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DISCOVERING THE MOST EFFECTIVE NEXT-GENERATION CARBON NANOMATERIAL PASSIVES AND INTERCONNECTS FOR BETTER FUEL EFFICIENCY, COMBUSTION PROCESSES, AND LOWERING EMISSIONS

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Abstract

In this study, diesel exhaust aerosol, lubricating oil, and lubricating fuel are used to look into the complex relationship between relative intensity and atomic mass unit (amu). One interesting thing that can be seen in the relative intensity versus amu plots for diesel exhaust aerosol is something called the "zig-zag phenomenon". The full-scan ESI mass spectra of acetylated monomers show changes in m/z values. The BC mass spectrum next to the ESI mass spectrum shows that the BC mass spectrum has higher m/z values, which means that it shows different parts of the polymer's structure. The study also suggests that carbon nanomaterial interconnects and passives may make lubricants more stable, which would allow for precise control over how the materials behave. The study shows that there is a clear link between spectra signal-to-noise ratios and particle mass-to-noise ratios. This shows that material performance and stability are linked and shows how important it is to come up with new materials and engineering solutions to problems with stability. Next-generation carbon nanomaterial passives and interconnects should be the focus of future research. This should include methods, material customization, stability improvement, testing in the real world, and collaboration between different fields. The search for carbon nanoparticles and constant innovation could lead to progress in technology, sustainability, and energy efficiency. This describes different levels of intensity, the zigzag effect, ESI mass spectra, carbon nanomaterials, aerosols, stability, mass-to-noise ratio, signal-to-noise ratio, new materials, electronic circuitry, sustainability, and technology.

Keywords: Carbon Nanomaterial, Aerosols, Transmission Electron Microscopy, Relative intensity, Atomic Mass Unit

I. INTRODUCTION

The ever-changing world of modern electronics has ushered in a new era of investigation into innovative materials and design paradigms thanks to the unrelenting pursuit of faster, smaller, and more energy-efficient gadgets. Carbon nanomaterials have emerged as frontrunners among these ground-breaking materials, and they are great candidates for transforming interconnect and passive component technologies [1]. Carbon nanomaterials, such as carbon nanotubes (CNTs), graphene, and its derivatives, display surprising and intriguing electrical, thermal, and mechanical properties. Because of this, how electronic circuits transmit, control, and optimize electrical impulses has to be rethought [2]. Research into carbon nanomaterials, their physics, and how to best utilize their features to solve nanoelectronics' looming scale and efficiency problems has increased dramatically in recent years. The Earth's atmosphere also includes many tiny particles (solid or liquid droplets) circulating in the air with basic gaseous components (N_2, O_2, Ar, CO_2), etc., are called atmospheric aerosols [3].

The composition and distribution of these aerosol particles, ranging in size from a few tens of a nanometre to a few tens of a micron, vary vertically and globally and significantly in time from the planet's surface to the stratosphere [4]. Aerosols play a significant role in the atmosphere by significantly influencing human health and urban visibility, changing the Earth's energy balance, and impacting the planet's temperature [5-8]. Small particles, either solid or liquid, suspended in the air are known as aerosols [9]. Aerosols are an essential part of the Earth's system, affecting not only the temperature and weather but also the air quality they breathe, the biogeochemical cycles, and the overall health [10-15]. There are many different types of aerosols in the atmosphere at any moment, and they come from both natural and anthropogenic sources. Natural sources include mineral dust, water spray, natural emissions, and volcanic eruptions, while anthropogenic include vehicle emissions, industrial processes, and biomass fires [16]. Because of the wide range of aerosols, it is difficult to predict their effects. Aerosols, for example, might affect the energy, precipitation, and hydrological cycle balance because they alter the microphysical properties of clouds. Pure aerosols are broken down into six categories: continental, continentally contaminated, dust, marine, smoke, and volcanic, as described in Table 1.

Table 1. Common terms for aerosol classification [17].

Aerosol type	Source	Particle characteristics
Continental	Land surface	Medium size, medium spherical, medium absorbing.
Dust	Desert surfaces	Karge, non-spherical, medium absorbing
Continental polluted	Industrial sites	Small, spherical, highly absorbing
Marine	Sea surface	Large, aspherical, non-absorbing
Smoke	Vegetation fires	Small, spherical, highly absorbing
Volcanic	Volcanoes	Large, non-spherical, highly absorbing

Researchers used ion and electron beam analytical techniques to learn more about the mechanisms that lead to aerosol generation. These techniques use chemical and physical concepts to better understand the complex processes that give rise to and alter these particles. Aerosols' chemical composition and size distribution can be better understood with the use of ion-based analytical methods like Mass Spectrometry (MS) and Ion Mobility Spectrometry (IMS) [18]. These techniques classify and quantify ions according to their mass-to-charge ratios. Ionization of aerosol samples allows researchers to learn more about the particles' chemical make-up and structure by observing the ions' responses to electric and magnetic fields.

