



BELLS UNIVERSITY OF TECHNOLOGY
OTA, OGUN STATE, NIGERIA

MAN AND MATERIALS: THE INDIVISIBLE ENTITIES

An Inaugural Lecture

by

OJO SUNDAY FAYOMI

*AMWISA, MNMS, MNATE, MNSE, COREN REG.
Professor of Mechanical Engineering
(Material Processing and Production Technology)
Dean, College of Engineering*



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Friday, 14th March, 2025



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Bells University of Technology, Ota, Nigeria
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CITATION OF PROFESSOR OJO SUNDAY FAYOMI

Professor Ojo Sunday Isaac Fayomi was born in Iyara, Kogi State, Nigeria on 14th March 1984. He is a Full Professor of Mechanical Engineering, bias in material processing and production technology. He is currently serving as the Dean of the College of Engineering, and Chairman, Corporate Affairs Unit, Office of the Vice Chancellor, Bells University of Technology, Ota, Nigeria. Prof. Fayomi obtained National Diploma (Distinction) from the Polytechnic, Birnin Kebbi, Kebbi State, Higher National Diploma in Metallurgical and Materials Engineering from Federal Polytechnic, Idah, Kogi State with Upper Credit, Bachelor of Engineering, (Honours) in Mechanical Engineering from Bells University of Technology (2nd Class Upper). He bagged his Master's degree with (Cum Laude) Distinction, and Doctoral degree in Metallurgical Engineering at the Department of Chemical, Metallurgical and Materials Engineering, Tshwane University of Technology, Pretoria, South Africa. He has a postgraduate diploma in environmental and natural resource management from Olabisi Onabanjo University, Ago-Iwoye.

Prof. Ojo Sunday Fayomi is a material processing and production technology expert and he has been instructing in the university and research environment since 2007. He rose to be a distinguished exceptional Professor in 2021 with a massive contribution to new materials development for multifaceted application. He is a visiting scholar to several universities locally and internationally. Prof. Fayomi served as a Visiting Research Director, Research and Innovation Associate at Surface Engineering Research Centre (2018-2021). He became an Extraordinary Professor with Tshwane University of Technology; Pretoria (2021 till date) where he trained and mentored over 150 training students. Due to his vast expertise, University of Johannesburg and University of South Africa engages him as Senior Research Associate and Extraordinary Professor to the Faculty of Engineering. He has to his credit over (600) indexed international, local peer-reviewed articles and conferences, (5) authored books, (2) patent with substantial impact factors and broad readership in Scopus and Web of Science. Currently has over 7201 citations, 40 H-index in Google scholar, 4282 citation, 32 H-index in Scopus. Professor Fayomi is an External Examiner to several Nigerian universities at both undergraduate, postgraduate levels, and some foreign universities. He has supervised over 150 international research/industrial projects, graduated 15 doctoral degree holders and 42 Master's degree students apart from the on-going postgraduate supervision.

Prof. Ojo Sunday Fayomi is a sought-after inspirational public speaker and lecturer to many industries, universities, and institutes. He is a global reviewer to the highly-rated Scientific Journals and Conference publisher such as Elsevier, Springer, Taylor and Francis, Wiley, and others. Today, he is an examiner to the National Research Foundation, South Africa, Portugal, and Technical Chair of one of the most sought largest researcher conference gathering in Africa, "ICESW". He is a Co-chairman of Standards and dredgers with the Standards Organisation of Nigeria (2000-2021). Prof. Fayomi is a member of several engineering bodies such as Council for the Regulation of Engineering in Nigerian (COREN), Member Nigeria Society of Engineers (NSE), Academic Member Water Institute of Southern Africa (AMWISA), Member Nigeria Metallurgical Society (NMS), and Member Nigeria Association of Technologist in Engineering.

He is an achieved researcher and lecturer, who has harvested over 70 awards locally and internationally. Among others is the Scientific Achievement by South African Association for Advancement in Science Medal Award (A2S3 Medal for Original Research) (2013), Africa Young Invention award (2014), Best doctoral fellow (2015), Best Postdoctoral fellow for Teaching and Innovations (2016), Outstanding African Researcher (2017), most Innovative Scholar in Composite deposition (2018), Chancellor's award at Covenant University (2019-2020), Top 50 in Africa out of top 500 researchers (2021-2022), Dr. Ibrahim Hassan Dankwambo Prize (2022-2024), BellsTech Vice Chancellor's excellent award for researcher (2022-2024) and 2% rated scientist in the world (2024).

Prof. Ojo Sunday Isaac Fayomi is a passionate, purpose-driven, self-motivated, result-oriented natural leader and an administrator par excellence. He has trained hundreds to thousands of people through Ignite world motivational summit, seminars, workshops and conferences. He presently serves as mentor to several people in Nigeria and around the world. As an international conference speaker, he has spoken to audiences in Belgium, Mauritius, Malaysia, United States, Greece, United Kingdom, South Africa, China and Nigeria,

Prof. Ojo Sunday Isaac Fayomi is a multi-gifted inspirational speaker who addresses critical issues that affect every aspect of human concept, professional practices, social, and inspirational empowerment. Fayomi is happily married to his sweetheart, Dr. Gloria Uche Fayomi who currently works with University of South Africa, and they are blessed with two children, Isaac Jnr and Triumph.

Preamble

Vice-Chancellor, Deputy Vice-Chancellor, Registrar, Bursar, and University Librarian, Deans and Directors, Distinguished Colleagues, Staff and Students of Bells University of Technology, Gentlemen of the Press, Distinguished Guests, Ladies and Gentlemen.

I give thanks and glory to God, the Almighty, for the privilege to stand before you to deliver this Inaugural Lecture. The Holy Bible says “But as it is written, Eyes hath not seen, nor ear heard, neither have entered into the heart of man, the things God hath prepared for them that love him.” – I Cor 2:9. I am a living witness of the fulfillment of this scripture and I owe God thanks. This is indeed the Lord's doing and it is marvellous in my eyes. Mr Vice-Chancellor, Sir, having felt so greatly honoured to be given the opportunity to stand here today to give a steward's account of my research experience, the contributions I have been able to make to advance the frontiers of knowledge as well as my current research efforts; I will seek your permission to let the audience know that today is not just an ordinary day or occasion in my life. Today marks my 41st birthday and 16 years of great, colourful, blissful, wonderful journey of marriage with a “priceless worth and wife” Temi, thanks for being the best always.

Mr. Vice Chancellor Sir, my journey to the world of academics, is not characterised by passion alone but by predestination. I am a product of mercy “Anu ni mo ri gba.” Growing up was very tough, my father was a rank and file police officer and a farmer. My mother was a petty trader and Garri fryer. Anywhere my father was posted to, because he loves farming, he must farm and I happen to be his trusted deputy, which means I must also learn to farm. Unfortunately, with my entire father farming massive skill, I got admission into the Polytechnic, Birnin Kebbi now Waziri Umaru Federal Polytechnic, Birnin Kebbi and getting money to school became a problem. I was with my father for two months after student resumption because of N5,700. This fateful day, a newly graduated Assistant Superintendent of Police saw me and my father on our way to the police station from where he just finished his Night Duty to return his rifle and said “Segi,” why is this handsome boy not in school? My father replied I am looking for money. The young ASP counted the exact money I needed and gave it to my father. Immediately my father gave me the money to travel back to meet my mum in a town called Share, He said “GET PROFESSOR FOR ME AND GET OTHERS FOR YOURSELF”. This professorial passage has been a journey of tireless and selfless Dedication, Devotion and Development. Indeed, I

owe God thanks. This Lecture is dedicated to “Jesus, my parent and my wife”.

Mr Chairman Sir, I started my career in life as a Cleaner in academic environment and standing here before great scholars and guests is a great honour of a life time for me. Today’s lecture is the 6th Inaugural Lecture series of this great Citadel and 2nd in the College of Engineering since its establishment where divine election, I am also serving as the Dean from 2021 till date. I am also glad to be the first to present an Inaugural Lecture after the Times Higher Education announcement of Bells University of Technology entering the 41st Sub-Saharan ranking and 13th in Nigeria. To the glory of God, I was also present at your Valedictory Lecture which was a huge success and you emphatically said THREE LECTURES TRADITIONALLY MARK SIGNIFICANT MILESTONES IN THE ACADEMIC JOURNEY OF A UNIVERSITY PROFESSOR: THE INAUGURAL LECTURE, THE PUBLIC LECTURE, AND THE VALEDICTORY LECTURE. You pressed on by saying, Inaugural and Valedictory lectures hold a particular significance.

Mr. Vice Chancellor, Inaugural Lecture is also supposed to serve as an opportunity for the Professor to inform the public in a simple language, what he/she professes, the contributions made, problems met and the projections for the future. Even though in doing so, there might be constraints for the lay-man to understand some of the technical terms the Professor may unavoidably have to use in order to justify being an expert. Mr. Vice Chancellor, Sir, I profess material processing and production technology to the study of Mechanical system. So, please permit me to use material terms. In doing so, I shall endeavour to be as modest as possible so as not to bore the professional in the attempt not to side line the non-professional.

1 Man and material

God, right from the commencement of creation, showed how important material things were in modelling the world. In Genesis 2:7, it was said that God formed man out of the dust of the ground and then breathed life into him so he became a living being. The action of God not only has shown the link between man and the materials but also the importance of the materials for keeping up and developing human lives. *Man is material, man must live on materials, and man must survive with materials, therefore, man is material and material is man.* From Genesis to Revelation, there are profound examples of materials used to accomplish divine purposes and fulfill human needs. The ark of Noah, made from wood and carefully sealed with pitch (Genesis 6:14), played a key role in the preservation of life through the great flood. The tabernacle and temple, built from gold, silver, acacia wood, and precious stones (Exodus 25), were at the very centre of worship and reflective of God's glory.



Figure 1: Man at his core is a material (SaltCity, 2023)

On the Exodus, God had instructed Moses to strike a rock at Horeb, from which flowed water to sustain the Israelites (**Exodus 17:6**). The miracle of provision through natural material highlights the value of natural materials in maintaining human life and God's provision through the physical world. In **2 Kings 4:1-7**, a

widow was instructed by the prophet Elisha to collect jars and then pour oil into them. This act of obedience multiplied her resources, showing that ordinary materials can serve extraordinary purposes when guided by divine wisdom. In the building of Solomon's temple, certain materials were selected for beauty and durability: cedar wood from Lebanon, overlays of gold, bronze for basins and pillars—all carefully used to build a temple representative of God's greatness, as recorded in **1 Kings 6**. The construction of the temple illustrates that material resources, when applied skilfully, can be used to construct structures of enduring importance. Even Jesus, in His ministry on earth, showed what materials could do. He changed water into wine at the wedding in Cana (**John 2:1-11**), showing how even the simplest elements can be transmuted for higher purposes. Later, He used clay to give sight to a man born blind (**John 9:6-7**), further illustrating that materials play a significant role, even in divine interventions.



Figure 2: Solomon's Temple (Thinking, 2015)

The mandate from God in **Genesis 1:28**, "*Be fruitful and multiply; fill the earth and subdue it,*" was an encouragement to explore, cultivate, and use what He had given. And, as a matter of fact, humankind has responded to the challenge from the Stone Age through the Bronze Age and then on to the Iron Age up to this present day of sophisticated materials. Nations have risen to global prominence by unlocking the potential of their material resources, using them

to leverage technological breakthroughs and economic growth. For example, the United States of America is richly endowed with natural resources like iron ore, coal, and petroleum and has thus developed a strong industrial base. The U.S. was a leader in the Industrial Revolution and later became a technological powerhouse by investing in advanced materials like silicon for semiconductors, which are the backbone of the global electronics and computing industries. Innovation in aerospace materials has also enabled the U.S. to dominate the aviation and space exploration sectors.

China, the so-called "world's factory," has risen to become a global leader by leveraging its rich reserves of rare earth elements, coal, and iron ore. Rare earth elements used in modern technologies such as smartphones, electric vehicles, and renewable energy systems have positioned China as the epicentre of high-tech manufacturing. With strategic investments in advanced materials like graphene and nanotechnology, China has positioned itself as a critical player in global supply chains. Germany focuses on precision engineering and innovation, using its material resources to attain leading positions in advanced manufacturing and renewable energy. Mastery of steel production and the development of lightweight composite materials by the country have driven its dominance in automotive manufacturing, making it home for some of the most renowned car brands in the world. Furthermore, the role that Germany plays in wind turbine materials and solar technology places it at the forefront of the global transition to renewable energy. But Japan, without major natural endowment, has had great success, proving that innovation in material science overcomes geographical constraints. By focusing on advanced materials—superconductors, carbon fibers, and ceramics, among other materials—Japan have made immense strides in several strategic industries: electronics, robotics, and automotive engineering. By inventing high-performance material in lithium-ion batteries, it has been able to gain a leading position in energy storage technologies. This is an exemplary example of how countries could exploit material resources into valuable successes. Their ability to develop, refine, and innovate using the materials they have at hand has propelled them to global prominence by shaping industries and driving economic growth.



Figure 3: Transforming the World through Material-Driven Innovations '(Tristin, 2019)

But where is Nigeria in this divine mandate to dominate the earth with the materials God has endowed us with? To be sure, God has so richly endowed Nigeria with solid minerals such as over 3 billion metric tonnes of iron ore in Kogi, Enugu, and Niger states, over 40 million tonnes of talc deposits, and a mass reserve nearing 3 billion tonnes of coal. These are enormous resources, but we have not yet managed to harness them into a well-functioning industrial base or achieved the desired level of national development. In sharp contrast, the material sector in Nigeria faces daunting challenges. Our steel rolling mills remain idle for incomplete infrastructure, energy shortages, and inconsistent policy implementation. For example, the Ajaokuta Steel Complex, an icon of hope for industrialization, has been allowed to lie idle as a testament to mismanagement and missed opportunities. This is coupled with the neglect of the foundational industries like steel and overdependence on oil, which has kept us behind in both innovation and industrial capacity.

