Engineering and Technology Journal for Research and Innovation (ETJRI)
ISSN 2581-8678, Volume VI, Issue I, Jan 2024

Study of Carbon Nano-Tube Field Effect Transistor for Biomedical Applications

Ravinesh Bhadoriya[1], Dr. Narendra Kumar Garg[2], Dr. Ajay Kumar Dadoria[3]
[1]Research Scholar, [2] Associate Professor, [3] Assistant Professor
Department of Electronics and Communication Engineering,
Amity School of Engineering and Technology, Amity University Madhya Pradesh Gwalior
[1]ravinesh.bhadoriya@s.amity.edu, [2]nkgarg41@gwa.amity.edu, [3]ajaymanit0@gmail.com

Abstract- **This paper provides an extensive overview of CNTFET is provided in biomedical field with significant knowledge and application of CNTFET along with its future scope of research. We present a thorough examination of the knowledge base surrounding CNTFETs, exploring their design, fabrication, and the underlying principles governing their functionality. The paper synthesizes findings from various research endeavors, highlighting the strides made by scientists and engineers in utilizing CNTFETs across different medical disciplines.**

Keywords: **CNTFET, MWCNT, SWCNT, Vision, Biomedical**

I. INTRODUCTION

Carbon nanotube field-effect transistors (CNTFETs) are electronic devices that utilize carbon nanotubes (CNTs) as the conducting channel between the source and drain electrodes, controlled by a gate electrode. CNTFETs have garnered significant interest due to the exceptional electrical, mechanical, and thermal properties of carbon nanotubes, making them promising candidates for next-generation nano electronics. A detailed introduction to CNTFETs can be broken down as follows, with accompanying diagrams to illustrate the key concepts:

PROPERTIES OF CARBON NANOTUBES (CNTs)

Structural Properties: CNTs are cylindrical structures composed of rolled-up graphene sheets, with diameters ranging from a few nanometers to tens of nanometers.

Electrical Properties: CNTs exhibit excellent electrical conductivity with high carrier mobility, enabling efficient charge transport.

Mechanical Properties: CNTs possess exceptional mechanical strength and flexibility, making them suitable for nanoscale device applications.

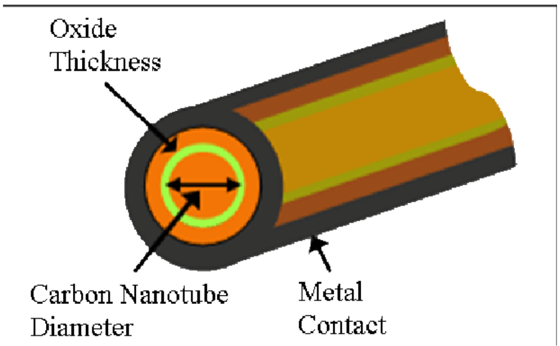

Fig 1: Illustration of a Carbon Nanotube Structure

FIELD EFFECT TRANSISTORS (FETs)

Working Principle: FETs operate based on the modulation of the conductivity of a semiconductor channel by an externally applied electric field from the gate electrode.

Engineering and Technology Journal for Research and Innovation (ETJRI)
ISSN 2581-8678, Volume VI, Issue I, Jan 2024

Components: FETs consist of source and drain electrodes, a semiconductor channel, and a gate electrode separated by a thin insulating layer.

Device Characteristics: FETs exhibit voltage-controlled behavior, with the gate voltage controlling the flow of current from the source to the drain.

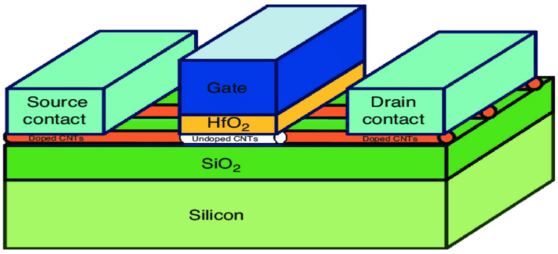

Fig 2: Schematic Diagram of a Field-Effect Transistor

CNTFETs:

Structure and Operation: In CNTFETs, a carbon nanotube serves as the conducting channel between the source and drain, with a gate electrode controlling the current flow by modulating the charge concentration in the CNT channel.