In contrast, electron beam-based techniques, such as Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM), provide high-resolution images and data on the shape, size, and internal structure of individual aerosol particles [19]. Aerosol particle and aggregate features can be seen in exquisite detail by sending a focussed electron beam onto a sample, producing images with nanometre-scale resolution. Aerosol production processes can be understood in great detail thanks to the complementary use of ion and electron beam methods. For instance, electron imaging exposes how these molecules combine to create complex structures, whereas ionization techniques can determine the chemical building components of aerosols and identify their origins. The complex relationship between chemical processes, atmospheric conditions, and particle dynamics that underpin aerosol generation and development could be better understood with this all-encompassing method. The study's primary purpose is to:

- To find out about the diverse causes of aerosols and the processes by which they are produced.
- To enhance understanding of air quality, climatic impacts, and human health management.
- To Construct an Extensive Collection of Performance Metrics to evaluate the Appropriateness of Carbon Nanomaterials as Interconnects and Passives.
- To explore commercial-scale manufacturing methods for carbon nanomaterial-based interconnects and passives that maintain quality and performance.

This study aims to investigate the formation of atmospheric aerosol particles from various sources. The outline of this research is as follows: The second section includes a summary of related research. The third section explains the issue and its resolution. The fourth section, Material Methods explained, briefly summarizes the writers' work. In the fifth section, results are discussed, and the conclusions are given in the last section.

1. Carbon Nanomaterial regarding Aerosol

Carbon nanoparticles, intriguing and versatile, offer new research and development opportunities in aerosol science. Due to their remarkable physical, chemical, and mechanical capabilities, carbon nanotubes, graphene, fullerenes, and their derivatives are of tremendous interest in atmospheric aerosol particle research. Aerosol carbon nanoparticles can be natural or manufactured. Human activities like combustion, industrial emissions, and automobile exhaust affect carbon nanoparticle aerosols, whereas natural sources like wildfires, volcanic eruptions, and biogenic emissions affect them. It is crucial to research the genesis, transformation, and climatic effects of atmospheric carbon-based aerosols from several sources [20].

These unique physicochemical features affect carbon nanoparticles' atmospheric interactions. Their high surface area to volume ratio and intrinsic reactivity allows them to interact with other aerosol components, trace gases, and environmental conditions. Carbon nanoparticle condensation nuclei can affect cloud dynamics and local precipitation patterns. These nanoparticles can also transport toxins and catalysed atmospheric chemical processes. Research into carbon nanomaterial aerosols is vital due to their health and environmental hazards. Inhaled and deposited carbon nanoparticles may harm the respiratory system due to their small size, surface chemistry, and oxidative stress. Understanding the mechanisms by which carbon nanomaterial aerosols traverse, modified, and dispersed over extended distances is crucial for evaluating their implications for human health and the environment. [21].

In the author's study, investigating carbon nanomaterials in atmospheric aerosols are intriguing and varied. A better understanding of nanoscale carbon particles' sources, transformation, interactions, and effects would help us understand atmospheric processes and climate dynamics. As we learn more, these materials may be used to develop new aerosol-based technologies and long-term solutions.

2. Atmospheric Aerosols

Particles of solid or liquid suspended in the air are called aerosols or particulate matter (PM) [22-23]. Direct emission of solids or liquids produces primary aerosols. Various chemical and physical processes, including heterogeneous phase chemical reactions, partitioning on pre-existing particles, gas-phase particle conversion, and gas-phase oxidation, generate secondary aerosols in the atmosphere. Both natural and human-caused processes can produce primary and secondary aerosols [24]. Mineral particles (caused by the recovery of soil particles of dust, agricultural activities, and transport), volcanic particles (caused by the inhalation of gas and elements over a hot eruption and lava), and biogenic particles (produced by living organisms) are all examples of natural particles. Anthropogenic particles originate from human activity, such as smoke from chimneys and the release of industrial waste into the environment [25-26]. Figure 1 shows examples of components of aerosols. They can consider these elements as either water-soluble or water insoluble.

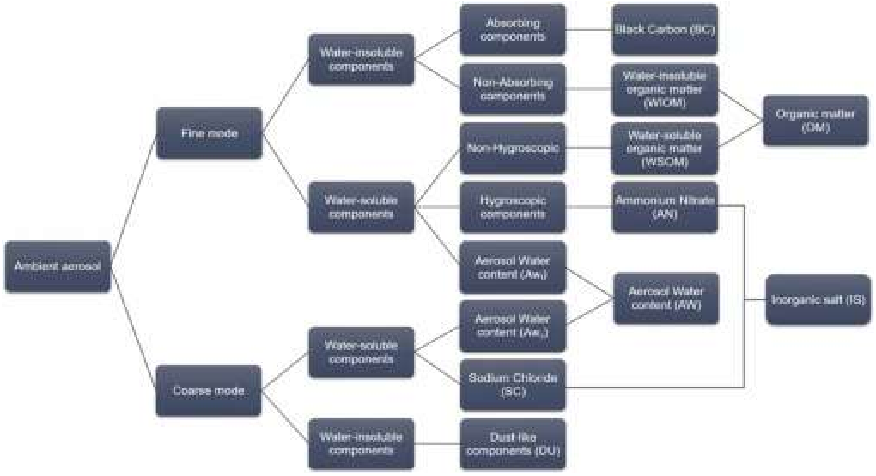

Figure 1. The classification of aerosol components [27].