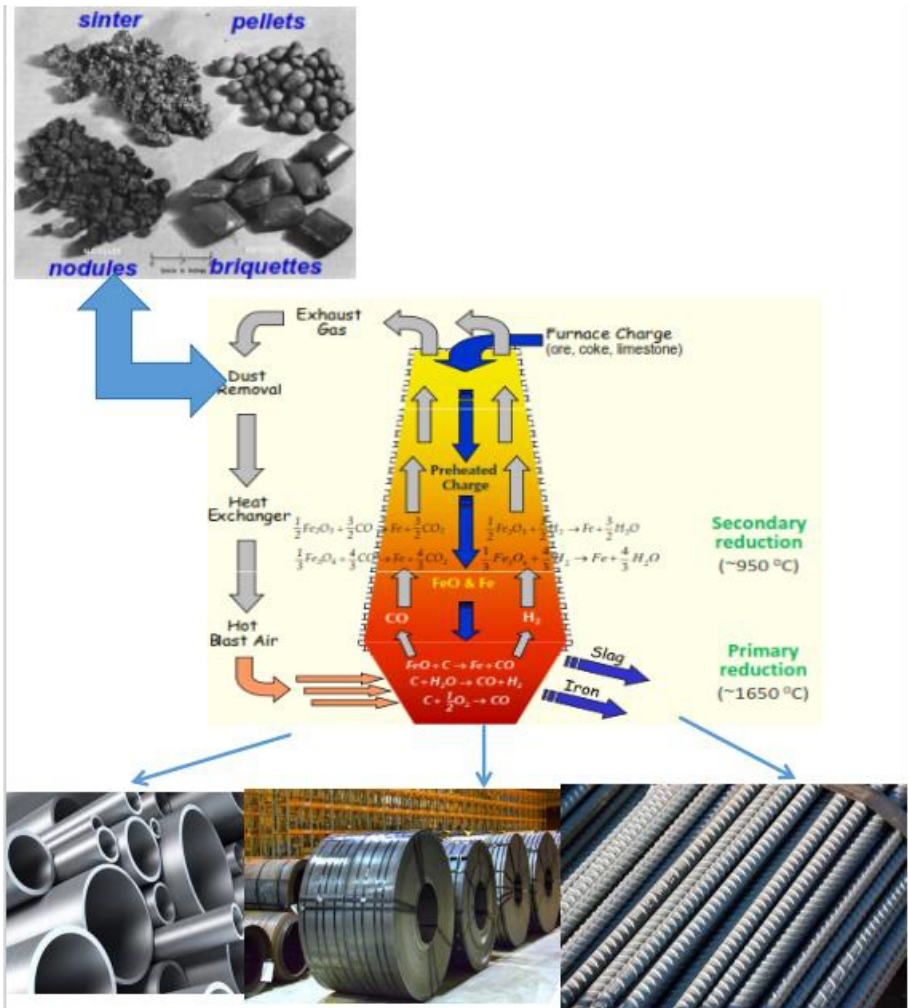


Figure 4: Iron and steel processing: A driver of economic growth and industrialization (Elizabeth, 2021)

But there is hope. God's provision of these resources reminds us of our potential to rise as a nation. Unless Nigeria takes responsibility, such entrusted worth cannot be explored. This, therefore, will take us on a journey into the world of materials, looking at their role in shaping human history, the transformative impact in global developments, and how material science and engineering will, or can, play a critical role in making Nigeria's future. As we journey through times, from ancient materials to today's state-of-the-art ideas, we will also be

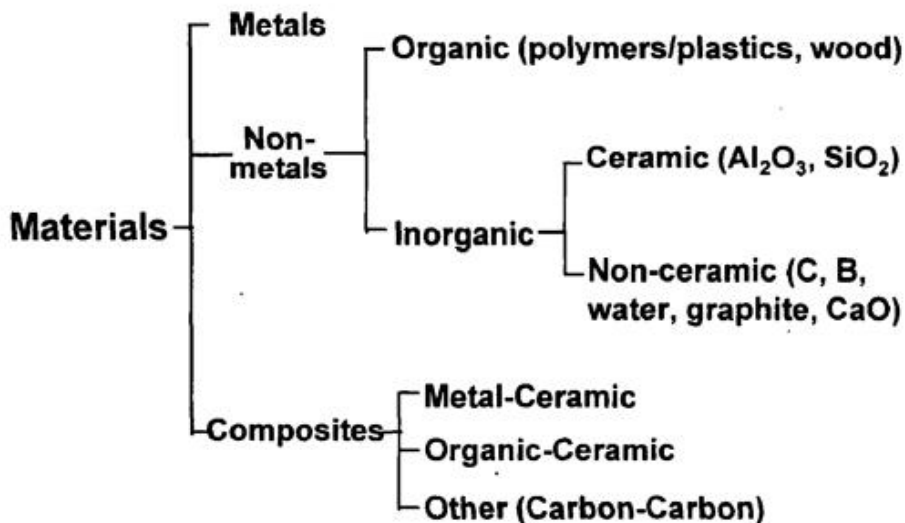
confronted by the question: how can Nigeria with all its vast resources make the leap from potential to prominence? I would like to contribute to this lecture on the area of material science and engineering, bringing out my contribution to research and innovation, indicating ways Nigeria can fully exploit her material wealth for sustainable development. Let me collectively reflect with you the indivisible bond between man and materials, charting a course toward the prosperity of our nation.

2 World of Material science and Engineering

2.1 Overview of Material Science, Its Significance, and Evolution

Material science is a branch whose foundation lies in the understanding of the behaviours of solid materials and their application in the contemporary world and industries. This is, the discipline aims at researching the structures, attributes, processing and performance of materials to be able to choose, design and specially manufacture materials for specific purposes (Dove, 2003; François et al., 2012). From primitive settlements, which knew only simple materials such as stones or metals, material science has grown into an intricate order that develops newer materials that cut across all walks of life. The necessity of material science is made manifest in one's use to create functional objects in particular technological developments. The progress which has been made in the field of engineering have enabled manipulation of materials within their ions or epitaxial growth and this has led to the creation of marvels like semiconductors, superconductors, biomaterials and nanomaterials (Durlo, 2023; Ikumapayi & Laseinde, 2024; Saint-Grégoire, 2017). These materials are imperative to the designers because the enhanced performance of the system would heavily depend upon materials with mechanical, thermal, electrical and chemical properties.

Development of the material science as a discipline can be benchmarked with important epochs of human development, for instance, the Stone Age, Bronze Age and the Iron Age among others (Barber, 2003; Maynes & Waltner, 2012; Pollard et al., 2023). The twentieth century however came with the commonly known “Materials Revolution” where impetus came from advanced polymer, ceramic and composite revolutionary materials. More than ever, as the world is calling for light, strong and environmentally friendly materials, material engineers are working to bring the impossible to reality (Ashby, 2012; Ashby & Jones, 2012; McDonough & Braungart, 2010). The innovations in materials such as graphene, carbon nanotubes, and new engineered alloys show the changes that have taken place over time.



Note: Elemental semiconductors (Si, Ge) fall under metals.
Compound semiconductors fall under inorganic materials.

4

Figure 5: Classification of Materials (Electrical4U, 2024)

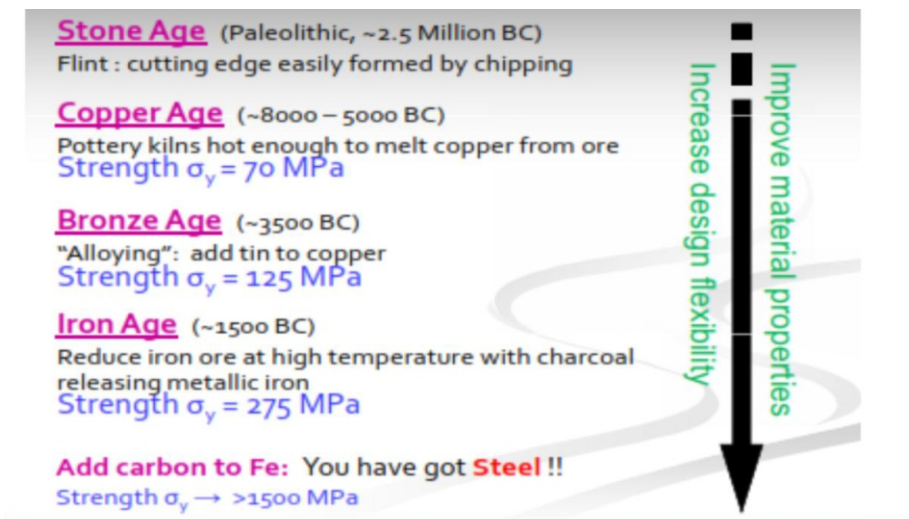


Figure 6: Mankind's Historical ages (Rashid, 2016)

2.2 Physics, Chemistry, and Metallurgy Interplay in Understanding Material Properties

To comprehend the properties of materials, it is necessary to synthesize concepts from physics, chemistry and metallurgy. Each one of these areas adds to the holistic explanation of the behavior of materials in different states, starting from the basic interactions between atoms and filling with macroscopic features. The basic ideas guiding the behaviour of matter and energy are the focus of physics. The mechanical, electrical, and thermal properties of materials are explained by physics in material science. For instance, quantum mechanics sheds light on how electrons behave in materials, which has a direct impact on characteristics like electrical conductivity and magnetism (Callister & Rethwisch, 2022; Solymar et al., 2014).

Chemistry, which is the study of materials and the way atoms come together to make new materials through bonds, governs the cross-section view of materials. The chemistry of a substance such as its polymer enhances and degrades or improves its properties such as its elasticity and tensile strength. As a discipline, polymer chemistry has changed the way materials which are strong yet lightweight and flexible are made and used in different applications industries. On the other hand, metallurgy, which is the study of processing and making of metals and their alloys, is also significant in implementation in analysing material properties enhancement such as strength, ductility, wear and corrosion resistance. Such processes as heat treatment, alloying, casting, etc. are metalworking processes performed to achieve certain qualified characteristics of the material's performance. These three domains are not mutually exclusive; rather they are interrelated and support each other —(Kumar et al., 2009; Lahiri, 2017; Okokpugie et al., 2024). For instance, advanced design of high-performance alloys is associated with metallurgical operations (alloying, heat treatment etc.) and with the knowledge of elemental interactions at the atomic level (a principle grounded in both physics and chemistry)(Odetola et al., 2024; Raabe, 2023);

2.3 Material Science in Industry Application

Materials science has many uses in several major sectors, each dependent on progress in the discipline for the creation and

enhancement of products and systems.

- **Electronics:** The emergence of semiconductors, superconductors, and conductive materials have changed the face of the electronics industry. Components such as silicon and gallium arsenide are highly beneficial when creating transistors, integrated circuits, and other devices that allow modern computer, communication, and any other electronic consumer devices to function (Behera & Behera, 2022; Braginski, 2019; Gupta et al., 2016).
- **Aerospace:** In aviation, the materials required need to be of high strength to weight ratio, due to their performance enhancing and safety benefits. Composite materials, titanium alloys and the high-performance plastics are heavily employed in the designing of aircrafts, satellites and space crafts. In addition, aerospace applications must endure extreme conditions, such as exposure to high temperatures and the need for corrosion resistance (Krishnamoorthy et al., 2025; X. Zhang et al., 2018).
- **Energy:** The energy sector particularly, in the modern scope of renewable energy, is also fostering the use of advanced materials for better energy conversion and storage efficiency. The use of perovskites for solar cells and hydrogen storage materials as well as advanced battery electrodes, which include lithium-ion and solid-state batteries are some of the materials being researched. Rogue materials also exist for energy production in nuclear reactors; zirconium alloys for example possess the ability to remain strong and corrosion resistant in adverse conditions and even extreme temperatures (Abolhosseini et al., 2014; Bin Abu Sofian et al., 2024; Ekechukwu & Simpa, 2024).



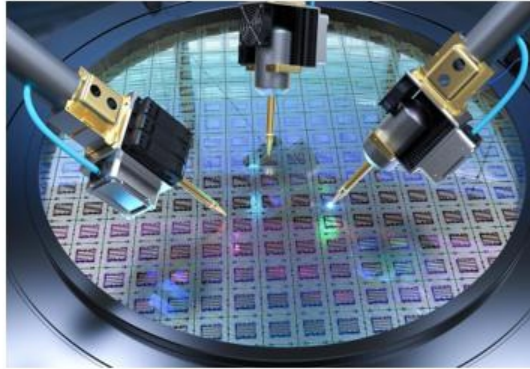


Figure 7: Advanced Materials Transforming Electronics, Energy, and Aerospace (Moe, 2019)

- Healthcare and Biotechnology:** In clinical practices, biomaterials are incorporated in devices which include implants, prosthetics and even drug delivery systems. Pharmaceutical devices such as artificial joints and dental implants or even stents are made using titanium, cobalt chrome alloys and biocompatibility plastics among others. In addition, nanomaterials are helping to make new possibilities in shaping the future of, drug delivery systems for infectious diseases, oncology as well as therapeutic and diagnostic imaging (Kar et al., 2022; Kutner et al., 2021; Ratner et al., 2004; Trucillo, 2024).
- Telecommunications:** The telecommunications sector is directly associated with the overall advancements in the telecommunications technology. Fiber optics are made from high-purity glasses or plastics which aids in long distance and high data rate transmission. Moreover, it's not only antennas and satellites that need to be shrunk, new materials for more efficient data storage have also been developed (Tong & Tong, 2014; Uzoka et al., 2024).
- Construction:** Due to the harsh conditions of external environment, the architects tend to use materials that possess high strength characteristics, durability, as well as energy efficiency. The introduction of modern concrete composites, steel protective alloys and intelligent insulation techniques has improved how structures are built, creating greener and more durable buildings.

These industries illustrate the large range of material science. For instance, the

creation and usage of materials on the nanoscale has provided **limitless possibilities** for the development of new products and new inventions which seemed impossible in the past —(Makul, 2020; Shufrin et al., 2023; Shukla & Kaul, 2025).



Figure 8: Some innovations Driving Communication and Biotechnology Advancements (Nick, 2023)

3 The Nigerian Material Sector

3.1 Material Science Landscape in Nigeria

Considering Nigeria's rich natural resources, there is enormous potential to develop a material science industry in the country. The abundant deposits of raw materials present in the country such as iron ore, limestone, silica and bauxite are quite suitable for the development of a few industries, construction, manufacturing and energy. Despite these natural riches, the field of material science in Nigeria can be termed as backward when viewed from the perspective of the outside world, and the reasons for this include poor infrastructure development investment, lack of adequate research funds, and research facilities and equipment. With time though, there has been a developing understanding of the importance of funding material science and engineering research so as to develop primary sectors such as construction, oil and gas, and renewable energy. For instance, the Nigerian Metallurgical Development Centre (NMDC) and even Bells University of Technology are among others in Nigeria that have begun to invest more in material science studies. These institutions are striving to achieve the integration between the industry and academia to promote innovation in the field of corrosion protection, advanced coatings and green materials.

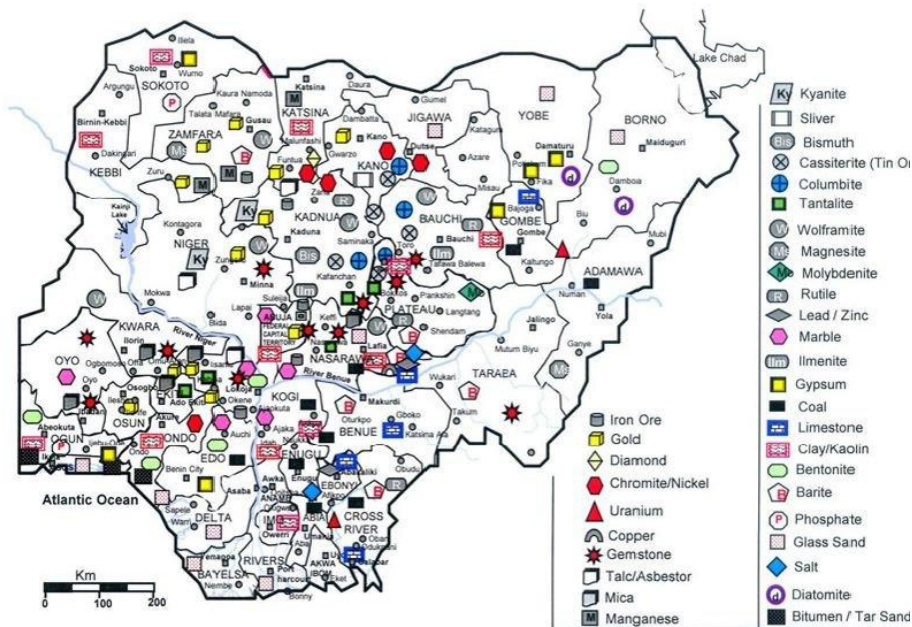


Figure 9: Nigeria: The mineral rich nation '(Falade & Adeyeye, 2016)

Table 1: Distribution of Major Mineral Resources Across the Geopolitical Regions of Nigeria

Region	Mineral Resources
North-West	Gold, Tin, Limestone, Gypsum, Kaolin, Granite, Marble, Lead, Zinc, Manganese, Phosphate, Laterite, Clay
North-East	Gypsum, Limestone, Iron ore, Kaolin, Bentonite, Magnetite, Lead, Zinc, Uranium, Coal, Clay, Laterite
North-Central	Gold, Lead, Zinc, Tin, Columbite, Tantalite, Iron ore, Granite, Limestone, Marble, Barytes, Talc, Feldspar, Coal
South-West	Bitumen, Limestone, Granite, Clay, Feldspar, Gold, Marble, Gypsum, Bauxite, Kaolin
South-East	Lead, Zinc, Limestone, Coal, Gypsum, Clay, Oil and Gas, Granite, Marble
South-South	Limestone, Clay, Gypsum, Tin, Granite, Barite, Lead, Zinc, Oil and Gas, Feldspar