Types of CNTFETs: Carbon Nanotube Field-Effect Transistors (CNTFETs) come in different types based on the structure and arrangement of carbon nanotubes. The primary types include:

1. Semiconducting CNTFETs: Utilize semiconducting carbon nanotubes to create the transistor channel. These are the most common type and function similarly to traditional silicon-based transistors.

2. Metallic CNTFETs: Incorporate metallic carbon nanotubes in the channel region. These are less common due to challenges in achieving proper transistor behavior with metallic nanotubes.

3. Schottky Barrier CNTFETs: Form a Schottky barrier at the carbon nanotube and metal contact interface, influencing the transistor's characteristics. This type is often used in electronic devices for specific applications.

4. Ambipolar CNTFETs: Allow the flow of both electrons and holes in the transistor channel, providing versatility in device applications. Ambipolar CNTFETs can function as either n-type or p-type transistors.

5. Bilayer CNTFETs: Involve the use of two layers of carbon nanotubes, often with different electronic properties, to enhance transistor performance and control charge transport.

6. Wrap-Gated CNTFETs: Employ a wrap-around gate structure that surrounds the carbon nanotube channel, enabling better control over the transistor's electrical properties.

7. Top-Gated CNTFETs: Feature a gate electrode placed on top of the carbon nanotube channel. This design allows for effective modulation of the transistor characteristics.

The specific choice of CNTFET type depends on the intended application and the desired electrical properties. Researchers continue to explore and develop new variations to improve the performance and versatility of CNTFETs in electronic devices.

Engineering and Technology Journal for Research and Innovation (ETJRI)
ISSN 2581-8678, Volume VI, Issue I, Jan 2024

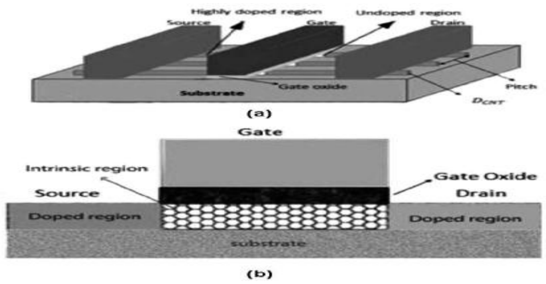

Fig 3: Schematic Representation of a Carbon Nanotube Field-Effect Transistor

Fabrication and Integration:

Growth and Assembly: CNTFETs can be fabricated using techniques such as chemical vapor deposition (CVD), solution-based processes, or directed assembly methods.

Integration with CMOS: CNTFETs can be integrated with complementary metal-oxide-semiconductor (CMOS) technology for potential hybrid applications.

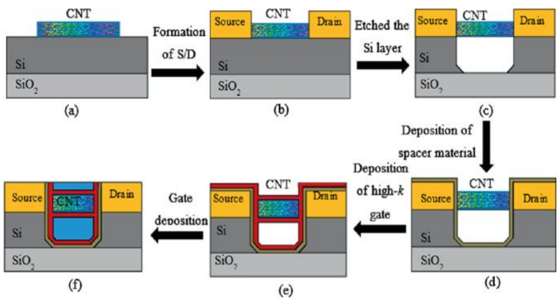

Fig 4: Illustration of CNTFET Fabrication Process

In summary, CNTFETs represent a promising class of electronic devices that leverage the remarkable properties of carbon nanotubes to achieve high-performance, nanoscale transistors.

In summary, CNTFETs represent a promising class of electronic devices that leverage the remarkable properties of carbon nanotubes to achieve high-performance, nanoscale transistors.

Advantages: CNTFETs offer advantages such as high carrier mobility, reduced power consumption, and potential scalability to nanoscale dimensions.

Applications and Future Directions: Carbon nanotubes (CNTs) have a wide range of applications and promising future directions in various fields:

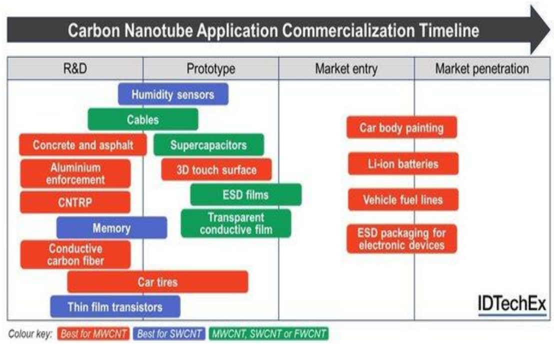

Fig 5: Carbon nanotube application coercialization timeline

1. Material Reinforcement: CNTs can reinforce materials like polymers and composites, enhancing their mechanical, thermal, and electrical properties.