3. Aerosol production mechanisms

Particles in the atmosphere come from various sources and undergo several transformations throughout their time here. The primary aerosols in the atmosphere come from disintegration, while the secondary aerosols are created when gases are converted to particles [28].

a) Primary Aerosols

Aerosols released directly into the atmosphere are called primary aerosols and can exist as solid or liquid. In the presence of wind, primary particles like dust and sea salt are dispersed throughout the air. Black carbon, or soot, from incomplete combustion, is another main particle.

b) Secondary Aerosols

Particles in the atmosphere form from in-situ aggregation or nucleation of molecules in the gas phase. Clouds arise atop particles, such as liquid water droplets or solid ice. There are two accepted mechanisms for transforming a gas into a particle: homogeneous nucleation and heterogeneous nucleation. New particles are created by homogeneous nucleation when precursor gases condense. As gas molecules condense onto pre-existing solid or liquid particles, a process known as heterogeneous nucleation occurs. Secondary aerosol production processes often contribute sulphate, nitrate, and ammonium aerosols, and these compounds do indeed exist as fine particles. Figure 2 indicates the Primary aerosol emission and subsequent aerosol generation.

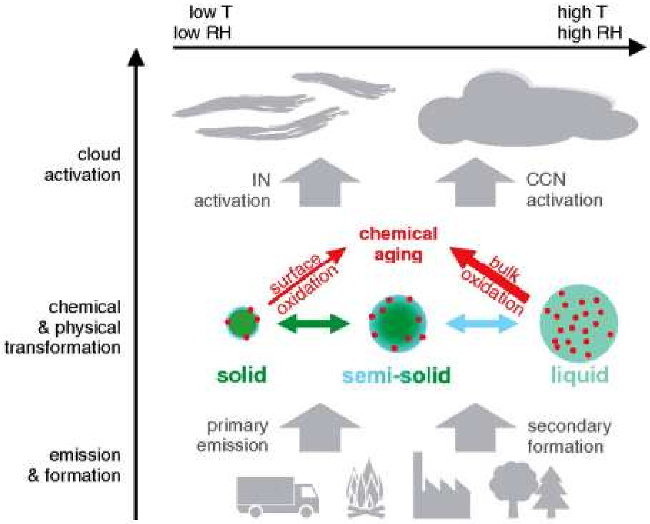

Figure 2. Primary aerosol emission and subsequent aerosol generation

II. LITERATURE OF REVIEW

This section provides an overview of the literature investigating the formation of atmospheric aerosol particles from various sources.

Nasonov et al. (2023) [29] presented findings from a data study covering 2010 through 2022. Both typical laboratory settings and the harsh environments typical of Siberian wildfires were used in the investigations. Briefly mentioned are the specifications of the lidars carried on the annual summer expeditions to Lake Baikal. The authors calculate the Angstrom parameter and the aerosol optical depth for different atmospheric conditions, finding values of = 1.57 0.16 and = 0.09 for the norm, = 1.41 0.07 and = 0.64 for the observation of smoke aerosol from distant wildfires, and = 1.05 0.08 and = 0.25 for observations of smoke aerosol from nearby fires, respectively.

Kumbhare et al., (2023) [30] examined zzMLGNR's metallic nature and hydrogen (H) and ruthenium (Ru) double-edge passivation. X-zzMLGNR-X (X = H or Ru atoms) transmission spectrum is investigated using pristine and intercalated doping materials such AsF5, Li, FeCl3, and MoCl5 between graphene layers. The number of conductive channels and Fermi velocity can be precisely extracted from the intercalated doped X-zzMLGNR-X structures thanks to their versatile arrangements. The parameters retrieved from X-zzMLGNR-X evaluate its performance for connection lengths from 2 to 12 μm. The improved arrangement models the first equivalent pi-type RLC network for pristine and intercalated doped X-zzMLGNR-X interconnects. The latency of Li-intercalated Ru-zzMLGNR-Ru is 47.03%, 54.75%, 75.63%, and 83.99% lower than FeCl3-, AsF5-, MoCl5-, and pristine-based on-chip interconnects.