Table 2: Steel plants in Nigeria

Name	Status	Location	Capacity
Ajaokuta Steel Company (ASC)	Non-operational	Kogi State	1.3 million tonnes of steel annually
Delta Steel Company (DSC)	Partially operational	Aladja, Delta State	1 million tonnes of liquid steel annually
Jos Steel Rolling Mill	Non-operational	Plateau State	210,000 tonnes of rolled products annually
Katsina Steel Rolling Mill	Non-operational	Katsina State	210,000 tonnes of rolled products annually
Oshogbo Steel Rolling Mill	Non-operational	Osun State	210,000 tonnes of rolled products annually
African Foundries Limited	Operational	Ogijo, Ogun State	500,000 tonnes annually
Sunflag Steel Nigeria Limited	Operational	Lagos	150,000 tonnes annually
Universal Steel Limited	Operational	Lagos	100,000 tonnes annually

** Nigeria's annual steel demand is estimated at **10 million tonnes**, meeting over **70% of this demand** from imports*

3.2 Nigerian Industries Leveraging Material Science

Construction, oil and gas, energy and manufacturing are the main industries in Nigeria and they all make use of materials that are able to withstand extreme surfaces, warmth, dampness, and erosive liquids among others. Here is the impact of material science in these areas:

- **Construction:** The construction industry is among the fastest-growing sectors in Nigeria, due to increased demand for infrastructural, housing, and commercial projects. This has ensured high usage of high-tech building materials for strength and durability, such as concrete composites, steel reinforcement, and advanced polymers. There are also efforts to use alternative local materials such as bamboo, laterite, and palm kernel shells in order to reduce dependency on such expensive imports. These will not only provide cheaper alternatives but also contribute toward sustainability. Dangote Cement is one of the largest cement producers in Africa and leads the front in this area. It has invested hugely in research to come up with high-performance cements suitable for a wide range of environmental conditions and can produce 48.6 million metric tonnes annually. In addition to large-scale cement production, Dangote Cement is committed to sustainability. It collaborates with research institutions like the Nigerian Building and Road Research Institute in the development of environmental-friendly construction materials such as bamboo-reinforced structures and laterite-based blocks. These innovations are intended to make housing more affordable and to reduce the environmental footprint of the construction industry. Others like Lafarge Africa have embraced green construction and sustainability in cement production. Lafarge's AshakaCem plant, located in Gombe State, produces more than 1 million tons of cement annually, with the use of alternative fuels and raw materials to reduce carbon emissions.

In addition, BUA Cement has grown to be a leading participant in Nigeria's construction industry with a total combined installed capacity of 11 million metric tonnes per annum. Moreover, BUA is still expanding its operations, adding a new cement plant in Sokoto among others. The strategic attention of the company toward environmentally friendly methods of production underlines the changes within the sector

toward sustainable development. These companies are the drivers that use innovative material use and commitment to sustainability as a torch that not only reshapes the Nigerian construction landscape but also cements the status of Nigeria as the modern hub for eco-friendly building practices. Investment in high-performance materials will be complemented by collaborative agreements with research institutions and, in the long run, will create a pathway to balanced growth and an environment-sensitive construction industry (Akinyoade & Uche, 2016; Bah et al., 2018; Meshack and Milala, 2023; Roche, 2023).



Figure 10: Nigeria's giants in the cement/construction industry '(Chris, 2024)

- Oil and Gas:** The oil and gas industry in Nigeria largely relies on materials that can resist corrosion and perform well under high-pressure conditions. Pipelines, tanks, and drilling rigs are highly susceptible to corrosion, which often leads to high maintenance costs and potential environmental hazards. To this effect, research institutions and companies such as NNPC and Shell Nigeria are developing advanced coatings and inhibitors from agro-waste and nanocomposite materials. These innovations are targeted at increasing the life service of critical infrastructure, reducing operational costs, and mitigating environmental risks. The emergence of the Dangote Refinery has been the latest landmark in Nigeria's oil and gas development in recent years.

Situated in Lagos, it is the largest single-train refinery in the world and has a capacity for processing 650,000 barrels of crude oil per day. This gigantic facility is all set to alter Nigeria's oil landscape and decrease the nation's reliance on imported petroleum products, including gasoline, diesel, and jet fuel (Akpan et al., 2023; Etim et al., 2023; Oritsejafor, 2021). Given the ability of the Dangote Refinery to meet 100% of Nigeria's demand for refined petroleum products and also produce surplus for export, the plant is expected to rake in enough revenue that could give Nigeria a good balance of trade. It would also create opportunities for the local development of materials and technologies applied in the oil and gas sector, such as corrosion-resistant alloys, coatings, and infrastructure materials. It will include, for instance, the quality anti-corrosion materials of a refinery pipeline system and storage tank for endurance of the harsh operating conditions of refining. This investment in material science again underlines the importance of this area to increase operational efficiency and prolong life in critical infrastructures of the oil and gas industry.



Figure 11: The state of a corroding pipeline (Siraj, 2021)

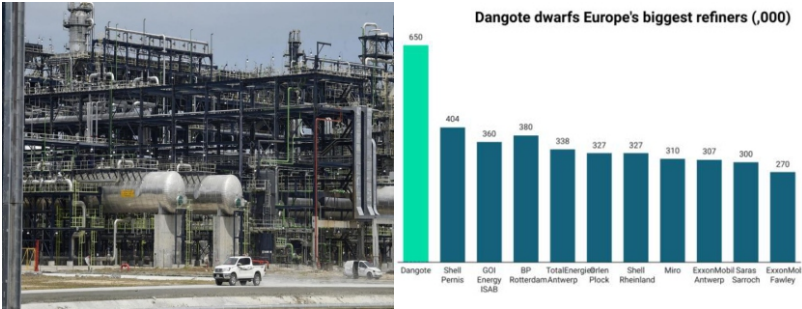


Figure 12: Dangote's refinery output against some of Europe's largest refineries (Oladehinde Oladipo, 2023)

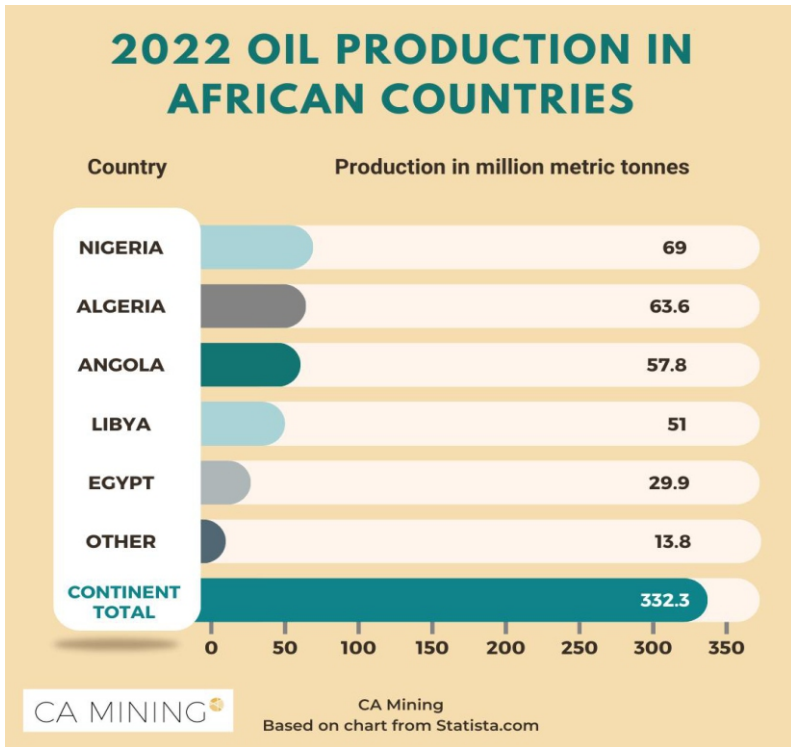


Figure 13: Africa's production output for oil as of 2022 (Mining, 2023)

- **Energy:** The renewable energy industry is on the increase in Nigeria, especially in the area of solar power, as the country wants to surmount long-standing electricity challenges. Material science is at the heart of this transition, driving technological advancements in solar power and energy storage systems. One of the key focuses is the realization of alternative materials for solar cells. Researchers are, therefore, looking at using perovskites—a rather cheap and highly efficient material easily manufactured with locally available raw materials. These perovskite-based solar cells belong to a class of materials believed to have the potential for higher energy conversion efficiencies at lower production costs than traditional silicon cells. Leading in the energy storage space are companies such as Rubitec Solar. Specializing in deploying solar-powered solutions for off-grid areas and incorporating advanced battery storage technologies that ensure stable power supply systems, Rubitec Solar goes a step further. The innovation in the usage of

lithium-ion batteries among other energy storage systems has completely revolutionized rural electrification projects for reliable energy access in these communities (Babalola et al., 2022; Iwegbu et al., 2023).

Another major player in the field is Blue Camel Energy, which has put up solar panel assembly plants in Nigeria and has been working on renewable energy solutions for businesses and residential areas (Okoh & Okoh, 2021). Blue Camel uses modern materials in its designs to improve efficiency and durability for its solar systems. Besides, Arnergy Solar concentrates on modular solar systems for urban and semi-urban areas. Equipped with superior energy storage systems that power homes and businesses for long periods, this minimizes the need to revert to fossil fuels and generators. Their solutions are easily scalable and hence suitable for everything from single households to large-scale enterprises. These developments are supported by research collaborations with universities and innovation hubs. Organisations such as the Energy Commission of Nigeria, in collaboration with academic institutions, are involved in the development of new materials for solar technologies and energy storage, including environment-friendly and cheap alternatives. This is coupled with Nigeria's giant solar potentials, averaging 5.5 kWh/m²/day of solar radiation, and thus the renewable energy industry could create leading interference with heightened awareness in the application of emerging materials and technology (Quintero et al., 2024). These have not only been responding to the demand for sustainable electricity but furthering common goals of reducing reliance on fossil fuel consumption across the globe.

- **Manufacturing:** This transformation of Nigeria's manufacturing into high-performance material will promote product quality and efficiency. Advanced materials-aluminum alloys, composites, and green alternatives-play a major role in modern manufacturing; they are what the industry needs to be at an advantageous edge within various global markets while meeting international standards. A typical success story in this domain is Innoson Vehicle Manufacturing, Nigeria's first indigenous automobile manufacturer. IVM uses lightweight aluminum

alloys and composite materials in the manufacture of its vehicles to achieve better fuel efficiency and durability. The company has a production capacity of over 10,000 vehicles annually, supplying the local and regional markets. By applying advanced materials, IVM contributes not only to the development of the automotive industry but also to the reduction of environmental impacts (Agulonye, 2020; Chen et al., 2016).



Figure 14: Innoson IVM (EV) Link (201-230KM Range) (Choice Arukwe, 2024)

Both Aero Contractors and other airlines in Nigeria have increasingly started integrating advanced composite materials into aircraft maintenance and repairs in the aviation sector. These composites are used to achieve high strength-to-weight ratios, which are very essential in ensuring fuel efficiency and passenger safety. The push toward sustainability in manufacturing is also evident in the rise of companies using green materials. Wecyclers and Chanja Datti, for instance, are pioneering the recycling of plastic waste into eco-friendly alternatives for traditional materials. These recycled products are being utilized in packaging, furniture production, and even building materials, significantly reducing Nigeria's dependence on imported plastics while addressing environmental concerns. Driving innovative development further, the industrial conglomerate known as BUA Group is expanding operations in businesses like cement production and packaging to include green manufacturing methods that limit carbon emissions. Its investment in sustainable materials is in tandem with the going rate globally and further highlights a place for the study of material sciences within the fast-developing manufacturing landscape in Nigeria.



Figure 15: An Aero contractor aircraft (Caleb Obiowo, 2024)

Others are academic institutions and research centers through partnerships like RMRDC that provide support to the manufacturing industry by developing indigenous materials to replace imported ones. The research covers all areas, such as those based on agro-waste-based materials, bio-composites finding their way into furniture, automotive parts, among others. This means that, with the development of material science, coupled with the adoption of eco-friendly practices, the manufacturing sector in Nigeria is now set to be a hub for innovation and sustainability. The adoption of high-performance, green materials thus propels the industry to contribute to economic diversification and drive the country toward a sustainable future.



Figure 16: Wecycler recycling plant in Lagos (Wecycler, 2023)

3.3 Challenges and Opportunities in the Nigerian Material Science Sector

Notwithstanding the abundant natural resources, Nigeria encounters a number of obstacles that hinders the development of the material science industry:

- **Insufficient Advanced Facilities:** One of the major challenges is the scarcity of research advanced research facilities. There are few laboratories available, which are equipped with material characterization instruments such as Scanning Electron Microscopes (SEM) and X-ray Diffractometers (XRD) that have high precision and accuracy. This incapacitates carrying advanced research and creating new materials.
- **Research Funding:** Public funding for Material Science research is rather little and as such, there is little if any advancement in the field. The greater majority of Nigerian universities and research centers are heavily dependent on government financial support which is rarely

sufficient. Hence, innovation progress was very much retarded, and communication with other research centers across the globe was very much limited.

- **Skilled Workforce:** There are hardly any workforce training programs specifically focused on material science, hence the scarcity of trained individuals in the area. Universities are providing degrees in relevant courses however, the main issue remains qualitative education and training in advanced materials science, engineering and nanotechnology.

Yet, these constraints have a positive impact on the economy and society as well. Government measures such as the Nigerian Metallurgical Industry Bill, which aims to stimulate the country's metallurgical and mining industries, creates a favorable environment for investment in material science. In addition, the growing emphasis on sustainable development and environmentally conscious materials has opened the possibility of research that explores local resources and focuses more on waste recycling.

3.4 Government Policies, Research Initiatives, and Industry Collaborations

Realizing the role of material science, the Nigerian government has embraced it as a catalyst for national industrial growth and innovation. To this end, several policies and initiatives have been put in place to encourage research and development in the area. In this case, for instance, the National Science, Technology, and Innovation Policy (NSTIP) aims at promoting the application of science and technology in any economic sector, with a special emphasis on material science. In addition, the trend of partnership between academia and industry is going up. Academic institutions are entering agreements with industrial establishments, particularly those in oil and gas, construction, and energy, to design materials for purposes. For example, there has been an increased demand for research about corrosion inhibitors and coatings to put on oil pipelines because of the issues that pipes get corroded and are costly to maintain which both domestic companies and foreign firms have come in to provide affordable solutions. The importance of the industry-academia ecosystem in fostering innovation cannot be overemphasized. The Nigerian Association of Metallurgical, Materials, and Mining Engineers (NAMMME) is concerned with the enhancement of research effort to address current industrial issues through organisation of workshops and conferences that encourage cooperation between researchers and industries.

3.5 Looking Forward: The Future of Material Science in Nigeria

Nigeria is poised for the advancement of materials science thanks to the growing number of programs aimed at the development of green materials and green energy, as well as advanced manufacturing. With a wealth of natural resources and growing commitment to research and education, it is reasonable to hope that Nigeria can excel in materials development in West Africa. As Nigeria grows industrially, it is also expected that there will be increased populations of people demanding high performance and globally acceptable materials that are also low in cost. The best way to harness this opportunity is to dramatically improve research and development capacity in the region, support the development of industry – academia collaboration and most importantly build the materials science capacity of people in the region.