2. Electronics and Nanotechnology: CNTs are used in the development of high-performance transistors and conductive films for electronic devices due to their excellent electrical conductivity.

3. Energy Storage: CNTs show potential in improving the performance of batteries and super capacitors, leading to higher energy storage capacities and faster charging times.

4. Sensors: CNT-based sensors can detect various gases, biomolecules, and chemicals with high sensitivity, making them valuable for applications in environmental monitoring, healthcare, and security.

ISSN 2581-8678, Volume VI, Issue I, Jan 2024

5. Medical Applications: CNTs are explored for drug delivery

6. Aerospace Materials: CNT-reinforced composites are being investigated for lightweight and strong materials in aerospace applications, potentially improving fuel efficiency and overall performance.

7. Water Purification: CNTs can be used in water filtration systems to remove pollutants and contaminants, addressing water purification challenges.

8. Thermal Management: Due to their exceptional thermal conductivity, CNTs are being explored for applications in thermal management, such as heat sinks in electronics.

9. Flexible Electronics: CNTs contribute to the development of flexible and stretchable electronic devices, offering new possibilities in wearable technology and flexible displays.

10. Catalysis: CNTs can act as catalyst supports, influencing chemical reactions, and finding applications in catalysis for industrial processes.

In the future, research and development may uncover additional applications and refine existing ones, contributing to the advancement of various industries and technologies.

In the biomedical field, researchers are actively exploring various applications of carbon nanotubes (CNTs) due to their unique properties. Here is a more detailed discussion of recent research technologies involving CNTs.

A. Drug Delivery Systems: Targeted Drug Delivery: CNTs can be functionalized to carry drugs and deliver them selectively to specific cells or tissues, thereby minimizing side effects. Researchers are currently developing CNT-based drug delivery systems to enhance the therapeutic efficacy of medications. - Controlled Release: The tunable properties of CNTs allow for the controlled release of drugs, ensuring a sustained and controlled therapeutic effect over time.

B. Biosensors: Sensitivity and Specificity: CNTs are utilized in the development of highly sensitive biosensors for detecting biomolecules. Functionalized CNTs can selectively bind to target molecules, thereby improving the specificity and sensitivity of biosensing devices.

C. Imaging Agents: Contrast Agents: CNTs possess inherent imaging contrast properties, making them suitable candidates for improving imaging modalities such as MRI, CT scans, and photoacoustic imaging.

D. Theranostics: Combining Therapy and Diagnostics: CNTs are being investigated for theranostic applications, where they serve dual roles as both therapeutic agents and diagnostic tools. This integrated approach aims to improve the treatment outcomes through personalized and precise medicine.

E. Biocompatibility and Safety: Surface Functionalization: Ongoing research focuses on enhancing the biocompatibility of CNTs through surface modifications, reducing potential toxicity concerns, and

ISSN 2581-8678, Volume VI, Issue I, Jan 2024

improving their interaction with biological systems.

Biological Barriers: Understanding the interactions of CNTs with biological barriers, such as the blood-brain barrier, is crucial for safe and effective biomedical applications.

F. Tissue Engineering: Scaffold Materials: CNTs have been explored as components of scaffold materials in tissue engineering. Their mechanical strength and electrical conductivity render them valuable for creating biomimetic environments for cell growth and tissue regeneration.

While these advancements demonstrate the potential of CNTs in biomedical applications, ongoing research is crucial to address challenges such as biocompatibility, scalability, and regulatory considerations for eventual clinical translation.

II. LITERATURE REVIEW

[1] In this paper, Carbon nanotubes (CNTs) have emerged as a highly researched carbon allotrope with unparalleled physicochemical properties, positioning them as prime candidates for diverse biomedical applications. This comprehensive literature review delves into the multifaceted landscape of CNTs in biomedicine, emphasizing their potential in drug delivery, gene therapy, biosensors, and tissue engineering. Despite their promise, the specter of CNT toxicity looms large, casting a shadow over their biomedical utility.