Groma et al., (2022) [31] evaluated the health consequences of various sources of particulate matter pollution in an urban greenbelt region in a city with a conventional European urban pattern. Three of the six sources were associated with combustion processes, with secondary aerosols from traffic and primary emissions (15 nm mode particles) from vehicles. Particle deposition patterns from each indicated source were simulated in the human airways utilizing a Stochastic Lung Model. During the winter months of the study, 31% of the entire amount of submicron particles were attributed to traffic, making it the single most hazardous source of pollution.

Deepthi et al., (2022) [32] proposed that the output of quality of service must be improved for system reliability. The results of this paper show that it wisely addresses and limits this grave issue. The structure and efficiency of connections made from Multi-Layer Graphene Nanoribbons (MLGNRs) are first analysed, representing a promising technology for the future. The most common types of MLGNR are the basic and dielectric-inserted side contact varieties. For another, the well-known nano-MLGNR interconnects employ a ternary logic architecture made possible by Carbon Nanotube Field Effect Transistors (CNTFETs), which are efficient and distinctive. Thirdly, the quality of service (QoS) of promising DS-MLGNR lines is enhanced by active shielding. QoS is then enhanced by the receiver's adaptive Least Mean Square (LMS) equalization. The suggested study employing efficient ternary logic systems, graphene interconnects, and QoS improvement approaches is a fantastic response to nano-interconnects in cutting-edge ICs. Analysis of delay, power, power-delay product, crosstalk, and eye diagram are just a few examples of the creative and seminal methods used in this work, contributing to its originality and efficacy. Performance analysis was done in vivid detail at a technology node of 10 nm.

Li et al., (2021) [33] employed a variety of cutting-edge microscopic techniques to examine the phase-separation of Organic Matter (OM) and inorganic salts in single particles gathered from a variety of air conditions, as well as one kind of surrogate particle manufactured in the lab. The authors found that most particles collected in the continental airspace have an inorganic aerosol core coated with OM. This core is larger than 100 nm in equivalent sphere diameter. The findings demonstrate that organic coatings on inorganic particles of single particles (> 100 nm) are formed through phase separation and that the numerical abundances of these coatings vary depending on particle size and the degree of OM aging.

Gusain et al., (2020) [34] described the current state of carbon nanomaterials (CNMs), including key previous and recent developments and prospective methods for water treatment with carbon-based nano adsorbents. This study focuses on adsorption foundations, mechanical features, CNM synthesis and characteristics, and CNM and nanocomposite adsorption performance with inorganic and organic materials. Material adsorptiveness and separation efficiency improve with structural engineering and activation. Additionally, 2D and 3D macro-/micro-structures with large porosities can improve adsorption efficacy and increase commercial utilization of CNMs.

Salesa et al., (2020) [35] defined alginate-based materials are promising for skin wound healing and tissue engineering scaffolds. Mammalian cells adhere poorly to hydrophilic materials. Polycaprolactone, poly(hydroxy-3-butyrate-co-3-valerate), and gelatin all benefit from the addition of hydrophobic Carbon Nanofibers (CNFs) and hydrophilic Graphene Oxide (GO) to promote cell adhesion and proliferation. Adding carbon nanoparticles (CNMs) to alginate films enhances their mechanical properties, wettability, water diffusion, and antimicrobial properties. The first report shows CNMs' influence on cell adhesion when added to alginate films. This research shows that the human keratinocyte HaCaT cells are resistant to the cytotoxicity of these nanocomposites.

Kumar et al., (2017) [36] determined how much of an impact crosstalk has on coupled Multi-walled Carbon Nanotube (MWCNT) interconnects. The crosstalk model has been developed using the USFDTD method, which stands for unconditionally stable finite-difference time domain. We have calculated the crosstalk noise, in-phase delay, and out-of-place delay for connected interconnect lines. It has been found that MWCNT interconnects mitigate the crosstalk effect better than traditional copper interconnects. Traditional FDTD analysis, the HSPICE simulator, and feature selective validation have all been used to validate the proposed model's results. The proposed model uses 46% less CPU runtime than the standard FDTD method for transient analysis. Copper and MWCNT interconnects have also had their stress and electro-migration effects studied. MWCNT interconnects are proven to have a longer mean time to failure than copper interconnects.

Ladani et al., (2017) [37] proposed that high ampacity of Carbon Nanotubes (CNTs) and Carbon Nanofibers (CNFs) is a crucial feature for miniaturized next-generation interconnects. Even at current miniaturization levels, copper (Cu), the state-of-the-art material utilized in interconnects, has reliability difficulties. Cu atoms are being electromigrated due to the high current density. So, it was postulated that CNTs and CNF may stand in for Cu in cutting-edge microelectronics. It is tricky to use CNTs or CNFs as freestanding structures and to achieve the same features as a single CNT or CNF. This study uses Cu to densify self-aligned CNTs and CNFs to achieve mechanical stability and high density. Different Cu deposition methods, CNT underlayer effects, and CNT quality are just a few of the factors studied that affect the quality of the final Cu-CNT composite layer. Electroplating, electroless plating, and Physical Vapor Deposition (PVD) are also used as Cu deposition procedures on the as-grown CNTs. While electroless plating successfully coalesced CNFs with Cu, the investigations also revealed that CNFs are brittle and dissolve during the plating process.

