production
13. Climate action
14. Life below water
15. Life on land
16. Peace, justice and strong institutions
17. Partnerships for the goals

My research work, Mister Vice Chancellor, in several ways identifies and contributes to one or more of these 17 point action plan. This is because chemistry as a discipline tries to understand and explain the makeup of all things that have mass and occupies space. As stated earlier, carbon which alone contributes to 90% of the Organic Chemistry discipline is at the fore front of sustainable development. Research in Carbon nanotubes and Graphene is contributing to industry, innovation and infrastructure, decent work and economic growth, clean water and sanitation, affordable and clean energy among others.

Ongoing Research

Research presently carried out in my research group and in the future will involve the synthesis of new compounds of graphene. The race is on to synthesize the compound SiC_7, Siligraphene, and silicene, a theoretically determined hybrid of siligraphene.

I want to synthesize, phosphographene. Mister, Vice Chancellor, these works will start as soon as possible.
Other research work in the next few years the Almighty willing, will concentrate on

1. Thermodynamics of solutions
2. Ionic liquid synthesis and its thermodynamic study
3. Electrochemical study of graphene aimed at using different forms (doped) of graphene to coat electrodes used in voltammetry.
4. MOF & Polymer – New Metal organic framework materials with very high potential applications will be studied. Their synthesis, characterization and application as a means of addressing affordable and clean energy sustainability will be carried out.

CONCLUSION

In this lecture, Mister Vice Chancellor, I have shown that the Nano Materials is at the centre of Nano research in chemistry. Carbon as an organic compound has shot to prominence in the last few years to be the most important material in research, industrial innovation and energy.

Soon, Mister Vice chancellor, we will not need any of these heavy blocks called phones and tablets in our pockets and hand bag. We will wear them. We will use our futuristic wearable phone to monitor our health more closely.
Nano is now the prefix of choice in several technological and non-technological nomenclature.
Research in carbon nanotubes and graphene and their composites with metal organic framework materials is at the centre of research funding internationally.
The strength of graphene, being 200 times stronger than steel is what is being exploited.

RECOMMENDATIONS

Mister Vice Chancellor, based on my experiences, I wish to humbly make the following recommendations

1. Equipment for research in NDU need to be improved.
2. Funds should be allocated to enable our young scientist to visit international laboratories in the form of exchange.
3. Our present laboratory space is inadequate, the University should look at ways of providing more research space.

4. Office spaces for lecturers in the faculty are insufficient. More office spaces are needed.

ACKNOWLEDGEMENTS

Foremost to me, I thank the Almighty God and the Mighty Angel of the Lord, my Guide and Protector.

I want to appreciate my wife and children who make do with my long absence from home always, as an academician, researching, experimenting and writing research papers, absence from home is inevitable.

I want to appreciate our Vice Chancellor. I thank you for being here as chairman of this occasion. Your approval has made this inaugural lecture possible. May I also thank our immediate past Vice Chancellor in whose tenure I became a Professor.

I want also thank Prof Don Wankasi, Deputy Vice Chancellor Academic (Hard-To-Believe), during whose tenure as Dean, Faculty of Science, I received my promotion as Professor.

I want to also thank my best friend and best man during my wedding, The Rt Rev FunkuroGodrules Victor Amgbare, Anglican Bishop, Diocese of Northern Izon.

This journey would not have been possible without the effort of my former supervisors and promoters. Prof. Dr. Hab. Romuald Grobelny, (Professor of Chemical Kinetics, Faculty of Chemistry, University of Wroclaw, Poland). He supervised my First and Master'sdegree. “He demanded results” “show me what you have done, as a rule everyday was his Mantra. I have imbibed this mantra, practise it, and instilled it in my students. It is a secret of my success”. I also wish to thank Prof David Isabirye, (Professor of Inorganic Chemistry, North West University, Mafikeng) who supervised my PhD Thesis, my best friend today, he encouraged me, always supportive and appreciative. He taught me to work hard daily.

I want to thank the researchers I have worked with, foremost are Prof Eno E. Ebenso, Prof Michal Horsfall, Prof D. Wankasi and Assoc Prof M. K Vala and Dr Himanshu Raghubanshi, Dr.FanyanaMtunzi, Dr. Michael Klink, Dr. Abasi, Dr Paul Diagboya, Dr.Shooto, Dr.NimibofaAyawei, Dr.AyasenKemeakega, Dr. Victoria Bennett, Dr. Adeniyi Osikoya and a host of others.

I appreciate staff (academic and non-academic) members of the Chemical Sciences Department, Niger Delta University for their support.

I will like to thank all my B. Sc/B. Tech, M. Sc/M. Tech and PhD/D. Tech students whom I push to the limit for results. One student wrote to the HOD recently, that I am after results and publications only. Yes, that I do, that is the reason we are here today.