The review meticulously scrutinizes various factors influencing CNT toxicity, with a particular focus on size, length, agglomeration, and impurities. Oxidative stress is identified as a predominant mechanism underpinning CNT toxicity, and the interplay of these parameters in inducing oxidative stress is thoroughly explored.

Additionally, the review probes into alternative toxic pathways associated with CNT exposure, contributing to a nuanced understanding of their potential risks.

In navigating the challenges posed by CNT toxicity, the review offers insights into potential mitigation strategies. These include modifications to synthesis methods, surface functionalization techniques, and the application of protective coatings. By providing a comprehensive overview of the current state of knowledge, this review serves as a valuable resource for researchers, shedding light on the promise of CNTs in biomedical applications while addressing the imperative need to address and surmount their toxicity concerns.

[2] In this paper, over the past decade, remarkable strides in nanomaterial research, particularly in carbon nanotubes (CNTs), have unfolded. This review encapsulates a contemporary overview encompassing the properties, synthesis, functionalization, toxicity, and diverse biomedical applications of CNTs. Researchers have unveiled CNTs' extraordinary mechanical, electronic, and physical attributes, bestowing them with unparalleled versatility. Functionalization techniques have proven instrumental in tailoring CNT properties, expanding their applications, and mitigating toxicity concerns. Notably, the burgeoning

utilization of CNTs in biomedical realms, such as drug delivery, tissue engineering, biosensors, bioimaging, and cancer treatment, has surged exponentially.

CNTs exhibit the potential to enhance drug lifespan within the human body, precisely deliver drugs to targeted cells, and serve as highly efficient, biocompatible biosensors and bioimaging agents. In addressing pressing global health challenges, CNTs have demonstrated efficacy in detecting the SARS COVID-19 virus, presenting promising outcomes for cancer treatment and tissue engineering. However, challenges persist, including concerns about cytotoxicity in in vivo biomedical applications and the associated high manufacturing costs.

This review provides a comprehensive exploration of the transformative landscape of CNTs, acknowledging their breakthroughs, applications, and hurdles, while underscoring their pivotal role in advancing biomedical science amidst contemporary imperatives.

This comprehensive review explores the myriad potential applications of carbon nanotubes (CNTs) across various sectors, prompting a critical examination of their diverse properties in catalysis, biosensors, and antimicrobial activities. The burgeoning interest in CNTs, particularly their biosensor and antibacterial potential, has ignited considerable enthusiasm for utilizing these carbon-based nanostructures as alternatives to conventional antibiotics. Despite the novelty of studying the bactericidal aspects of CNTs, there is a pressing need for a deeper understanding of their physicochemical characteristics and antimicrobial nature.

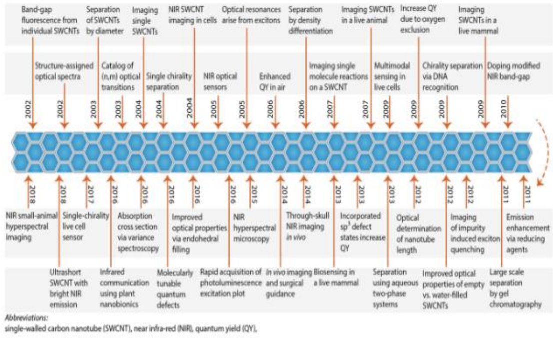

Fig 6: Schematic Representation of research on Carbon Nanotube Field-Effect Transistor

[3] In this paper, the review meticulously delves into the impact of framework substitution, elucidating membrane disintegration and oxidative stresses crucial for antimicrobial activity. Furthermore, it scrutinizes the effects of preparation methods, nanoparticle deposition, and framework modification on the structural integrity of carbon nanotubes.

Notably, the exploration extends to recent research on graphene-modified biosensors for healthcare and clinical settings, nanomaterials and their applications in major physicochemical factors influencing bacterial killing, including size, functionalization, high surface area, and aggregation features of CNTs, are intricately outlined. In summarizing the advantages of functionalized carbon nanotube/graphene-based nanostructures, the review emphasizes their potential role in protecting and reducing bacterial/viral infections within the healthcare sector. This literature review serves as a comprehensive guide, encapsulating the current state of knowledge on single and multi-walled carbon nanotubes, paving the way for advanced materials in healthcare applications.