4 Advanced Material Development and Characterization

4.1 The Importance of Advanced Materials in Modern Engineering

Advanced materials occupy a central place in technological developments across the aerospace, electronics, automotive, and health care sectors (Asyraf et al., 2022). These materials have been designed to showcase certain improved properties such as improved strength to weight ratio, enhanced durability, better resistance to corrosion, or distinct conductivity to heat and electric current (Moskowitz, 2014). Understanding the science of materials is critical in the development of these composites as well as the ability to modify the structure of materials at the nano, micro and macro levels. The need for high-performance materials has triggered fundamental research on advanced composites, nanomaterials, and high-entropy alloys, HEAs. The materials are designed to complement some of the most sophisticated functionalities and hence possess a great concern for advanced designs within applications such as renewable energy, lightweight car parts, and complex medical devices.

4.2 Development of Advanced Materials

The process of developing advanced materials often involves altering their microstructure or composition to achieve specific properties. Some key areas of material development include:

4.2.1 Nanomaterials

Nanomaterials, which typically range between 1 and 100 nanometers, have

many properties that are considered unique due to the surface area to volume ratio and quantum mechanics (Asha & Narain, 2020; Pokropivny et al., 2007). For example, carbon nanotubes, graphene, and metal nanoparticles, are among many other nanomaterials which have been the subject of many investigations, with new uses including energy storage and biomedicine.

- **Carbon Nanotubes (CNTs):** Known to have superlative mechanical strength, outstanding electrical conductivity and thermal stability, CNTs are used in advanced composite materials, advanced sensors, and even as delivery mechanisms of drugs (Abubakre et al., 2023; Mohd Nurazzi et al., 2021; P. Sharma et al., 2016).
- **Graphene:** A two-dimensional compound that is made of just one layer of carbon atoms, graphene is known to have very high electrical conductivity, very high mechanical strength and very high flexibility (Armano & Agnello, 2019; Katsnelson, 2007; Xu et al., 2013). Potential applications include electronic circuits, bendable screens, and for supercapacitors, which are a device for energy storage.

4.2.2 Composite Materials

Composites are readily available in nearly every industrial sector owing to their exceptional performance, especially in outmatching other materials. For instance, fiber reinforced composites have found numerous applications in the airline industry and automobile construction as a result of their light weight to strength ratio.

- **Polymer Matrix Composites (PMCs):** PMCs are composites that use reinforcing fibers such as carbon and glass, in the resin polymer matrix. These systems are very light with outstanding mechanical performance and therefore, they are mostly used in aircraft parts as well as sports equipment (Chauhan & Bhushan, 2017; Sharma et al., 2022).
- **Metal Matrix Composites (MMCs):** Metal Matrix Composites (MMCs) are materials that consist of a metal matrix with either ceramic or metallic reinforcements, where such materials are designed to enhance strength, stiffness, and wear resistance. These materials are used in high temperature apparatus like engine parts or blades for turbines —(Casati & Vedani, 2014; Ravi Prakash et al., 2017).

4.2.3 High-Entropy Alloys (HEAs)

HEAs represent a novel category of materials characterized by the incorporation of several principal components in nearly equal atomic fractions (Pickering & Jones, 2016; Zhang et al., 2014). Such alloys present remarkable mechanical strength, corrosion resistance, and thermal stability, which allow their application to extreme environments typical of offshore oil and gas exploration and marine fabrication industries.

- **Mechanical Strength:** As a result of their intricate atomic structure, HEAs are much stronger and withstand deformation better than conventional alloys.
- **Corrosion and Wear Resistance:** HEAs easily withstand corrosion and abrasion, making them suitable for extreme conditions, especially in the marine environment or in chemical processing facilities.

4.3 Advanced Characterization Techniques

The evolution of innovative materials entails that their structure, properties, and performance must be characterized with utmost accuracy. Such characterization techniques are important as they shed light on the material's behavior as one goes from atomic or molecular level to macro level and even enhance the design and performance of any materials.

4.3.1 Scanning Electron Microscopy (SEM)

The use of SEM is important when it comes to understanding of any surface. High energy focused beam of electrons is used to develop images of a material's surface on whatever magnification possible including up to several micrometers features such as the surface textures, grain boundaries, cracks, and even the openings in the material. It is also very important in the study of thin layers as coatings, composites, or thin films materials (Bauer, 2014; Inkson, 2016; Zhou et al., 2007).

- **Surface Morphology:** It gives all the information concerning the texture of the surface and the defects present that are likely to affect the performance of the material in structural applications or corrosion resistance.
- **Elemental Analysis:** It is aiding in elemental analysis of materials if used with SEM Energy Dispersive X-ray Spectroscopy, hence allowing testing

for chemical compositions and contaminants in raw materials.

4.3.2 X-ray Diffraction (XRD)

The crystal structure and the phase composition of materials are studied with the aid of X-ray diffraction technique. The technique allows that upon placing a material within a beam of x-ray radiations, the structure of the matter which includes the x-ray arrangements, distances between these atoms, their lattice parameters, and also different phases of the x-ray radiations within the material are examined (Ali et al., 2022; Bunaciu et al., 2015).

- **Phase analysis:** XRD is beneficial for phase characterization of materials, which is important in evaluating mechanical properties, corrosion resistance, and thermal behavior of materials.
- **Residual Stress Analysis:** Besides the typical applications of XRD in the determination of the microstructure of materials, residual stress measurement is another essential aspect especially in the evaluation of the material's performance.

4.3.3 Atomic Force Microscopy (AFM)

AFM describes nanometre scale surface topography in 3D at very high resolution. It is of great importance when characterizing surface architectures of nanocomposites or biomaterials that contain complexities in their structures. AFM is based on the interaction between a sharp tip and a surface in order to map the surface topography, roughness, elasticity, and adhesion of materials (Gangadoo et al., 2015; Garcia, 2020).

- **Nanoscale Surface Properties:** AFM focusses on the assessment of texture and roughness of the surfaces of materials for instance coatings, since such effects can influence their performance.
- **Nanomechanical Properties:** AFM can also be performed on a given material to study its mechanical properties at a scale of a few hundred nanometers including the hardness and potential ability of the material to bear loads which explains how the materials will behave when subjected to weight.

4.3.4 Transmission Electron Microscopy (TEM)

This is one of the advanced methods that can be utilized to study the

arrangement of materials on an atomic level. This technique involves the passage of electrons through a very thin specimen for instance a few hundred atomic units thick, where the electron beam carries information regarding the material structure such as materials imperfections in the form of dislocations or grain boundaries(Carter & Williams, 2016).

- **Atomic-Scale Imaging:** In addition, TEM has atomic level resolving power, which allows scientists to see the atomic structure and arrangement in a material and how this affects its mechanical or electrical properties.
- **Defect Analysis:** Among its various applications, defect analysis using a transmission electron microscope is vital for understanding such issues as cavities, dislocations, and other empty spaces inside materials that can be detrimental to their abilities.

4.4 Applications and Advancements in Advanced Material Development

It is no doubt that the achievements and growth in material fabrication and characterization are carried in a great proportion across numerous sectors, especially those that require high-performance properties. Some of these include:

- **Aerospace:** Advanced materials, optimized to allow the integration of lightweight structures, such as CFRP and high-temperature alloys to aircraft bodies without compromising strength and durability. The case is like HEA which find usage in the aircraft engine among other uses in turbine blades and parts that require high temperature resistant materials.
- **Renewable Energy:** Within the renewable energy industries, new revolutionary materials such as perovskites, and cells made from nanostructured materials are already being overhauled and incorporated into the modern as well emerging solar cell and energy storage system designs. Today, such high-performance materials are vital for increasing efficiency of solar panels, wind energy turbines and storage batteries and this is in support of the change of energy sources systems.
- **Healthcare:** The introduction of biocompatible materials has made the greatest impact on the creation of matrixes for medical implants and

devices. This involves the use of titanium alloys, polymer composites and nanomaterials in producing strong and light implants, stents and prosthetics with better performance and lower chances of rejection or failure.

- **Automotive:** The use of lightweight materials such as aluminum alloys, composites, and high-strength steels places great significance on fuel efficiency and emissions reduction in the automotive industry. The advent of modern composites has helped the manufacturers to produce vehicles that are safe and lighter, which has been one of the drivers of sustainability in the sector.

4.5 Future Directions in Advanced Material Development

In advanced material development, the attention is turning to sustainability, functionality and cost over the advanced materials. The following are the main topics of research in this area:

- **The Eco-Friendly Materials:** The focus is increasing on the problems related to the environment and the enhancement of materials that are biodegradable, recyclable, or non-toxic. Renewable sourced or agro-waste based materials are playing a major role in industries like packaging, construction, resin, and paints etc.
- **Multifunctional Materials:** The materials with multiple purposes, such as self-healing polymers that can restore themselves, or thermoelectric materials that transform heat into energy, are researched by scientists. These materials are expected to be useful in the fields of aerospace, electronics and energy systems.
- **Smart Materials:** Smart materials are those developed to active environmental factors such as temperature, pH or stress and is very interesting as well. These so-called shape memory alloys and piezo materials are anticipated in the near future to have far reaching uses in sensor, actuator and medical device fields.

5 Corrosion Science

5.1 Fundamentals of Corrosion and Its Industrial Relevance

Corrosion is a process which is omnipresent in nature and results in the ever-time removal of the available materials, mainly metals because of their

chemical or electrochemical action with the surroundings. The process which is caused by the law of thermodynamics is without a doubt inevitable; that is, every type of metal has to oxidise into the stable form of that metal. Corrosion is defined as the destructive attack of a material cushioned in its environment but it does however affect other materials as well, metals are easily corroded in hostile environments like marine, chemical, and industrial environments (Kamachi Mudali et al., 2019). The industrial importance with respect to corrosion is immense because it is a business concern and a safety issue. The World Corrosion Organization reports that corrosion incurs losses to the global economy amounting to more than \$ 2.5 trillion every year in which sectors of economies such as oil and gas, transportation, infrastructure and power generation are the most affected (Koch, 2017). This corrosion causes structural weakness in the paid liabilities resulting in breakdown of equipment; halt in production and in extreme cases, large storage tank bursts or buildings coming down. For this reason, in many industries eliminating or even better preventing the occurrence of corrosion is very important. Key factors influencing corrosion include:

- **Environmental Conditions:** The presence of moisture, heat, and the contact of salts, acids, oxygen among others instigate quicker deterioration of metals.
- **Material Composition:** Materials are not equal when it comes to corrosion resistance. For instance, long lasting stainless steel is made with passive coating of chromium oxide whereas carbon steel is easily corroded.
- **Electrochemical potential:** This refers to differences in electrochemical potentials of materials soaked in an electrolytic as a result resulting to galvanic corrosion.

5.2 Methods of Studying and Mitigating Corrosion in Materials

The study and treatment of corrosion in extreme conditions utilize several techniques encompassed by research on corrosion science. These methods aid in material performance evaluation in operation as well assist in formulating control measures.

5.2.1 Electrochemical Techniques

In controlling corrosion and developing other protective measures,

electrochemical techniques are mostly employed to understand corrosion processes and measure the rate of corrosion. They include the following (Farghaly et al., 2014; Nyholm, 2005);

- **Potentiodynamic Polarization:** This technique applies to the substrate present inside an electrolyte solution wherein the substrate's current as a function of the applied potential is measured. It enables one's comprehension of electrochemical properties of materials, which includes the identification of anodic and cathodic reactions, corrosion rates and assessment of their passivation characteristics.
- **Electrochemical Impedance Spectroscopy (EIS):** EIS is the technique used for determining the value of impedance of a solid or composite material when an AC signal is applied to it. EIS gives information about kinetic aspects of the corrosion process as well as the efficacy of protective coatings. EIS has the additional advantage of helping to monitor corrosion of interest on real materials, which can help detect the onset of any material's degradation before it is advanced.
- **Open Circuit Potential (OCP):** OCP gives the value of potential of a specific metal with respect to a reference electrode under static condition without any current being passed through the metal. OCP indicates how stable a metal will be in the particular surrounding with respect to corrosion.

5.2.2 Accelerated Corrosion Testing

Methods of accelerated testing predict the performance of structural materials, even under the conditions of severe stress, in much less time than their actual behaviour is characterized. Typical methods are as follows (Feng et al., 2021; LeBozec et al., 2008).

- **Salt Spray Testing:** This technique is employed in a dedicated chamber where materials are subjected to a fine, atomized spray of saltwater. The objective is to achieve similar climatic conditions as those found in marine and coastal areas. The corrosion mechanism and damage processes show how well the material can withstand corrosion due to salt water.
- **Cyclic Corrosion Testing:** This process enables the exposure of materials to wet and dry phases cyclically but uses higher or lower

temperatures to imitate the conditions of environmental exposure for weathering. This is good for testing the coatings and treatments performed in automotive and aerospace industries.

5.3 Innovative Coatings, Inhibitors, and Treatment Techniques for Corrosion Protection

Corrosion prevention strategies have evolved significantly over the years, with the development of innovative coatings, inhibitors, and treatment techniques that extend the service life of materials in harsh environments.

5.3.1 Coating

Protective coatings are placed between material and the environment and protect the material from penetrating moisture, oxygen, and other corrosive substances. Many kinds of coverings have been modified for their appropriate purpose and use (Fotovvati et al., 2019; Giurlani et al., 2020; Nazari et al., 2022; Presuel-Moreno et al., 2008).

- **Metallic Coatings:** Metallic coatings, such as galvanisation (zinc coating) and aluminization, are commonly applied to protect steel structures. Zinc coatings are sacrificial in nature, with the zinc losing iron itself preferentially and thus protecting the steel underneath. These coatings have wide applications in the construction industry, automobile industry as well as marine industries.
- **Polymeric Coatings:** Polymers coatings such as epoxies, polyurethanes and fluoropolymer, are used for coating as they provide an impermeable, long-lasting coating to prevent corrosion. These kinds of coatings are provided where chemicals and moisture are excess like chemical plants and offshore platforms.
- **Nanocomposite Coatings:** Nanocomposite coatings are newly introduced due to nanotechnology. Nanocomposite coatings include polymer matrix with nanoparticles (e.g. ZnO, TiO₂) which are used in polymer coatings to strengthen, offer UV protection and protect against corrosion. These coatings possess high performance even in highly difficult atmospheric conditions like those experienced in aerospace and energy sectors.

5.3.2 Corrosion Inhibitors

Corrosion inhibiting compounds are defined as those which can decrease the corrosion rate on metals or coatings when placed in a corrosive medium by reacting with it to form a layer on its surface or by inhibiting the electrochemical reactions taking place. They are categorized into several types (Fateh et al., 2020; Kadhim et al., 2021; Raja et al., 2016):

- **Anodic Inhibitors:** These inhibitors enhance the formation of a passive oxide film on the surface of the metal thereby depressing anodic dissolution of the metal. For instance, chromates and phosphates.
- **Cathodic Inhibitors:** Cathodic inhibitors are used to decrease the rate of reduction processes such as oxygen reduction on the metal surface. Organic compounds like amines and imidazolines are used extensively as cathodic inhibitors in upstream oil and gas treated pipelines.
- **Mixed Inhibitors:** Mixed inhibitors provide protection against corrosion by acting on anodic and cathodic sites. Extracts from plants from agro waste are now gaining popularity as safer substitutes for synthetic mixed inhibitors as they are low cost and efficient.

Over the past few decades, studies have begun to prove effective the use of non-harmful materials like natural plant-based products, known as green inhibitors. For example, orange peel and green banana locules herbal extracts have also been used successfully as green inhibitors in the mitigation of steel corrosion in acidic solutions.

5.3.3 Surface Treatments and Alloying

Surface treatments as well as alloying techniques may be performed for the purpose of improving or enhancing metals' resistance to corrosion (Critchlow & Brewis, 1996; Kumar et al., 2019).