Let me use this opportunity to appreciate and thank my co-researchers, Dr Fanyana Mtunzi (VUT), Dr Simphiwe

Nelana (VUT), Dr Indra Bahadur (NWU), Dr Lucky Sikhwivhilu (Mintek, SA), Dr Hilary Rutto, Dr James Wesley, Prof Afolabi, Prof Chris Enwerenmadu, Prof Peter Osifo, Prof Kazeem Okosun, Prof and Prof (Mrs) O. O. Oyedeji, Dr Benedette Johnson and staff members of the department of chemistry VUT.

Thank you to my Mother and late father, brothers and sisters who stood with me. My inlaws and all family members for their encouragement.

I thank you all, wonderful people and friends who have come from far and near to grace this occasion.
Mister Vice Chancellor, academic and non-academic staff, colleagues, students and distinguished ladies and gentlemen, I have come to the end of this phase of the journey. I am done. I thank you all sincerely for your patience to listen to this inaugural lecture

Thank you

Prof Ezekiel Onisodianikume Dixon Amakiri Dikio
Ph D, M.Phil, PGDE, B.Sc, HND, FRSC

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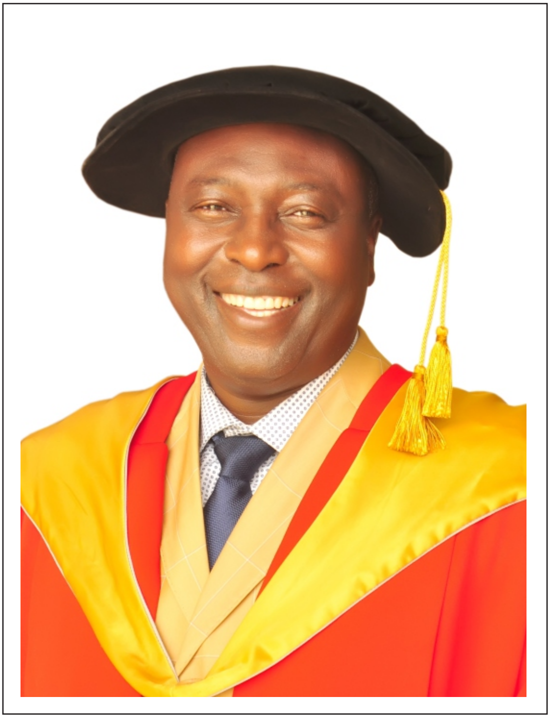
PROFILE

Prof Ezekiel Dixon Dikio *(PhD, FRSC)*
Professor of Physical Chemistry.



Prof Ezekiel Dixon Dikio was born at JoinkramaGeneral Hospital in the then Eastern Region now Ahoada West Local Government Area of Rivers State.Prof Ezekiel Dixon Dikio is the son of Late Chief Dixon AmakiriAmutegbo Dikio and Madam Beatrice Dikio of MbiamaEngenni.

Prof Ezekiel Dixon Dikio attended several primary schools, being the son of a teacher and the effect of the Nigerian Civil War, among which are, Government Demonstration School, Surulere, Lagos 1965/67, St. Peter's Primary School, Yenegoa, 1967/68, St. Peter's Primary School, Akinima, 1968/69, St Andrew's Primary School Diobu Port Harcourt, 1969/70, St Paul's School, Garrison Port Harcourt, 1970/71, Ako State School, Kreiganinear Omoku, 1972/73 and finally State School, Mbiama 1974 where he did his First School leaving examination.

He then attended Government Secondary School, Joinkrama from 1974 to 1979 where he graduated with a Grade One in the West African Schools Certificate examination.

Desiring to study medicine, he entered then College of Science and Technology (CST), now Rivers State University of Science and Technology, in the Department of Chemistry, as a transition point, rather than seat at home. He never made it to the Medicine he desired but remained at the Rivers State University of Science and Technology where he completed his undergraduate andmaster'sdegrees.His Master's degree dissertation project work, supervised by Prof Romuald Grobelny and Prof Victor Omuaru, then took him to the

Faculty of Chemistry, University of Wroclaw in Poland in 1988.

As a teacher with the Rivers State Government, all teachers were directed to acquire a teaching qualification, Prof Ezekiel Dixon Dikio, then enrolled with the Institute of Education, University of Port Harcourt for the Post Graduate Diploma in Education (PGDE) which he completed in 1989 graduating with a Merit grade.

After several years of working as a Teacher and living overseas, Prof Dikio, decided to go back to school, he then enrolled at the University of North West (UNW) now North West University (NWU) in Mafikeng campus, South Africa, where he completed his PhD in 2005.
Prof Ezekiel Dixon Dikio was employed in the Department of Chemistry, North West University as a Lecturer from 2004 to 2007. He left the North West University to join Birla Institute of Technology University (BITS Pilani) in Dubai, United Arab Emirate (UAE), in 2007/2008 as an Assistant Professor.