Engineering and Technology Journal for Research and Innovation (ETJRI)
ISSN 2581-8678, Volume VI, Issue I, Jan 2024

[4] In this paper, the literature review highlights the significance of carbon nanotubes (CNTs) as a crucial class of nanomaterials with unique electrochemical, mechanical, and biosensing properties. CNTs possess a distinctive 3-D structure, allowing for efficient biomaterial loading onto solid surfaces, rendering them superior sensors compared to other nanomaterials. Their ultra-sensitivity, stemming from a large length-to-diameter ratio, accelerates electron transfer between molecules and electrodes, enhancing sensing capabilities.

Despite inherent insolubility challenges, CNTs play a pivotal role as substrates for biomolecule immobilization, enabling signal amplification. Overcoming solubility constraints, surface modification techniques involving organic, inorganic-organic hybrid, or inorganic materials have garnered significant attention. This review outlines established functionalization approaches for designing sensors using CNTs, emphasizing their synthesis and applications in electrochemical and biosensors for detecting diverse analytes.

The chapter underscores the potential of CNT-based sensors to address challenges in clinical diagnostics and therapeutics. The versatility of CNTs in functionalization broadens their application scope, promising drastic advancements in the sensor industry. As a nexus of electrochemical innovation, CNTs are poised to contribute significantly to the future of sensing technologies, offering solutions to intricate diagnostic and therapeutic demands in healthcare.

[5] In this paper, Carbon nanotubes (CNTs), as an extensively studied allotropic form of carbon, exhibit unique physicochemical properties that make them promising for various biomedical applications. However, their utilization is overshadowed by concerns about toxicity, necessitating thorough investigation. This review delves into the multifaceted aspects of CNT toxicity, shedding light on associated mechanisms and potential mitigations.

The small size and expansive surface area of CNTs are pivotal factors influencing their toxicity. Examining physicochemical attributes like metal impurities, length, size, solubilizing agents, functionalization, and agglomeration, the review scrutinizes their role in inducing oxidative stress and activating toxic signaling pathways. Despite the widespread use of CNTs in diverse applications, a comprehensive understanding of their toxicity remains crucial.

The review synthesizes the latest mechanistic evidence, offering new insights into the molecular-level toxicological effects of CNTs. By elucidating these mechanisms, the review aims to contribute to the development of strategies for mitigating harmful effects arising from CNT exposure. This comprehensive exploration of CNT toxicity not only highlights existing challenges but also provides a foundation for future research endeavors, paving the way for safer and more informed applications of CNTs in biomedical contexts.

[6] In this paper, the literature review focuses on the potential of carbon-nanotube-related (CNT-related) materials in the realm of flexible electronics and

photonics, emphasizing the challenge of globally controlling the Fermi level in microscale-thick CNT films.

Despite the remarkable applications envisioned for CNT-related materials, maintaining free-standing shape and bendable flexibility in thicker films while globally controlling the Fermi level remains a hurdle.

The review highlights a significant breakthrough in Fermi-level-controlled flexible terahertz (THz) imagers, achieved through chemically adjustable Fermi-level-tuning methods for CNT films. The electronic-double-layer technique with ionic liquids is employed to tune the Fermi level optimally, enhancing THz detector performance with an impressive on/off resistance ratio of 2758 for a semiconducting-separated CNT film (30 μm thickness). Additionally, the introduction of a gate-free tunable doping technology, utilizing a variable-concentration dopant solution, enables the creation of Fermi-level-tuned p–n junction CNT THz imagers.

This work underscores the potential of chemically tunable doping techniques in advancing flexible THz imaging applications. The demonstrated capabilities not only enhance the performance of THz imagers but also pave the way for large-area THz photonic devices through cost-effective fabrication methods like inkjet coating.

This review contributes valuable insights into the evolving landscape of CNT-based flexible electronics and photonics, opening avenues for diverse applications in the field.

[7] In this paper, the contemporary landscape of biomedical research, nanotechnology has emerged as a rapidly advancing field, particularly in the realm of delivering therapeutics for the treatment of tumor cells. Cancer, a formidable and often lethal disease, results from genetic mutations that silently proliferate within the human body. The conventional chemotherapeutic approach, though potent, is plagued by indiscriminate cytotoxicity, causing collateral damage to healthy cells alongside the targeted cancer cells.