- **Anodising:** Anodising is a method in which the thickness of natural oxide layer, found on metals like aluminum, is increased through an electrochemical process in order to enhance resistance to corrosion and protect from wear and tear. The process is primarily adopted in aircraft manufacturing and construction industries.
- **Passivation:** Corrosion resistant steel finishes, such as stainless steel, are treated by immersion with an aqueous oxidizing solution, for

example, nitric acid, to promote the development of a passive oxide layer that resists corrosion, a process known as passivation.

- **Alloy Development:** Introduction and widespread use of performance alloys e.g. stainless-steel mix - chromium, nickel, molybdenum and so called as HEAs properties and improvement of their corrosion resistance has been augmented. HEAs are especially distinguished with their resistance to corrosive, melting and abrasive elements, which makes them usable in quite a harsh surrounding.

6 Fayomi's Story and Contribution to Knowledge

Life has a way of purifying those who would dare surrender to its processes and life lessons. My story is one of endurance, faith, and an unrelenting pursuit of excellence against all odds. I grew up knowing the essence of hard work, resilience, and the power of vision. It was an unexpected turn in my academic journey, right after my National Youth Service in Abia State, which I was brought into the gates of Canaan Land by my fiancée, now my wife, seeking greener pastures. It was then that a notice of vacancy for cafeteria staff, cleaners, and stewards popped up. She proposed we apply, but I protested. I had a plan to secure a teaching job in a secondary school. I had never imagined that I would be doing any cleaning job. Against my unwillingness, she applied on behalf of us and made me go along with her to the interview. We were selected. I was given my first assignment: a cold room left for seven months, fully loaded with rotten fish and rotten tomatoes. It stunk to high heavens, and I wanted to procrastinate the task. But my fiancée, wiser than me, behind my back, had already told my boss that I wanted to escape. And so, I had no other choice but to dive into the deep right away. And that day, scrubbing the filth, I knew all too well: greatness usually begins with a pinch of humility.

A month later, I walked into an interview at Covenant University, and fate smiled on me. Unprepared and not properly dressed, I took a leap of faith. The interview panel, headed by late Professor C.A Loto and Prof AAA Atayero, saw prospects in me. I was employed as a Technologist in the Department of Mechanical Engineering-a position that stirred my interests in research and innovation. It wasn't a soft way up the road. My intention was to do innovative research and to publish research papers in reputable outlet, but all end up with discouraging words. Someone told me, "stay in your lane" as a Technologist, you are not meant to be a lecturer. I did a lot of readings and got inspired by one

book titled “How Faith Works” by Dr. Frederick K.C. Price. I vowed to myself - my background would not determine my future. A divine connection brought me to Tshwane University of Technology, South Africa, for my postgraduate studies in Metallurgical and Materials Engineering. The journey was not easy; it was characterized by financial struggles. There were nights when I had to sleep in the laboratory because I could not afford decent housing. At times, I could barely afford meals. Yet, through faith, discipline, and relentless determination, I pressed forward. I remained steadfast amidst scepticism by peers who doubted my ability to transit from a Technologist to a Lecturer. When the institutional policy seemed to be an obstacle, I prayed that God should divine the means and He did.

Today is a different story, as I celebrate this professorial height. Through dedication and God's grace, I have published over 600 peer-reviewed journal articles, supervised numerous research projects, and mentored the next generation of engineers and material scientists. My name has appeared among the Top 50 scholars in Africa, a testament to the belief that hard work, resilience, and faith can deny any circumstance. By the grace of God, I have been able to collaborate with different industries and universities across the world, along with multiple awards in academia. Continuing this journey, my research and contributions in the field of material science and engineering have been greatly instrumental in deciding on world-wide practices in this domain. Contributions on advanced material characterizations with special reference to thin film depositions and electrodeposition have gained prominence in those industrial segments dealing with high performance and corrosion resistance materials. In corrosion science, my research has provided sustainable solutions for mitigating corrosion in harsh environments, particularly in the oil and gas sector, through the investigation of green inhibitors and high-entropy alloys. Additionally, my studies in material sustainability for marine applications have led to innovations in corrosion-resistant coatings and eco-friendly composites, ensuring durability and longevity for marine structures. The journey is far from over, and my vision remains to propel research in materials engineering, bridge the gap between academia and industry, and contribute to sustainable industrial advancement around the world. My story simply reminds us that setbacks are just setups for comebacks, and yes, the sky is wide enough for all to fly.

Below are some of my life journey advances, and contributions in the field.



Figure 17: God's Faithfulness when the going was tough



Figure 18: Prof Fayomi's Early Research years.



Figure 19: Mentorship that sparked my growth



Figure 20: Mentoring others: Charge before laboratory sessions



Figure 21: My last academic visit to USA Ohio and Zhongshan Institute in China



Figure 22: Prof Fayomi and other researcher at Centre for Opto/Bio-Nano Measurement and Manufacturing, Zhongshan Institute of Changchun University of Science and Technology.

6.1 Advanced Materials Characterization

1. *O. S. I. Fayomi*, and A. P. I. Popoola (2012) conducted a study on the mechanical and corrosion behaviours of different samples of Zn Coated Mild Steel in 3.65% NaCl solution. The authors prepared a thin film of Zn on steel substrates using an electrodeposition technique with Zn particles to form a bath plating solution. They used Scanning Electron Microscope (SEM) and Atomic Force Microscope (AFM) to study the surface morphology, topography, and surface adherent properties of the coatings. X-ray Diffraction Pattern (XRD) and Energy Dispersive X-ray Diffraction Spectrometer (EDS) were used to observe the crystal particles present in the deposits. The authors investigated the microhardness of deposited plate, electrochemical behaviour, and corrosion properties of the deposits using Vickers microhardness and polarization measurements. The uniform deposits of Zn showed fine grains and good protection against corrosion, with 75% hardness value achieved. Overall, this study contributes to the development of effective techniques for protecting mild steel from corrosion, which can have significant implications for various industries that rely on this material (Popoola & Fayomi, 2012).

Table 3: Summary of Potentiodynamic polarization Tests for the Zinc coated Mild steel

Sample	i_{corr} (A)	I_{corr} (A/cm ²)	RP (Ω)	E_{corr} (V)	CR (mm/yr)
As-received	2.04×10^{-3}	7.04×10^{-2}	2.76×10^2	-1.536	41
Zn 1	1.89×10^{-4}	1.15×10^{-3}	2.97×10^2	-1.068	6.7×10^{-1}
Zn 2	6.73×10^{-5}	4.10×10^{-4}	3.15×10^2	-1.025	7.4×10^{-2}
Zn 3	2.71×10^{-6}	1.77×10^{-5}	4.56×10^2	-1.004	6.6×10^{-2}

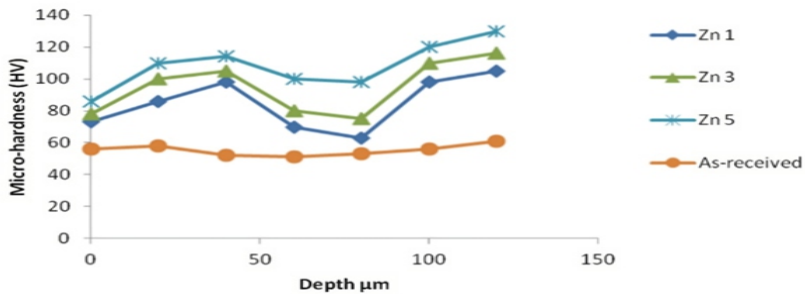


Figure 22: Microhardness plots of the samples

2. O. S. I. Fayomi, M. Abdulwahab, and A. P. I. Popoola, 2013 aimed to develop a multilayer-modified coating that enhances the surface characteristics of mild steel against chemical and mechanical deterioration using electrolytic chemical deposition. The authors employed a ternary Zn-Ni-Al₂O₃ composition induced with monoethylanine (MEA) and triethylanine (TEA) as surfactants. The microstructures, adhesion, and topography of the coating were characterized using X-ray diffractometry (XRD), scanning electron microscope equipped with electron dispersive spectroscopy (SEM-EDS), and atomic force microscopy (AFM), respectively. The microhardness and corrosion properties of the developed composites were also examined. The deposition of admixed Zn-Ni-Al₂O₃ ternary composite particles in the presence of bath-additive surfactant on to the substrate was significantly enhanced. The corrosion resistance of the coated surface was also improved. The addition of TEA and MEA as surfactants during the deposition process, along with the electro-deposition variables considered, led to an improvement in the structural modification and better interfacial adhesion of coatings on the substrate (Popoola & Fayomi, 2012).

Table 4: Formulated bath composition of Zn-Ni-Al₂O₃ induced with TEA/MEA surfactants

Sample Identification	Ternary/Additive Composition	Time of Deposition (min)	Potential (V)	Current (A)
Blank	-	-	-	-
Sample 1	Zn-Ni-Al ₂ O ₃ + TEA/MEA	10	0.5	2A
Sample 2	Zn-Ni-Al ₂ O ₃ + TEA/MEA	10	1.0	2A
Sample 3	Zn-Ni-Al ₂ O ₃ + TEA/MEA	15	0.5	2A
Sample 4	Zn-Ni-Al ₂ O ₃ + TEA/MEA	15	1.0	2A

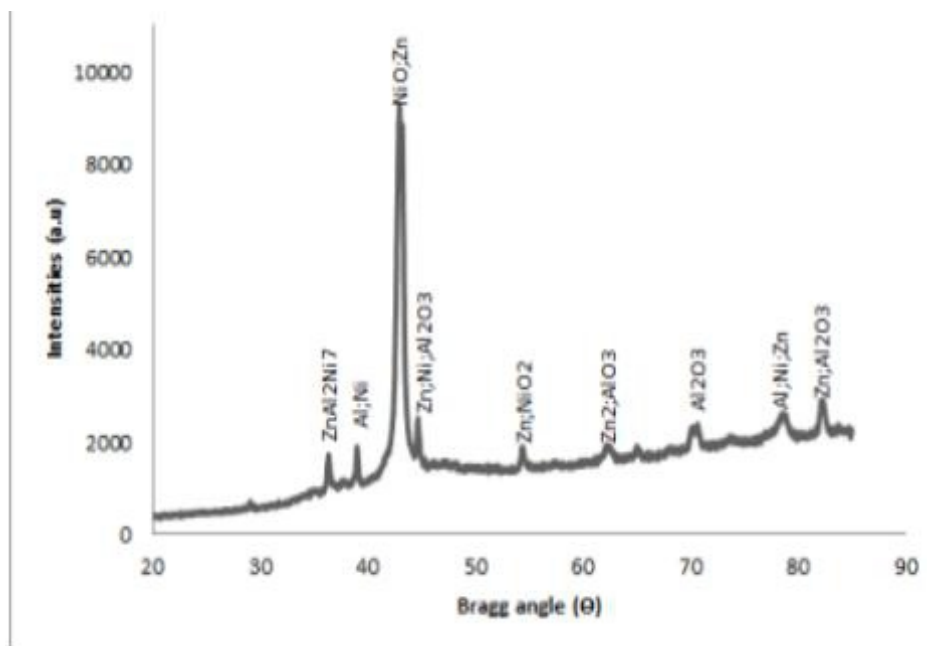


Figure 23: XRD for Zn-Ni-Al₂O₃+Tea/Mea at 0.5 V in 10 minutes plating time

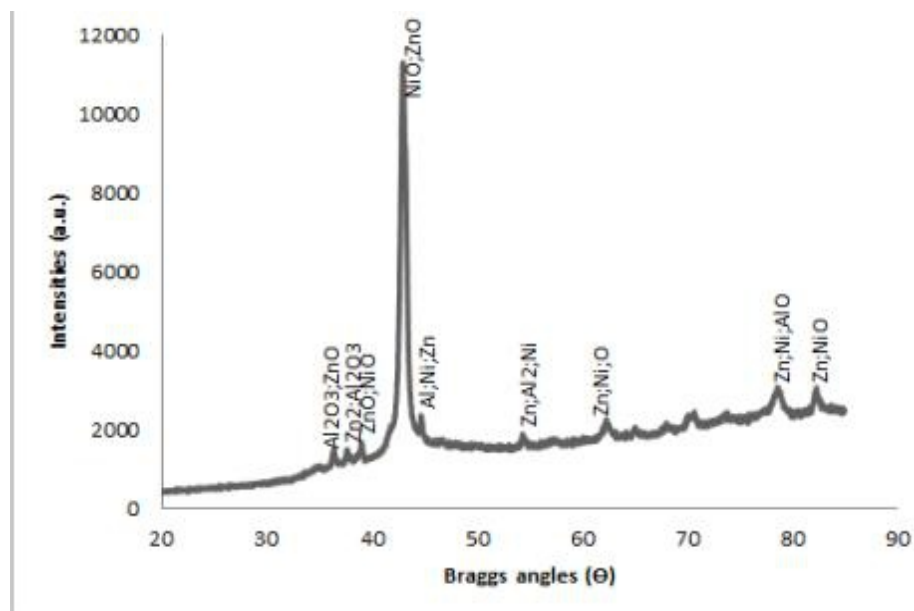


Figure 24: XRD for Zn-Ni-Al₂O₃+Tea/Mea at 1.0 V in 15 minutes plating time

3. **Fayomi, O. S. I., Akande, I. G., Abioye, O. P., & Fakehinde, O. B. (2019)** did a review of the latest developments in thin film deposition and its applications. Their study critically examined recent advances in thin film deposition, defining the terminologies used in the process. The authors reviewed and discussed various applications of thin films, including storage, electronic semiconductor devices, detectors and sensors, energy and optoelectronics applications, resistance to wear, corrosion and abrasion. Their contribution lies in highlighting the need for new materials for manufacturing applications in the material world, which has become a necessity. By examining the new trends in thin film deposition and its applications, the authors have provided a useful resource for researchers and professionals in the field. This paper serves as a mini review that provides a concise summary of the advancements in thin film deposition, making it a valuable reference material for those interested in the field. Overall, the contribution of the authors to the study of thin film deposition cannot be overemphasized, as their work has shed light on the importance of this technology in various applications (Fayomi et al., 2019).
4. **O. S. I Fayomi, O. P Abioye, A. J Musa, C. A Loto, and G. P Gaiya (2019)** conducted a study on the use of Zinc electrodeposition techniques to protect mild steel from corrosion. Mild steel is widely used in various industries due to its mechanical properties, but its susceptibility to corrosion is a major drawback. Through a systematic review of literature, the authors investigated the effects of deposition potential, current, bath composition (including temperature), deposition time, and concentration on the structure and crystallinity of the films deposited. Their research revealed that introducing zinc into the coating process significantly improves the mechanical and chemical characteristics of mild steel. Overall, their study contributes to the development of effective techniques for protecting mild steel from corrosion, which can have significant implications for various industries that rely on this material (Abioye et al., 2019).
5. **In their study, Udoeye, N.E.; Fayomi, O.S.I.; Inegbenebor, A.O.; Okolie, S.T.A.; Dirisu, J.O.; and Jen, T.C. (2022)** conducted research on samples of clay kaolinite that were pulverized to obtain 75 μm . The clay was blended with AA6061 in different compositions to produce four samples labeled A, B, C, and D, with clay percentages of 2%, 4%, 6%, and 8% respectively, and the

remaining percentage being made up of the aluminium alloy. Mechanical property analysis was carried out on each sample. Polarization tests were conducted in 0.75 M of H₂SO₄ on the composite, which revealed enhanced corrosion susceptibility. However, corrosion analysis of the clay inserted in AA6061 showed improved corrosion performance. The integration of clay in AA6061 aluminium alloys also caused changes in the microstructure, as observed through SEM, which minimized corrosion impacts (Udoeye et al., 2022).