He left BITS University Dubai and joined the Vaal University of Technology, VUT in 2008, as a Senior Lecturer. At Vaal University of Technology, he was promoted Associate Professor (Reader) 2010 and Full Professor in 2013 before leaving to join the Niger Delta University.

Prof Ezekiel D. Dikio joined Niger Delta University in 2013 as a Reader (Associate Professor), from Vaal University of

Technology in South Africa and promoted Full Professor in 2015.

Prof ED Dikiohas published over ninety (90) research papers in peer reviewed journals in the areas of Solution Thermodynamics, Nanotechnology (Materials Chemistry), Metal Organic Framework and Layered Double Hydroxides and others. He started Nanotechnology research at the Vaal University of Technology in 2009.He has supervised Post-doctoral researchers, graduated five (5) PhDs, Ten (10) Master's and several Bachelors.

Prof Ezekiel Dixon Dikio research profile are:

(1) Researchgate; RESEARCHGATE SCORE 30.35;H-INDEX 11, READS 28,745, CITATIONS 465.

(2) Google Scholar: CITATIONS = 750, H-INDEX = 14, i10 INDEX = 29,

(3) Scopus: H-INDEX = 11, ARTICLES = 64, CITATIONS = 450

Before joining the Niger Delta University in 2013, Prof ED Dikio, won in the First Place, Faculty of Science Research Excellence Awards, University (VUT) Research Excellence Award 2nd Place, 2012, Faculty of Science Research Achievement Award, 1st Place, 2010, and Faculty Research Excellence Award, 3rd Place 2011.

He is a reviewer for several international and local journals, Journal of Materials Chemistry and Physics, Journalof Synthesis and Reactivity in Inorganic, Metal-Organic and

Nano-Metal Chemistry, Journal of Carbon, Journal of Analytica Chimica Acta, Journal of Textile Research, Journal Nano Letters, Journal of Industrial and Engineering Chemistry Research, Journal of Chemical & Engineering Data. (American Chemical Society), Journal of Fuel, Journal of Coloration, Arabian Journal of Chemistry, Journal of Fullerenes, Journal of Carbon Nanotubes and Nanostructures, Journal of Molecular Liquids, Journal of Solid State Chemistry, Journal of Physical Chemistry Chemical Physics, South African Journal of Chemistry, Journal of Nanoscale, Journal of Taiwan Chemical Society, Journal of Applied Water Science, Journal of Environmental Science and Pollution Research, Journal of Adsorption Science, Journal of Desalination and Water Science to mention a few.

Prof Ezekiel D. Dikio has been invited as Plenary speaker at several conferences, Chemical Society of Nigeria, University of Ibadan, Ibadan 2018, Nano Africa Conference, University of Nigeria Nsukka, 2018, North Sea Conference Inverness Scotland 2013, International Conference on Computational and Mathematical Methods in Science and Engineering. Vanderbijlpark, South Africa,International Winter School on Coordination Chemistry Conference, Karpacz, Poland. Humboldt-Kellog International Conference, Ladoke Akintola University of Technology, Ogbomosho 2011, to mention a few.

He wasappointed external examiner/moderator (Examination questions, students scripts and mini-dissertation) to the Department of Chemistry, North West

University, Mafikeng Campus (2013 to 2016).

He has examined PhD Thesis and Master's Dissertations from Alagappa University, Karaikudi India, Bharathidasan University. Tamilnadu, India, Acharya Nagarjuna University, Guntur, India, University of Fort Hare, South Africa, North West University and University of South Africa. Durban University of Technology South Africa, University of Johannesburg, South Africa.

Prof ED Dikio had served in several South African National Research Foundation (NRF) Panels from 2012.
Prof ED Dikio is a Member and a Fellow of the Royal Society of Chemistry.

He is an experienced Teacher/Lecturer with over 30 years' experience. He has travelled and taught in Nigeria, Britain, Botswana, the United Arab Emirates and South Africa. His industrial experiences include work as Quality Control Chemist in a Pharmaceutical company and as a Quality controller in a Paint manufacturing company (Berger Paints PH). He is married to Mrs Charity Wokwu Dikio and they have three children, Ukarionisofien (UK), Umeonisofien (Natasha) and Onisokumen (Grace).

Prof Ezekiel Dixon Dikio
(PhD;M. Phil.; PGDE; BSc; HND;FRSC; MSACI)

NIGER DELTA UNIVERSITY
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3	Engr. (Dr.) Dau S. Ziborkere	Post-Harvest Agricultural Processing: Lessons from the Honeybee	30-03-2011
4	Prof. Kingsley Danekete Alagoa	A Probe as a Predictive Tool: A Theoretical Physicist's Pathway (Plasma as a Model)	25-05-2011
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32 Prof. Onyaye Edgar Kunle-olowu	Best Evidence: Best care for Newborns, the Prospects in Bayelsa State.	18-07-2018
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