Agrawal et al., (2016) [38] use the Finite-Difference Time-Domain (FDTD) method to examine the efficacy of the Current-Mode Signaling (CMS) scheme in a multiwall carbon nanotube (MWCNT) bundle on-chip interconnect based on carbon nanomaterials. Furthermore, this model can be used for delay-efficient CMS systems and the more common Voltage-Mode Signalling (VMS). It is shown through analysis that MWCNTs with a greater number of shells in a bundle connection outperform MWCNTs with fewer shells and copper interconnects. Analysis shows that the CMS scheme outperforms the VMS scheme due to its lower crosstalk-induced delay and shorter propagation delay. SPICE simulations verify the results of various assessments undertaken for the 32-nm technology node. The suggested FDTD-based model and

SPICE produce results that are very consistent with one another, with a maximum error of only 3%.

The authors' study approach and an overview of the relevant literature are presented in Table 2.

Table 2. Comparison analysis of Related work

Authors [Reference]	Techniques/Model Used	Outcomes
Nasonov et al., (2023) [29]	Lidars	The Angström parameter () and aerosol optical depth () were calculated to be = 1.57 0.16 and = 0.09 under background conditions, = 1.41 0.07 and = 0.64 for smoke aerosol from distant wildfires, and = 1.05 0.08 and = 0.25 for smoke aerosol from nearby wildfires, respectively.
Kumbhare et al., (2023) [30]	LMS	The latency of Li-intercalated Ru-zzMLGNR-Ru is 47.03%, 54.75%, 75.63%, and 83.99% lower than FeCl3-,AsF5-, MoCl5-, and pristine-based on-chip interconnects
Groma et al., (2022) [31]	Stochastic Lung Model	Particles smaller than 1 m in metropolitan areas have been traced back to traffic (30% of the total). Extreme human or recreational activity could not be safe in certain metropolitan areas due to the prevalence of automobile pollution.
Deepthi et al., (2022) [32]	LMS	The finding shows that the 10 nm technology node was used for the vivid performance evaluations.
Li et al., (2021) [33]	Nano SIMS	The findings demonstrate that organic coatings on inorganic particles of single particles (> 100 nm) are formed through phase separation and that the numerical abundances of these coatings vary depending on particle size and the degree of OM aging.
Gusain et al., (2020) [34]	coagulation	The result shows that 2D and 3D macro-/micro-structures with large porosities can improve adsorption

		efficacy and increase commercial utilization of CNMs.
Salesa et al., (2020) [35]	Raman spectroscopy and HR-TEM	Adding carbon nanoparticles (CNMs) to alginate films enhances their mechanical properties, wettability, water diffusion, and antimicrobial properties.
Kumar et al., (2017) [36]	USFDTD	The proposed model uses 46% less CPU runtime than the standard FDTD method for transient analysis.
Ladani et al., (2017) [37]	coagulation	The investigations revealed that CNFs are brittle and dissolve during the plating process.
Agrawal et al., (2016) [38]	SPICE simulations	The suggested FDTD-based model and SPICE produce results that are very consistent with one another, with a maximum error of only 3%.

III. BACKGROUND STUDY

This study created a technique for characterizing polymers on the market made from a combination of substituted cellulose and starch. Hydrolysis using targeted enzymes allowed us to separate the two polymers in the mixture. Starch was broken down using enzymes that break down 1-4 beta-D and 1-6 beta-D glycosidic bonds, whereas cellulose was broken down using enzymes that break down 1-4 beta-D glycosidic bonds. Size Exclusion Chromatography (SEC) was used to separate the hydrolysed fraction from the unhydrolyzed fraction and characterize it to verify that the various polymers' enzyme hydrolysis had occurred. The fractions' UGU content was calculated using High-Performance Anion-Exchange Chromatography (HPAEC). The substituents were identified via Electrospray Ionization Mass Spectrometry (ESIMS). All products were acid-hydrolysed to monomers for easier mass spectrum identification of the substituents. The monomers were acetylated with acetic acid anhydride to further identify the substituents. Results from the many analyses were combined to form a complete picture of the materials [39].

IV. PROBLEM FORMULATION

This study aims to understand how tiny particles called aerosols form in the air from different sources. These aerosols are important because they can affect the weather, air quality, and health. Despite knowing a lot about aerosols, authors still don't understand how they are made. They want to figure out how they are created from pollution, natural sources, and chemical reactions. By learning more about how aerosols form, authors can better protect the environment and people's health by managing air quality and dealing with climate change.