The inefficiency of conventional drugs in precisely targeting tumor cells has fueled the imperative for nanomedicine. Nanoparticles (NPs), characterized by their diminutive size, expansive surface area, and the ability to selectively target tumor cells, offer a promising alternative. This targeted delivery minimizes damage to normal cells, enhancing the therapeutic efficacy of anti-cancer agents. The classification of NPs into organic and inorganic categories, based on durability and molecular weight, underscores their versatility in combating cancer.

Organic and inorganic nanoparticles have demonstrated notable effectiveness in cancer treatment, exhibiting high efficacy values attributed to their unique mechanisms of action.

The small size and specialized targeting capabilities of NPs position them as valuable tools in the ongoing quest for more effective and targeted cancer therapies, marking a paradigm shift in the approach to combating this complex and multifaceted disease.

[8] In this paper, the building and construction industry, a major consumer of natural resources, significantly contributes to carbon emissions. To foster sustainability, there is a growing emphasis on utilizing waste materials in construction composites, particularly in bricks and cement/concrete mortar, to reduce reliance on non-renewable resources. This review centers on the incorporation of waste plastics and coal fly ash into building composites, focusing on bricks. The assessment of properties such as mechanical strength, water resistance, and thermal stability elucidates the feasibility of these waste-derived composites in construction applications.

A noteworthy advancement involves the integration of nanomaterials, specifically carbon nanotubes (CNTs), renowned for their exceptional mechanical strength, as fillers in these composites. The fine-scale dispersion of CNTs, in contrast to conventional fillers, allows for remarkable enhancements with minimal content. The resultant waste-derived composites, fortified with CNTs, emerge as lightweight yet robust materials capable of withstanding challenging environmental conditions such as weather extremes, fire, and seismic activity.

Addressing environmental concerns, the review also scrutinizes the sustainable application of CNTs, ensuring minimal environmental impact. This synthesis of waste materials and nanotechnology holds promise for fostering eco-friendly practices and resilience in the construction industry.

[9] In this paper, the pervasive applications of nanotechnology in pharmaceuticals, biomedicine, and cosmetics underscore its transformative potential. Nanoparticles (NPs), characterized by exceptional properties, have garnered attention for their diverse benefits. However, concerns regarding their safety loom large, particularly due to their heightened interaction with organs, tissues, and cells upon entering the body. Traditional toxicity studies prove inadequate, as NPs exhibit distinct properties compared to bulk materials.

This gap in understanding has given rise to the emergence of "Nanotoxicology" – a specialized branch designed to systematically evaluate the potential harmful effects of NPs on human health. This chapter delves into the applications of NPs, navigating through the intricate landscape of nanotoxicity. It sheds light on the nuanced mechanisms underpinning NP toxicity, emphasizing the necessity for tailored toxicological studies. Unlike conventional approaches, nanotoxicological studies delve into the unique properties of NPs, providing a more accurate assessment of their potential risks.

The review outlines the regulatory relevance of nanotoxicological studies, recognizing the imperative of comprehensive safety evaluations in the face of expanding NP applications. By offering insights into both the applications and potential risks associated with NPs, this literature review contributes to a holistic understanding of the evolving field of nanotoxicology.

In the exploration of inhaled carbon nanotubes (CNTs), the interaction with pulmonary surfactant (PS) in the deep lung

Engineering and Technology Journal for Research and Innovation (ETJRI)
ISSN 2581-8678, Volume VI, Issue I, Jan 2024

has become a focal point, potentially reshaping the fate and toxicity of CNTs. This study employs passive dosing and fluorescence-based techniques to reveal the partial solubilization of BaPs (benzo[a]pyrene) adsorbed on CNTs by PS in simulated alveolar fluid. Molecular dynamics (MD) simulations further elucidate the intricate competition of interactions among BaPs, CNTs, and PS.

The dual role of PS in modulating the toxicity profile of CNTs is unraveled. Firstly, PS coronas are identified to mitigate CNT toxicity by diminishing hydrophobicity and reducing aspect ratio. Paradoxically, PS interaction enhances the bio accessibility of BaP through PS interactions, potentially exacerbating the inhalation toxicity of CNTs. This revelation underscores the complexity of PS-modified CNT toxicity, necessitating consideration of coexisting contaminants and CNT characteristics like size and aggregation state.

The findings advocate for a nuanced understanding of inhalation toxicity, emphasizing the need to assess the bio accessibility of contaminants in conjunction with the intricate interplay of CNTs and pulmonary surfactant, offering critical insights for future studies in nanotoxicology.