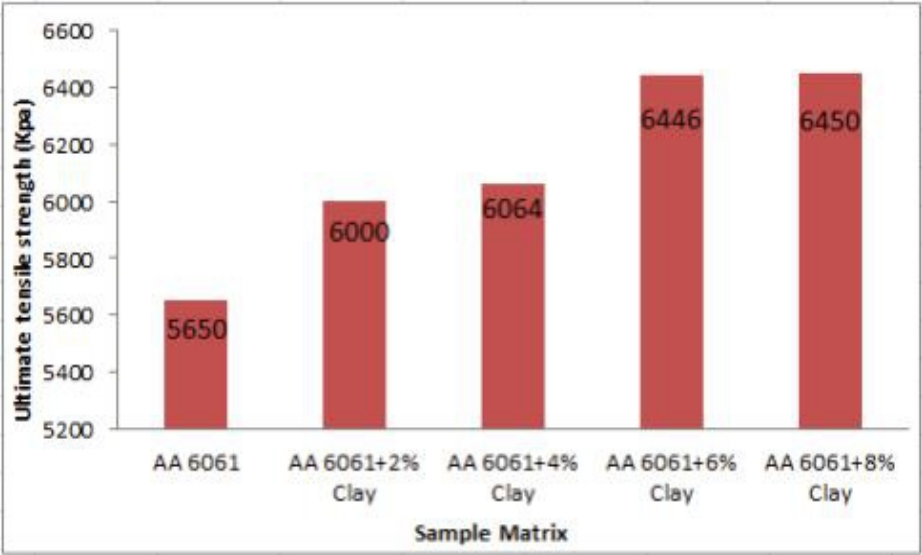


Figure 25: Effect of Clay particles on the Tensile strength of Aa6061

6. **Fayomi, O.S.I.; Samuel, A.U.; and Omotosho, O.A. (2022)** conducted research on high entropy alloys (HEAs) as potential materials for minimizing the problem of aluminum cookware leaching, pitting, wear, and cracking due to thermal stress. The researchers produced Cu-Al-Zn-Sn HEAs and compared their properties with that of the existing aluminum cookware material. They followed the ASTM G102 standard to investigate the corrosion rate (CR) of these materials in 3.65 wt.% NaCl using the potentiodynamic polarization technique. They examined the Vickers hardness (VH) of the materials using a nanoindenter following the ASTM A-370 standard. The researchers also used the CETR reciprocating sliding tribometer to investigate the wear rate (WR) in line with the ASTM G99 procedure. With the aid of a thermo-gravimetric analyzer, they examined

the maximum temperature of stability (MTS) of the materials. The microstructural analysis of the materials was conducted using scanning electron microscope (SEM) and X-ray diffractometer (XRD). For the existing aluminum cookware material sample, the CR, VH, WR, and MTS were 0.9327 mm year⁻¹, 56.25 mN mm⁻², $1.888 \times 10^{-5} \text{ mm}^3 \text{ N}^{-1} \text{ m}^{-1}$, and 610 °C, respectively. For the HEA samples, the CR, VH, WR, and MTS ranged from 0.1708-0.4080 mm/year, 159.99-398.18 mN mm⁻², 1.565×10^{-5} - $1.944 \times 10^{-5} \text{ mm}^3 \text{ N}^{-1} \text{ m}^{-1}$, and 680-690 °C, respectively. The microstructural examination of the HEA samples revealed the existence of better morphology, higher texture quality, and enhanced microstructural homogeneity compared to the aluminum (Al) sample. The dendrites observed on the HEA samples on the surface are indications that the samples exhibited superior mechanical properties and could be employed for advanced applications (Samuel et al., 2022).

7. **Fayomi, O.S.I.; Akpoborie, J.; Sanni, O.; Ren, J.; Wan Nik, W.B.; Oyebanji, J.A.; Oluwasegun, K.M.; Ojediran, J.O.; Zulkifli, F. (2022)** researched on the inhibition performance of citrus x aurantiifolia extract (CXA) on the corrosion of mild steel in 1.5M H₂SO₄, 2M H₂SO₄, 3M H₂SO₄, and 4 M H₂SO₄ solutions was evaluated by weight loss, potentiodynamic polarization techniques, and scanning electron spectroscopy equipped with energy-dispersive X-ray spectroscopy. CXA inhibited the mild steel corrosion in the sulphuric acid solutions with optimal inhibition results of 96.06% in 1.5 M H₂SO₄ and 86.57% in 4 M H₂SO₄ from weight loss measurement. Weight loss, potentiodynamic polarization, and scanning electron microscopy tests confirm the inhibitive performance of this compound and the increase in inhibitor efficiency increases with inhibitor concentration. The polarization data showed that the inhibitor acts as a mixed-type inhibitor and fits the Langmuir adsorption isotherm. The adsorption studies clarify the excellent adsorption of this compound on the mild steel surface. The inhibited steel in the acid solution displayed improved surface morphology due to the surface protection effect of CXA molecules. The citrus x aurantiifolia studied here easily mitigates the effect of stress corrosion cracking on mild steel in a sulphuric acid environment (O S I Fayomi et al., 2022).

6.2 Corrosion

1. **Joshua O. Atiba and Ojo S.I. Fayomi** investigated the corrosion inhibition

activity of expired Amoxicillin and Griseofulvin on corrosion of AA6063 in a 1 M HCl solution. Their investigation involved the application of potentiodynamic polarization and adsorption isotherms in determining inhibitive performance at four temperatures, which were 30°C, 40°C, 50°C, and 60°C at three concentrations each for the two inhibitors: 0.2 g, 0.4 g, and 0.6 g of Amoxicillin, and 0.2 ml, 0.4 ml, and 0.6 ml of Griseofulvin. The results indicated that both inhibitors were effective in reducing corrosion rates, with Griseofulvin exhibiting better performance at low concentrations. At 30°C, the corrosion rate decreased from 0.39649 mm/yr for the blank sample to 0.1643 mm/yr with 0.6 ml of Griseofulvin, while Amoxicillin decreased the corrosion rate from 0.60794 mm/yr to 0.37575 mm/yr at the same temperature and concentration. Adsorption of the inhibitor on the metal surface followed the Langmuir adsorption isotherm, which indicated physisorption. However, with an increase in temperature, efficiency decreases owing to thermal desorption effects. This study also pointed out the potential of expired drugs as inexpensive and environmentally friendly alternatives to traditional corrosion inhibitors for AA6063 aluminium alloy protection in aggressive acidic media.

Table 5: Tafel data summary of Amoxicillin Inhibited samples

Temp. (°C)	Sample	E_{corr} (V)	J_{corr} (A/cm ²)	CR (mm/yr)	PR (Ω)
30	Control	-0.68434	3.82E-05	0.60794	530.28
	0.2 g A	-0.65969	2.61E-05	0.41635	609.11
	0.4g A	-0.6479	2.49E-05	0.40545	613.33
	0.6g A	-0.627	2.40E-05	0.37575	638.42
40	Blank	-0.78864	4.26E-05	0.81939	291.28
	0.2 g A	-0.76399	3.05E-05	0.6278	370.11
	0.4g A	-0.7522	2.93E-05	0.6169	374.33
	0.6g A	-0.7313	2.84E-05	0.5872	399.42
50	Blank	-0.89294	4.7E-05	1.03084	52.28
	0.2 g A	-0.86829	3.49E-05	0.83925	131.11
	0.4g A	-0.8565	3.37E-05	0.82835	135.33
	0.6g A	-0.8356	3.28E-05	0.79865	160.42
60	Blank	-0.99724	5.14E-05	1.24229	291.28
	0.2 g A	-0.97259	3.93E-05	1.0507	370.11
	0.4g A	-0.9608	3.81E-05	1.0398	374.33
	0.6g A	-0.9399	3.72E-05	1.0101	399.42

2. **G Akande, O. S. I. Fayomi, and O.O. Oluwole (2022)** investigated the use of Zn-ZrB₂ nanocomposite coatings to protect SAE-1020 carbon steel from corrosion. The authors noted that although other coating materials have been explored, literature is scarce on the use of Zn-ZrB₂ despite its relative stability in saline environments. The authors designed the study to examine the mechanical properties and corrosion resistance of the coatings on carbon steel, with the aim of contributing to the development of effective techniques for protecting carbon steel surfaces in marine applications. The authors procured and characterized carbon steel and zinc bar and produced cathode and anode samples for the experiment. They evaluated the microstructures of the coatings using SEM, OPM, and XRD, and analysed data using ANOVA at $\alpha 0.05$. The authors found that the Zn-ZrB₂ nanocomposite coated samples exhibited better wear and corrosion resistance compared to the as-received steel, with the CR and WV indicating the passivating and high strengthening ability of the coatings tested. Overall, the study contributes to the understanding of the properties of Zn-ZrB₂ nanocomposite coatings and their potential as a protective coating for carbon steel surfaces in marine environments –(Akande et al., 2022).
3. **O. Sanni, O.S.I. Fayomi, and A.P.I. Popoola (2021)** aimed to identify cheap, effective, and green inhibitors from agricultural waste (coconut shell) as sustainable inhibitors for pure cast aluminium corrosion in 0.5 molar sulphuric acid medium at different concentrations. The inhibitive effect of coconut shell (CS) in 0.5 molar sulphuric acid solutions on aluminium was studied using a series of standard corrosion monitoring methods: gravimetric and electrochemical techniques. The nature of adsorption and aluminium surface morphology was conducted with scanning electron microscopy and energy-dispersive X-ray spectroscopy (SEM/EDX) method. The obtained result implies that the CS can serve as an environmentally friendly inhibitor for aluminium corrosion in 0.5 molar H₂SO₄ environments with the highest corrosion inhibition efficiency of 99% at 10 g. The inhibition mechanism was proposed to be physical adsorption and fits the Langmuir adsorption isotherms. The inhibitive effect of CS was proposed to be a mixed inhibition mechanism as shown by the potentiodynamic polarization method. The SEM and EDX observation show that the CS species formed a protective layer on the aluminium surface. The

results obtained confirmed that CS is a sustainable inhibitor, which could be used in the industry as an environmentally friendly corrosion inhibitor (Omotayo Sanni et al., 2021).

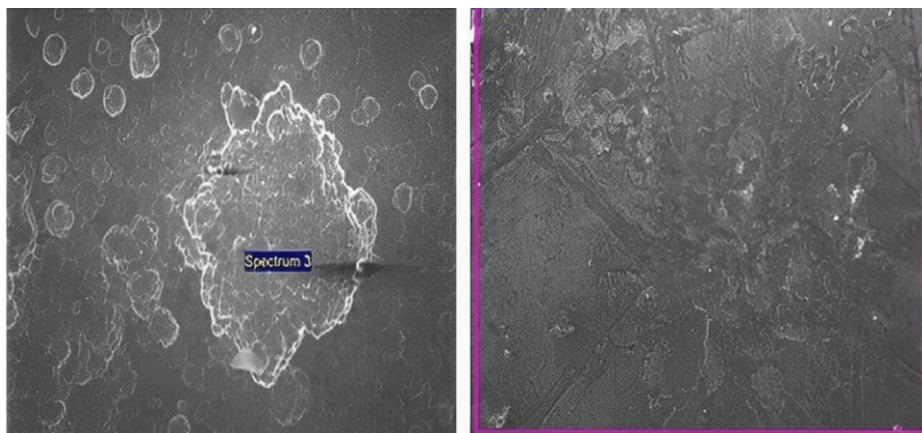


Figure 26: SEM images of the aluminum sample: (a) aluminium alloy after immersion in H₂SO₄ for 168 h, (b) aluminium alloy after immersion in H₂SO₄ containing 10 g CS for 168 h.

4. **Ayodeji, A.A., Fayomi O.S.I., Godwin, A.I., and Chinemerem, M.F.** (2021) evaluated the corrosion inhibitive performance of pawpaw fluid on A315 mild and 304 stainless steels in 0.5M H₂SO₄ (through weight loss approach). The investigation involved the effects of variation in the inhibitor concentrations (0 – 10 %vol/vol) on weight loss, corrosion rate, inhibitor efficiency and the morphological structure of the metal samples. The weight-loss method involved the subjection of metal samples to the corrosion process in the acidic medium for 21 days. The results of both weight loss and corrosion rates revealed that pawpaw fluid inhibitor with a concentration of 10 %vol/vol gave the highest inhibitor efficiency of 89.9% and 87.1% for A315 mild and A304 stainless steels respectively. Also, results obtained showed that Langmuir adsorption isotherm accurately described the behaviour of the adsorption mechanism and the physical adsorption (spontaneous) nature of the inhibitor was justified by the negative values of ΔG_{ads} . Chemical composition results and the SEM analysis revealed that stainless steel has better corrosion resistance performance in 0.5M H₂SO₄ medium compared to mild steel (under the same experimental condition) –(Ayodeji et al., 2021).

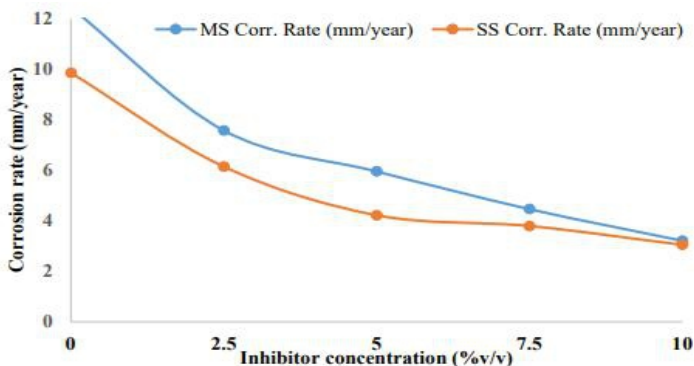


Figure 27: Corrosion Rate of the Mild Steel and Stainless Steel at varying Inhibitor Concentrations

5. **Fajobi, M.A., Fayomi, O.S.I., Akande, I.G., Odunlami, O.A., and Oluwole, O.O. (2021)** examined the corrosion inhibition potency of inhibitive Ibuprofen drug (IID) on aluminium 6063. The effect of the inhibitive drug was tested in 0.5 M of H_2SO_4 solution using potentiodynamic method. The concentration of IID was mixed to the acidic medium in 0, 5, 10, 15 and 20 ml respectively. The polarization experiment shows IID adsorbed on aluminium specimens. Increase in IID concentration decreases corrosion rate of aluminium specimens. Maximum inhibitive efficiency of 80.58 % and further studies on the inhibitory effect of the drug inhibitor revealed that Freundlich isotherm displayed a regression coefficient value of 0.7893 while Langmuir isotherm exhibits a regression coefficient value of 0.8864. These values of regression establish the reliability of IID as inhibitor, which shows that IID can be used as inhibitor corrosion of aluminium in aggressive environment such as marine and petrochemical industries where protection of aluminium is a necessity(Fajobi et al., 2021).

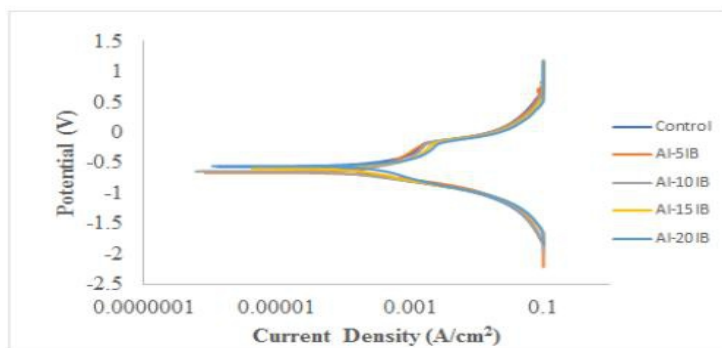


Figure 28: Curves of potentiodynamic polarization for Al in non IID and IID.