V. MATERIAL AND METHODS

1. Sample Collection and Preparation:

- Specify the study locations where aerosol samples were collected (industrial).
- Describe the sampling equipment, such as high-volume samplers, impactors, or diffusion chambers.
- Explain the duration and frequency of sampling campaigns and how they were designed to capture different source contributions.

the investigation of aerosol particle formation using ions and electron beams involves various materials and methods. One of the well-known methods is called the "CLOUD experiment" (Cosmics Leaving Outdoor Droplets), which takes place at CERN (the European Organization for Nuclear Research). This experiment focuses on understanding the role of cosmic rays in aerosol particle nucleation and growth in Earth's atmosphere. Here's an overview of the material and method used in the CLOUD experiment:

Material:

Gaseous Precursors: The CLOUD experiment uses a controlled environment where different gaseous precursors, such as sulfuric acid and ammonia, can be introduced. These precursors are representative of molecules found in the atmosphere and are known to play a role in aerosol formation.

Neutral Particles: Neutral particles are formed by the reaction of the gaseous precursors. These particles are initially very small and serve as the starting point for aerosol growth.

Cosmic Ray Simulators: In the CLOUD experiment, cosmic rays are simulated using particle beams, such as protons or alpha particles. These beams are used to ionize molecules in the controlled chamber, mimicking the ionization effects of cosmic rays in the atmosphere.

Method:

Controlled Chamber: The experiment takes place in a specially designed chamber that allows for precise control of temperature, pressure, humidity, and gaseous precursor concentrations. This controlled environment enables researchers to study aerosol formation under controlled conditions.

Ionization: Cosmic ray simulators, such as proton beams, are directed into the chamber. These high-energy particles ionize molecules in the chamber, leading to the production of ions and free electrons [40].

Nucleation and Growth: The ionization of gaseous precursors leads to the formation of ions and electrons, which can serve as centers for aerosol particle nucleation. Neutral particles formed by the reaction of gaseous precursors can cluster around these ions and electrons, gradually growing in size through condensation and coagulation processes.

Measurement Instruments: Various measurement instruments are used to monitor and characterize the aerosol particles formed during the experiment. These instruments include particle counters, mass spectrometers, and particle size analyzers. They provide information about particle size distribution, composition, and concentration.

Data Analysis: The data collected from the experiment are analyzed to understand the role of ionization in aerosol particle formation that will explain how different factors, such as precursor concentrations, temperature, and ionization rates, influence the nucleation and growth processes.

VI. EXPERIMENT AND RESULTS

In this section method of experimentation, as well as results obtained regarding the correlation between relative intensity and amu.

Relative intensity vs. amu

Relation between relative intensity and amu for diesel exhaust aerosol.

As the intensity increases, there is a brief drop in the amu value, followed by oscillations. This phenomenon is known as the zig-zag phenomenon, and it indicates that there is only moderate stability.

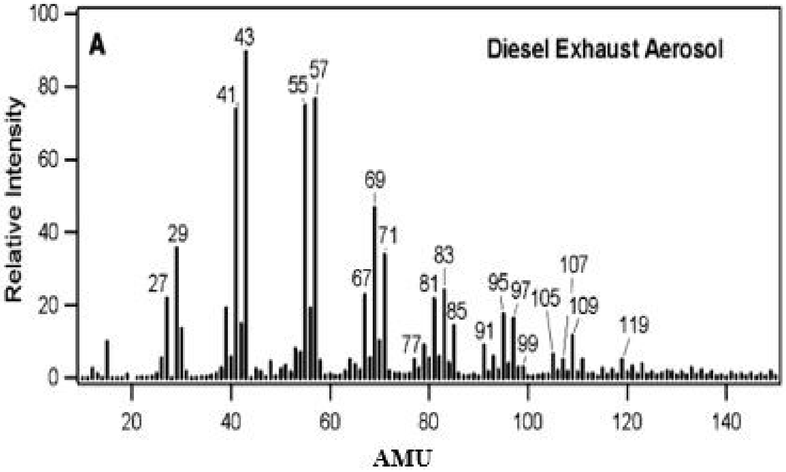

Figure 3 Relative intensity vs. amu for diesel exhaust aerosol

Relation between relative intensity and amu for lubricating oil.

The amu value drops as the relative intensity increases, and the output of the system only remains partially constant during this process.

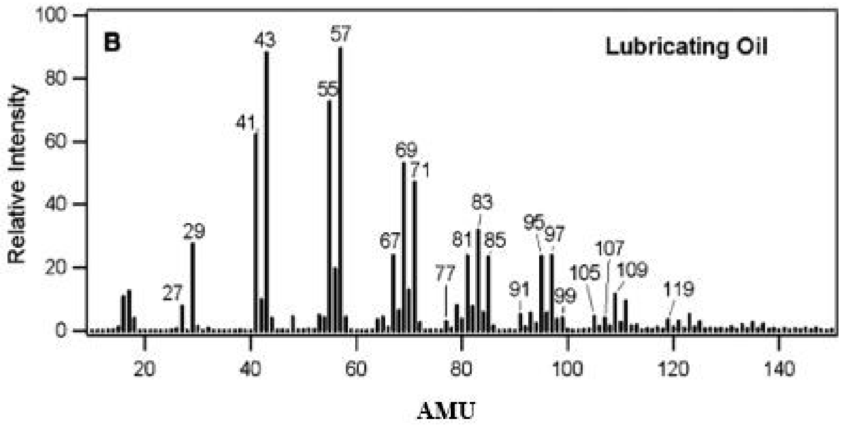

Figure 4 Relative intensity vs. amu for lubricating oil

Relation between relative intensity and amu for lubricating fuel.