III. CONCLUSION

In conclusion, this paper offers a comprehensive overview of Carbon Nanotube Field-Effect Transistor (CNTFET) applications in the biomedical field, showcasing significant advancements in knowledge and practical utilization. The extensive exploration of CNTFETs reveals their multifaceted roles in diverse medical applications, underscoring their potential to revolutionize diagnostics, sensing, and therapeutic interventions.

Researchers have made substantial contributions across various medical domains, harnessing the unique properties of CNTFETs to enhance sensing capabilities, improve signal transduction, and enable precise drug delivery systems. The amalgamation of nanotechnology with biomedical sciences through CNTFETs has paved the way for innovative solutions, offering improved sensitivity, specificity, and efficiency in diagnostic and therapeutic modalities.

As we reflect on the achievements highlighted in this paper, it becomes evident that the future scope of research in CNTFETs holds immense promise. Further exploration and refinement of CNTFET applications in biomedicine are anticipated, with a focus on addressing challenges, optimizing performance, and expanding the range of medical applications.

The collaborative efforts of researchers from diverse fields have propelled the integration of CNTFETs into the biomedical landscape, fostering a dynamic synergy between nanotechnology and healthcare. This paper serves as a valuable resource for researchers and practitioners alike, offering insights into the current state of CNTFET applications in biomedicine and inspiring future endeavors in this rapidly evolving and promising field.

REFERENCE

[1]. Reem Alshehri, Asad Muhammad Ilyas, Anwarul Hasan*, Adnan Arnaout, Farid Ahmed, and Adnan Memic* "Carbon Nanotubes in Biomedical Applications: Factors, Mechanisms, and Remedies of Toxicity.

[2]. Bhushan O. Murjani1 · Parikshit S. Kadu1 · Manasi Bansod1 · Saloni S. Vaidya1 · Manish Kumar D. Yadav Carbon nanotube in its biomedical applications- current status, promises and challenges.

[3]. Jothi Ramalingam Rajabathar 1, *, Govindasami Periyasami 1,* , Amer M. Alanazi 2, Mani Govindasamy 3 and Prabhakarn Arunachalam "Review on carbon nanotube varieties for healthcare Applications: Effect of preparation methods and mechanism insight".

[4]. Sumera Khizar, Amal A. Al-Dossary, Nadia Zine, Nicole Jaffrezic Renault, Abdelhamid Errachid, and Abdelhamid Elaissari* "Applications for surface modified carbon nanotubes I electrochemical sensors and biosensors".

[5]. Mansab Ali Saleemi More by Mansab Ali Saleemi, Mohammad Hosseini Fouladi, Phelim Voon Chen Yong, Karuthan Chinna, Navindra Kumari Palanisamy, and Eng Hwa Wong "Toxicity of carbon nanotubes: Molecular mechanism, signaling cascades, and remedies in biomedical applications".

[6]. Daichi Suzuki, Yuki Ochiai, Yota Nakagawa, Yuki Kuwahara, Takeshi Saito, and Yukio Kawano* "Fermi-level-controlled semiconducting separated carbon nanotube films or flexible terahertz imagers."

[7]. Bakhtawar Bukhari, Muhammad Naveed, Syeda Izma Makhdoom, Khizra Jabeen, Muhammad Farrukh Asif, Hira Batool, Naveed Ahmed, and Yean Yean Chan "A comprise between organic and inorganic nanoparticles: Prime nanoparticles for tumor curation".

[8]. Boitumelo Makgabutlane [a e], Manoko.S. Maub ane-Nkadimeng [a b c], Neil J. Coville [a c], Sabelo D. Mhlanga "Plastic-fly ash waste composites reinforced with carbon nanotubes for sustainable building and construction applications: A review".

[9]. Indrani Maji, Srushti Mahajan, Anitha Sriram, NeeleshKumar Mehra, Saurabh Srivastava, Jite nder Madan, Shashi Bala Singh, Pankaj Kumar Singh "Nanotoxicology: toxicity and safety issues of nanoparticles".

[10]. Zhen Luo, Dongfang Xu, Yan Xu, Jian Zhao, Guoqing Hu, Tongtao Yue "Dual role of pulmonary surfactant corona in modulating carbon nanotube toxicity and benzopyrene bioaccessesibility".