6. In this study, conducted by **Elewa, R.E.; Fayomi, O.S.I.; Afolalu, S.A.; Ademuyiwa, F.T. (2021)** the experimental investigation and simulated prediction of the selective material in 3.5 % NaCl condition were presented. The corrosion resistance properties were examined using the potentiodynamic polarization technique and COMSOL. The mathematical modeling and simulation analyzed when done with model geometry in a single electrolyte domain and predicted for 1, 6 and 12 months for a sample labeled A-E. The results show that sample C provide lower corrosion deformation among all sample under investigation with R_p of 234.24Ω , and CR of 0.51052 mm/y and corr value of -1.2837 (V) compared to sample A with higher corrosion rate of 2.9085 mm/yr and corr of -1.489 (V) (Elewa et al., 2021).

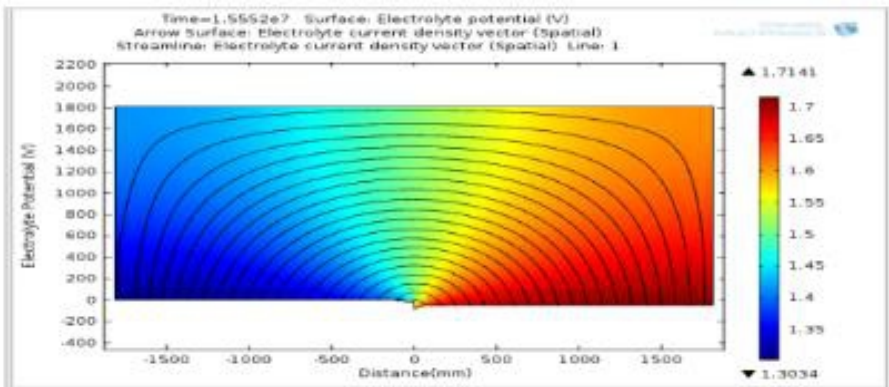


Figure 29: Deformation of Sample C after six months in NaCl (Sodium chloride) Electrolyte

6. **Ajide, O. O., Anifalaje, O. O., Akande, I. G., Musa, F. A., Fayomi, O. S. I., Oluwole, O. O., Oluwasegun, K. M., & Ajao, O. J. (2023)** conducted a study to examine the effect of post-weld heat treatment (PWHT) on the corrosion and microstructure properties of two mild steels, SAE 1015 and 1010, which were fused using electric metal arc welding. The authors noted that welded joints may exhibit poor corrosion resistance due to changes in the weld surface or heat-affected zone chemical composition, residual stress, and metallurgical structure. They aimed to enhance the corrosion resistance and microstructure properties of the welds through PWHT. The authors cut the mild steel samples to the desired dimensions, separately welded them, and subjected them to PWHT at varying temperatures (650, 750, 850, and 950 °C) for 1 hour. They then investigated the corrosion and microstructure properties of the PWHT mild steel samples immersed in 3.5 wt.% NaCl, using potentiodynamic polarization (PDP)

and scanning electron microscopy (SEM), respectively. The results showed that the PWHT SAE 1015 and 1010 mild steel samples exhibited the lowest corrosion rate (CR) values at 650 °C, while the highest CR values were observed at 950 °C. The SEM images revealed that the PWHT mild steel samples at 650 °C had smaller grain sizes and boundaries and less porosity than those at 950 °C. Based on their findings, the authors recommended the use of PWHT at 650 °C for advanced industrial applications(Ajide et al., 2023).

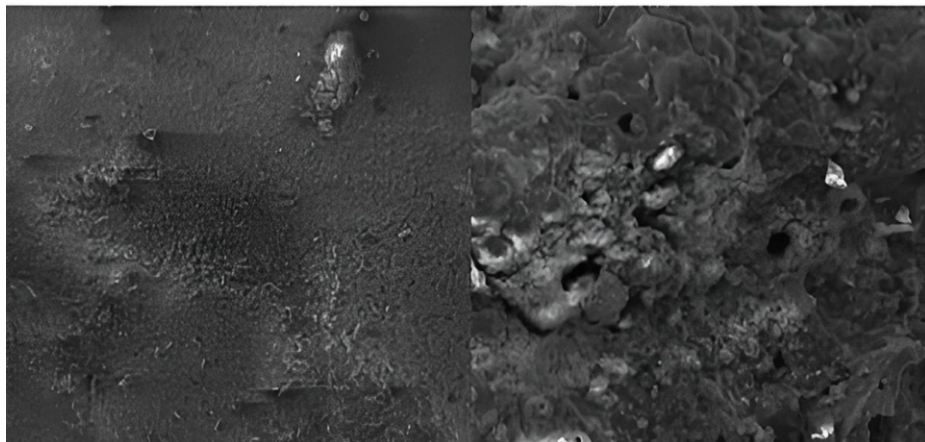


Figure 30: SEM images of PWHT SAE 1015 MS sample, at 650 and 950 °C.

7. Sanni, O, Popoola, A. P. I., & Fayomi, O. S. I. (2018). conducted a study on the effect of egg shell powder as a corrosion inhibitor on N08904 austenitic stainless steel in simulated saline solution. They employed various experimental techniques such as potentiodynamic polarization, weight loss, and SEM/EDX to evaluate the inhibitive tendency of egg shell powder. Their research showed that egg shell powder can effectively inhibit the corrosion of stainless steel, with inhibition efficiencies ranging from 57% to 100% at inhibitor concentrations of 2 g to 10 g. The results demonstrated that the corrosion rate decreased progressively with increasing inhibitor concentration due to anions adsorption at the interface of the metal film. The authors identified the compounds in the egg shell powder that completely adsorbed onto the surface of stainless steel through EDX analysis, and the adsorption followed Langmuir adsorption isotherm. The SEM images showed that the presence of egg shell powder prevented the formation of pits on the surface of stainless steel, indicating its potential as an environmentally friendly corrosion inhibitor (O Sanni et al., 2018).

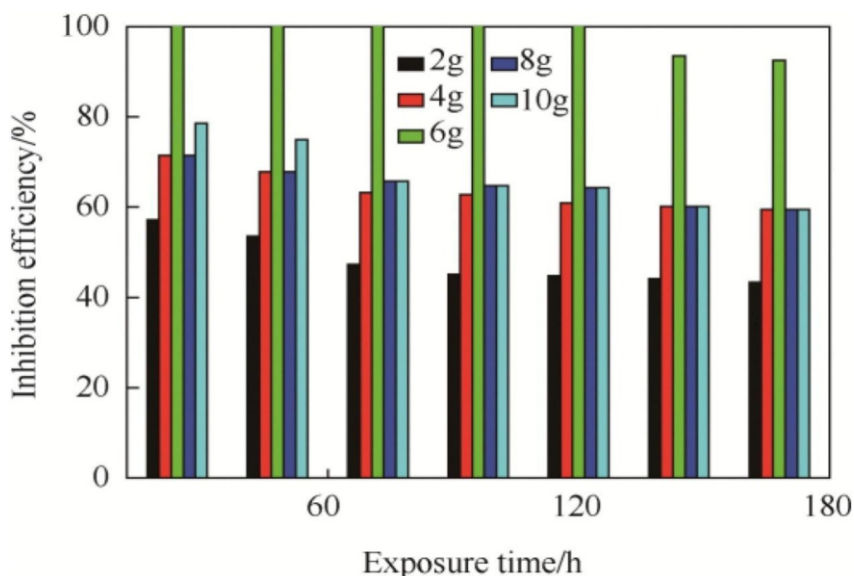


Figure 31: Inhibition efficiency (%) variation of stainless steel in the presence of ES in 3.5% NaCl solution.

6.3 Marine Industry

1. In this review article, **O. S. I Fayomi, O. Agboola, K. W Kupolati, A. O Ayeni, A. Ayodeji, J. J Akinmolayemi, O. Olagoke, R. Sadiku and K. M Oluwasegun (2022)** discussed the issue of corrosion in reinforced concrete structures in marine environments. The authors highlighted the need for a cost-effective system to protect reinforcing steel in concrete from corrosion, as the demand for reliable and durable structures in the marine industry increased. The review covered various studies on corrosion-induced by carbonation and chloride in marine milieus and the extension of service life in concrete structures. The authors discussed the use of corrosion-inhibiting admixtures as a potential solution for combating corrosion in reinforced steel in concrete structures. The review classified inhibitors based on the method of application and reported on corrosion-inhibiting admixtures used in new construction, repairs, and maintenance in the marine industry. The authors also highlighted the growing interest in the implementation of functional materials, such as nanostructured materials, in inhibiting admixtures in concrete. The significance of corrosion inhibitors employed as admixtures in concrete for practical applications in the marine industry was the suppression or mitigation of the corrosion process of metals used in the industry and the patches of already constructed structures.

The authors discussed the current problems related to corrosion-inhibiting admixtures in concrete and suggested future research and development directions(Agboola et al., 2022).

2. The research study titled “Corrosion Resistance of AA6063-Type Al-Mg-Si Alloy by Silicon Carbide in Sodium Chloride Solution for Marine Application.” by **Ojo Sunday Isaac Fayomi, Malik Abdulwahab, Abimbola Patricia Idowu Popoola, and Ferdinand Asuke**. Corrosion inhibition of AA6063 type Al-Mg-Si alloy in sodium chloride solution with the use of silicon carbide inhibitor is undertaken for marine applications by means of a potentiodynamic electrochemical method. Scanning electron microscopy (SEM) with energy dispersive spectroscopy (EDS) is used in this study to characterize the surface morphology of both the as-received and the as-corroded (uninhibited) aluminum alloy. Results from linear polarization analysis revealed a very high corrosion potential for the as-received unprotected alloy. With 10.0 g/v addition of silicon carbide, inhibition efficiency calculated to be 98.82%, increased polarization resistance significantly while decreasing the current density significantly with inhibition as opposed to un-inhibited aluminum alloy. Langmuir adsorption isotherm fitted the adsorption mechanism of the silicon carbide inhibitor; this means the addition of such inhibitors can substantially reduce the corrosion rate of the AA6063 alloy in a NaCl environment (**Ojo Sunday Isaac Fayomi et al., 2015**).

Table 6: Electrochemical corrosion data for AA6063-type Al-Mg-Si alloy in a static SiC/3.5% NaCl solution with and without silicon carbide addition obtained from polarization technique at 25 °C

C (g·v ⁻¹)	I _{corr} (A·cm ⁻²)	b _a (V·dec ⁻¹)	b _c (V·dec ⁻¹)	LPR/Rp (Ω·cm ²)	-E _{corr} (V)	CR (mm·yr ⁻¹)
0.0	9.75E-06	0.11851	0.11631	1541.6	1.3520	0.027178
2.0	1.72E-07	0.06170	0.05931	39431	0.7253	0.000480
5.0	4.48E-06	0.05028	0.05132	2052.7	1.3158	0.012479
10.0	1.15E-07	0.03836	0.02415	56051	0.9344	0.000320

3. **Joshua O. Atiba and Ojo S.I. Fayomi** discovered that this treatment successfully enhanced the corrosion resistance with significant synergistic influence between plantain peel and snail shell particle nanoparticles within the Zn-MgO matrix for mild steel coatings suitable for applications within marine environments. The ZnO-MgO-20SSP-20PP coating exhibited superior electrical characteristics, reduced thickness, high-quality films, and increased hardness of

78 HRB that are all very important when considering the withstanding of the harsh marine environment. The corrosion tests showed an amazing reduction in the corrosion rate by about 70%, proving that the coating can prevent material degradation in chloride-rich conditions, as is common with seawater exposure. Optical micrographs confirmed the coating's ability to reduce surface damage, which is important for the protection of marine structures, ship hulls, and offshore platforms from long-term deterioration. It also presents a reliable predictive model through ANOVA, showing the interaction of SSP and PP concentrations to affect corrosion resistance-a sustainable, optimized approach in the development of eco-friendly corrosion protection systems for marine applications——(Atiba & Fayomi, 2024).

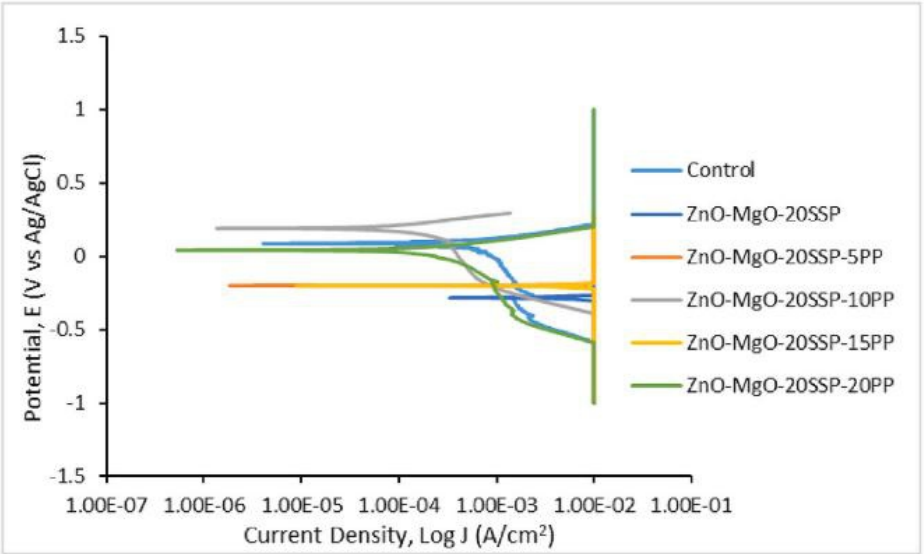


Figure 32: LSV plot of ZnO-MgO-20SSP-PP samples.

4. Ojo S.I. Fayomi and Joshua O. Atiba researched the addition of pepper waste as reinforcement in AA6063 aluminum composites for morphological, mechanical, electrochemical, and optoelectric properties. It was obtained that the reinforcements provided significant improvements in the performances of the materials; hence, pepper wastes could serve as an eco-friendly reinforcement for marine applications. In this context, the test result showed that the 25% pepper-reinforced sample had a maximum hardness of 37 HRB, with an increase in the value by 31.7%, as compared to the unreinforced control

sample. The corrosion resistance was also significantly improved, as revealed by the decrease in corrosion potential to -0.59 V and the decrease in corrosion rate to 7.69 mm/yr, which translates into good durability in corrosive environments. Optoelectrical testing further showed that higher pepper content increased conductivity, with the 25% reinforcement achieving a conductivity of $0.1979 (\Omega\text{m})^{-1}$, making the composite suitable for applications requiring improved electrical properties. Morphological analyses (SEM and XRD) confirmed a uniform distribution of pepper particles and the presence of multiple reinforcing phases that contributed to the material's enhanced properties (Fayomi & Atiba, 2024).

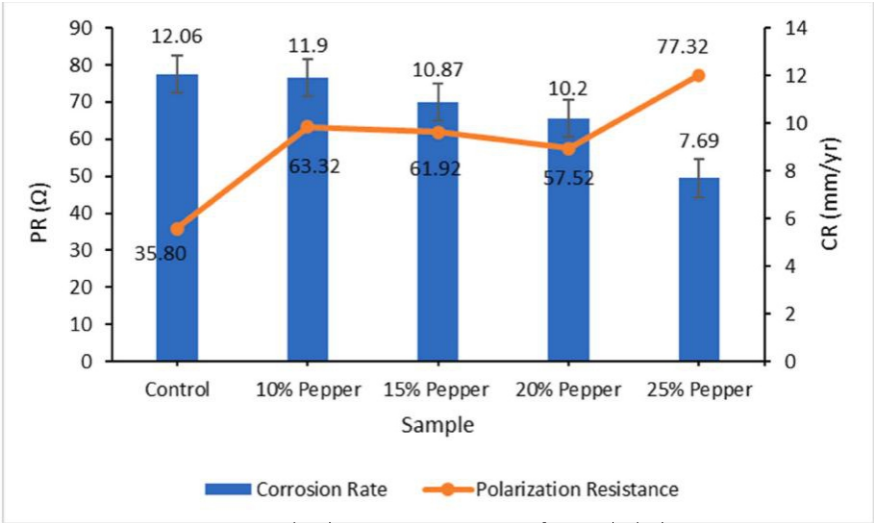


Figure 33: Corrosion Rate and Polarisation resistance of corroded Al-pepper composites.