The amu value reduces dramatically with increasing relative intensity, indicating that the system is in a condition of reasonable stability**.**

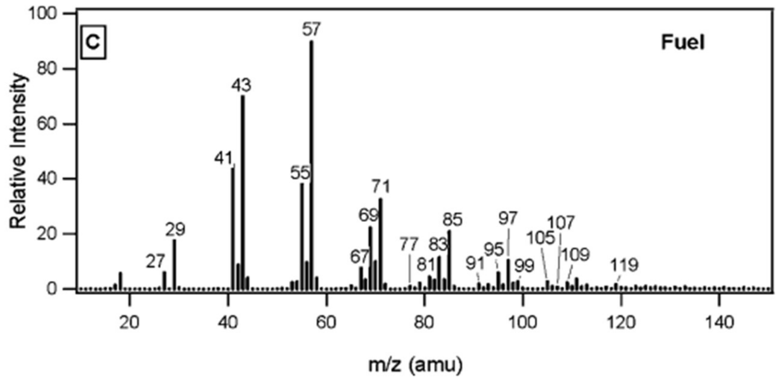

Figure 5 Relative intensity vs. amu for lubricating fuel

Relationship of Ratio signal and mass ratio.

A direct proportionality can be seen between the spectra' signal-to-noise ratio and the particles' mass-to-noise ratio.

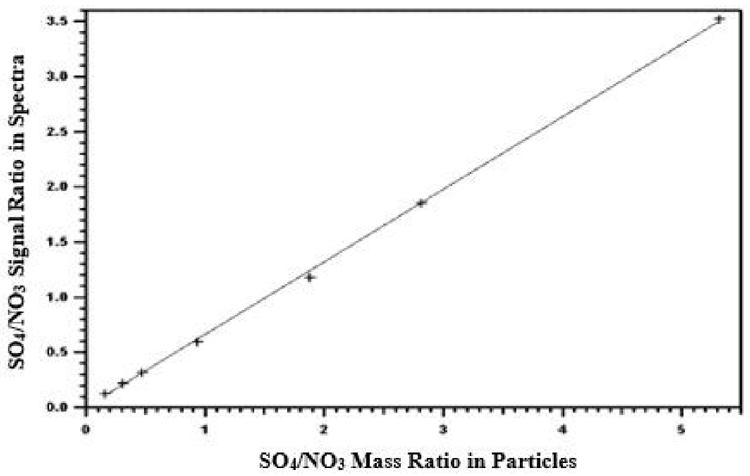

Figure 6 Ratio signal vs. mass ratio

ESI mass spectra of the BC fraction of monomer.

A Full-scan Electrospray Ionization Mass Spectrum (ESI) of the BC fraction at the monomer level is shown. Full scan spectra at the monomer level avoid some of the identification issues posed by overlapping m/z values from different DP/DS, so the products of enzyme hydrolysis were further hydrolyzed by acid into monomers to obtain more information about the composition of the polymers and to simplify examining the substituent distribution of the fractions.

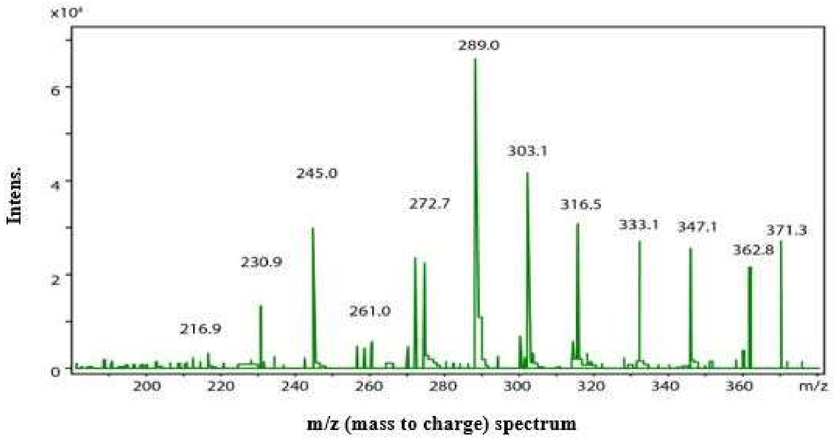

Figure 7 Full-scan Monomer-level ESI mass spectra from fraction BC.

ESI mass spectra of the BC fraction of acetylated monomer.

According to the figure, the m/z value obtained by the ethyl-substituted monomer is 42 points greater than that obtained by the dimethylated monomer.

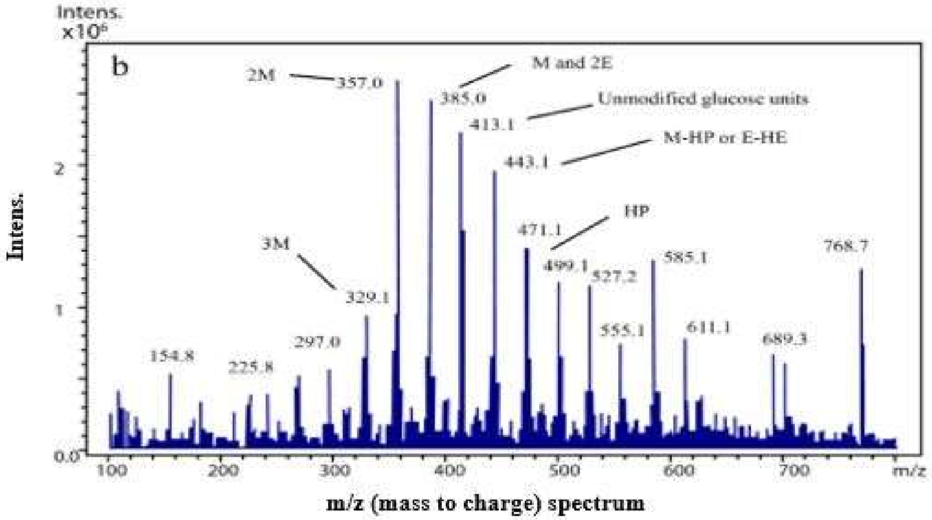

Figure 8 Full-scan ESI mass spectra of proportion BC acetylated monomers.

Relationship of BC mass spectrum and ESI mass spectrum.

Figure 7 shows that the peaks in the BC mass spectra have higher m/z values than the peaks in the AS mass spectra. The polymer can be divided into blocks comprising cleavable unsubstituted portions and non-cleavable substituted sections, as indicated by the m/z values.

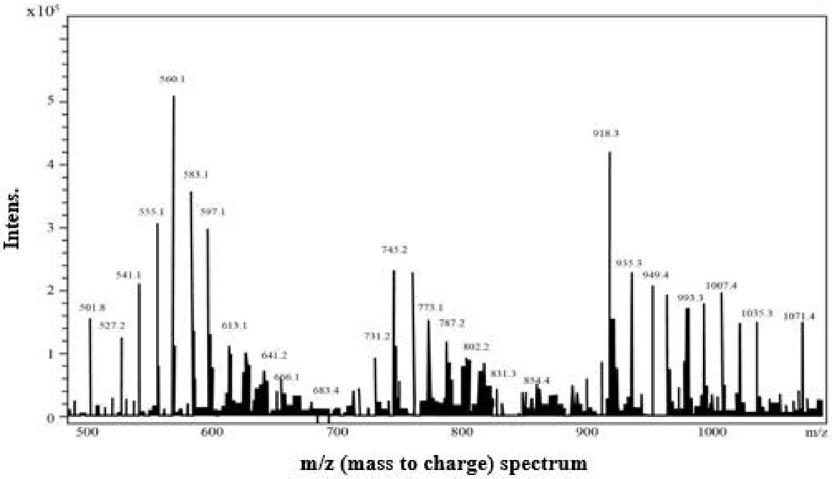

Figure 9 Starch fraction BC of enzyme-hydrolysed sample B: full-scan ESI mass spectrum

VII. CONCLUSION AND FUTURE SCOPE

Next-generation carbon nanomaterial interconnects, and passives have revealed their physics, status, and possible applications in electronics and materials research. This study shows a strong link between amu and relative intensity in diesel exhaust aerosols. Surprisingly, the amu value decreases as the relative intensity rises, highlighting system complexity. The system's partial constancy during the amu value decline emphasizes the need for sophisticated understanding and control over the material's behavior in lubricating settings. The study also shows fuel-related uses for carbon nanomaterial interconnects and passives. The large decrease in amu value, growing relative intensity, and signs of stability support their use in fuel efficiency, combustion processes, and emissions reduction. The zig-zag phenomenon, which causes amu oscillations after the initial intensity increase, shows the tight balance between material performance and stability. Next-generation carbon nanomaterial interconnects, and passives have great potential, warranting additional research. Future research should investigate underlying mechanisms, create and customize materials for specific uses, improve stability, stimulate interdisciplinary collaboration, and test materials in real life. With persistent innovation, these carbon nanoparticles could spur industry breakthroughs in sustainability, energy efficiency, and technology.

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