5. Oluwamayomikun D. Akinfenwa, Ojo S. I. Fayomi, Joshua O. Atiba, and Benjamin E. Anyaegbuna studied the performance of Zn-ZnO-Starch coatings for corrosion protection in marine environments. In these studies, the Zn-ZnO coating was electroplated onto the mild steel substrate from a sulfate bath electrolyte with starch additions from 0 to 5 g to adjust the properties of the coating. The corrosion resistance was investigated by the potentiodynamic polarization test; it was shown that the corrosion rate of Zn-ZnO control was as high as 14.311 mm/year, while the starch addition significantly enhanced corrosion resistance and reduced the corrosion rate in the range of 7.8024 to 11.006 mm/year. According to SEM/EDS, starch granules distributed homogeneously with higher concentration-especially at 4.5 g-means enhancement in structural integrity. XRD analysis confirms the presence of FeO

and FeO₂ crystallites and hence stable phase transitions. Therefore, the experimental results obtained hereby prove that the Zn-ZnO-Starch coating can really enhance the durability in marine media and might constitute one of the promising systems for corrosion protection in harsh saltwater conditions.

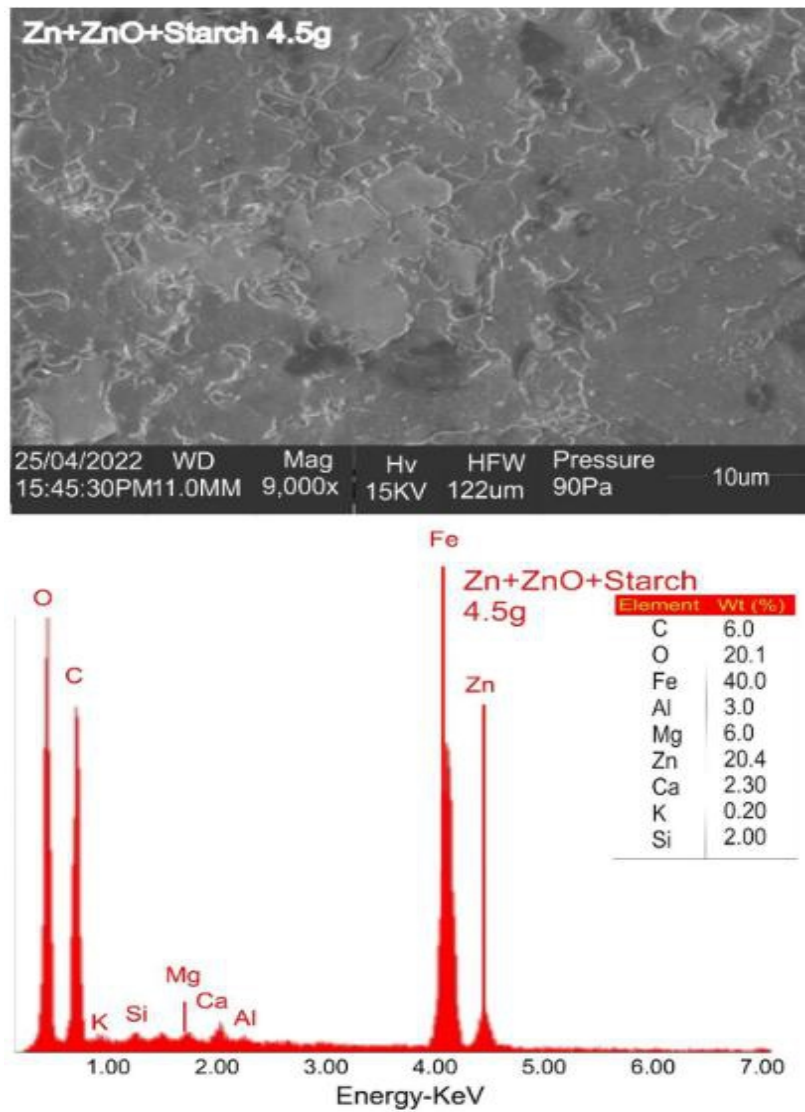


Figure 34: SEM/EDS Images of Zn-10ZnO-4.5 g Starch Coated Steel

6. **A.P.I. Popoola, V.S. Aigbodion, and O.S.I. Fayomi** conducted a study on the corrosion and wear resistance of mild steel reinforced with Yttria by applying an electroplating process in a marine environment. The Zinc-Yttria bath formulation was prepared under controlled temperature and pH conditions for coating the mild steel samples. The corrosion and wear behaviors were studied using an electrochemical potentiostat and an abrasive test rig, respectively, while the microstructural analysis was done using the standard characterization techniques. Fine-grained deposits were obtained on the surface of mild steel from the deposited sample at 10% Yttria concentration, hence enhancing the properties of the material. The test results indicated an improvement in corrosion resistance in a sodium chloride solution and an improved wear resistance with the addition of Yttria particles. Micro-hardness measurements also pointed out an increase in hardness values of both the pre- and post-heat-treated conditions. In this, work electrodeposition of Yttria upon mild steel developed as a highly encouraging way towards enhancement of substrate durability, especially by making them apt for serving under corrosive-aesthetic environments.

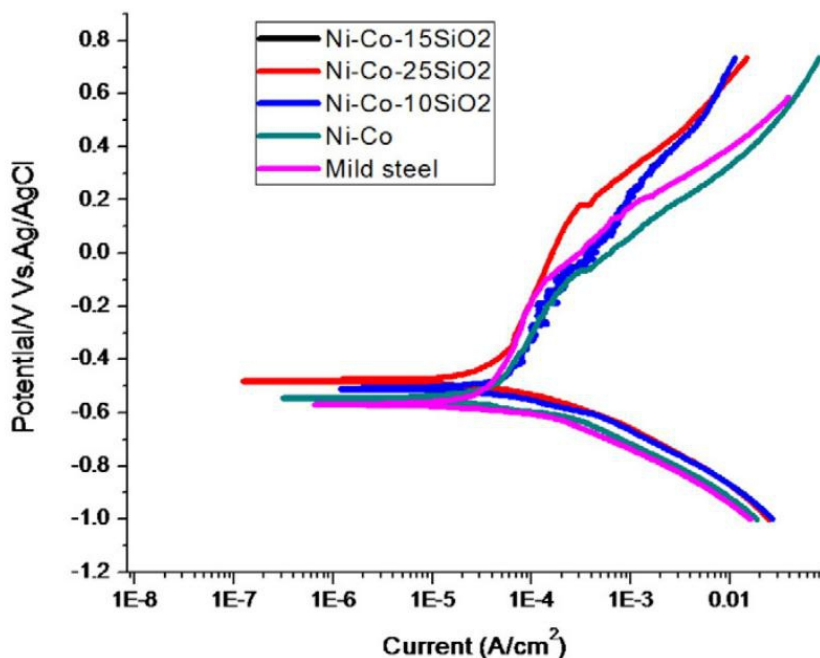


Figure 35: Potentiodynamic linear polarization curves of the Zinc-Yttria samples.

7. O.S.I. Fayomi, A.P.I. Popoola, L.R. Kanyane, T. Monyai studied the influence of *Solanum tuberosum* (ST) as an additive to Zn-TiO₂/Zn-TiB₂ sulphate bath coating on mild steel for marine application. It was noticed that the Zn-TiO₂/Zn-TiB₂ coatings displayed a needle-like pattern, but the addition of ST resulted in a more compact and distinctive structure. The addition of TiO₂ and TiB₂ significantly increased the microhardness of the coatings, while further enhancement caused by the addition of ST changed the morphologies of the composite coatings. Compared with the control sample, there was a marked reduction in the corrosion rate of all coatings attributed to the dispersed strengthening effect from the embedded additive of TiO₂/TiB₂/ST. Besides, the wear rate of the coatings reduced remarkably, which evidences an increase in wear resistance. The thermal stability of the coatings was examined at 600°C, and further characterizations by a high-tech optical microscope confirmed that the coatings were durable under high-temperature conditions. Generally, this work proved that the addition of ST, along with TiO₂ and TiB₂, remarkably enhanced structural, mechanical, and anti-corrosion properties of the coatings for advanced engineering applications.

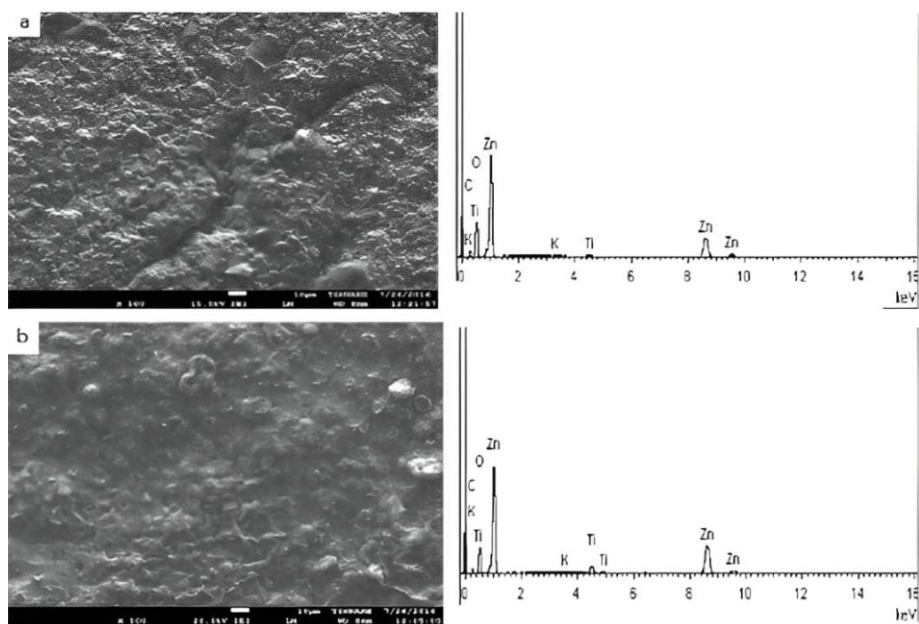


Figure 36: SEM/EDS micrographs of a) Zn-TiB₂ b) Zn-TiB₂-Solanum.

7 Conclusion

Mr. Vice-Chancellor, Sir, from the creation of man from clay to the modern advancements in the field of material science shaping the industries of today, the journey of man and materials has been inseparable. The ability to develop and exploit materials has underpinned technological and economic advances. Nigeria is well endowed with natural resources, but the country has not been able to develop its full potential because of policy inconsistencies, inadequate funding for research, and overdependence on raw material exports. Lack of a materials industry has retarded industrialization, thereby making Nigeria dependent on imports and susceptible to economic instability. If the nation is to be guaranteed a certain future, then investment in research, infrastructure, and policies that encourage local content and innovation in materials development must be pursued. The development of corrosion-resistant alloys, smart coatings, and biodegradable composites represents great opportunities for key industries in construction, oil and gas, energy, and manufacturing. Collaboration between academia, industry, and government will drive innovation and economic growth. For Nigeria to rise to her full height, she must do so on the back of materials that God has given us. By harnessing these resources judiciously, we will be able to build a stronger, self-reliant, and globally competitive nation.

8 Recommendation

To guarantee sustainable development and technological advancement in the nation, materials science and engineering investment in this area should come first, for which infrastructure, industries, and national security are concerned. The government should encourage advanced materials development and R&D programs such as corrosion-resistant alloys, composites, and biodegradable polymers for improved durability and environmental sustainability. Increased funding for research institutions and universities would create a conducive environment for innovation and provide solutions that meet national needs. Efforts should be made to create stronger linkages between academic institutions, industries, and government agencies so that the gap between theoretical research and its practical utilization can be narrowed. Research centres on materials innovation can be established for knowledge transfer and commercialization purposes. This will lead to lesser dependence on imported materials while developing local industries. It should also spur corporate investment in materials research, including tax incentives and grants.

The country should also focus on policies that stress the use of local content for both manufacturing and infrastructural development: ensuring that, where possible, construction materials, transport, and energy are sourced and processed locally. The promotion of beneficiating raw materials such as bauxite, iron ore, and agro-waste for industrial applications will create jobs and improve economic resilience. Also, there should be an emphasis on sustainability by encouraging the development and use of at least eco-friendly material with minimal environmental impact and capable of high performance. Education and capacity building need to be strengthened to adequately prepare the future generation with expertise in materials science and engineering. Integration of curricula on specialized areas into secondary and tertiary institutions with vocational training will ensure a pipeline of professionals with expertise in driving innovation in the sector. Scholarships and research grants supported by government should be expanded to encourage postgraduate studies and specialized training in this field. It is important to establish national standards and regulatory frameworks for the development, testing, and certification of materials. These will ensure quality control, safety, and reliability in material applications, especially within the construction, aviation, and defines industries. Strengthening regulatory bodies that enforce compliance to global best practices will enhance competitiveness and foster international collaborations.

The government should take a lead in the development of strategies for corrosion monitoring and prevention across the country. It will go a long way in bringing down the operational costs, increasing the life cycle of assets, and ensuring reliability in critical infrastructures related to industries like oil and gas, marine, transportation, and more. Promote public awareness for material selection and maintenance practices to ensure informed decisions at all levels. The country should therefore embrace the Fourth Industrial Revolution. In doing this, attention should be given to emerging technologies in additive manufacturing, nanotechnology, and smart coatings. Encourage research on nature-inspired materials and bio-based coatings that can create self-healing, adaptive high-performance materials with industrial applications. This can facilitate the country being among the forerunners in the industry of materials internationally through support given to innovations here. This calls for the eventual development of a national roadmap on materials science and engineering, in tune with the broader vision of economic and technological

development. The strategy must highlight priority areas, funding, and implementation structures that will be followed to guarantee sustained progress in the area concerned. With good policies and targeted investment, materials science can drive industrialization and economic growth for overall national development.

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Ojo Sunday Fayomi

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INAUGURAL LECTURE SERIES.

(June 25, 2015 - March 14, 2025)

1. The 1st Inaugural Lecture titled: "Food Product Development, Quality Assurance and Nutrition: Whither the Humane Senses?" by Professor Olugbenga A. Ben Ogunmoyela of the Department of Food Sciences and Technology. June 25, 2015.
2. The 2nd Inaugural Lecture titled: "Crisis in Forest Conservation in Nigeria: Threats to Livelihoods and Human Survival" by Professor Gbadebo Jonathan Osemeobo of the Department of Biological Sciences. January 13, 2016.
3. The 3rd Inaugural Lecture titled: "Minerals, Metals & Materials: The Hidden Wealth of A Nation" by Professor Gabriel Oladipo Oluwadare of the Department of Biomedical Engineering. May 18, 2016.
4. The 4th Inaugural Lecture titled: "Fungal Impact on Man: From Waste to Health" by Professor Olubukola Kuforiji of the Department of Biological Sciences. March 8, 2017.
5. The 5th Inaugural Lecture titled: "Chemistry is Reaction: Reaction is Chemistry" by Professor Violette Nkechi Atasie of the Department of Chemical and Food Sciences. March 7, 2018.
6. The 6th Inaugural Lecture titled: "Man and Materials: The indivisible Entities" by Professor Ojo Sunday Fayomi of the Department of Mechanical Engineering. March 14, 2025.

