International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 8, Issue 4, pp 363-366, April-2024

https://doi.org/10.47001/IRJIET/2024.804058

Carbon Nanotubes for Neural Applications

[1]Rithik Vinay P.S, [2]Shashank Sivakumar, [3]Prof. Dr. Saibol Ray

[1,2,3]Department of Student Research, SSVM World School, Coimbatore, Tamilnadu, India

***Abstract* - This research proposal investigates the feasibility of utilizing carbon nanotubes (CNTs) for neural applications. Due to their exceptional mechanical strength, electrical conductivity, and biocompatibility, CNTs present significant potential for biomedical uses. This study focuses on their role in peripheral nerve regeneration and as components of neural interfaces. We hypothesize that CNTs can promote nerve regeneration and serve as efficient neural electrodes due to their unique properties. The objectives include assessing biocompatibility, evaluating electrical properties, designing CNT-based scaffolds, and developing CNT-based microelectrodes. The expected outcomes will contribute to advancements in neural regeneration and neural interface technologies, with significant implications for prosthetics and neurological disorder treatments.**

Keywords: Carbon Nanotubes, Neural Applications, CNTs, Microelectrodes.

I. Introduction

Carbon nanotubes (CNTs) are cylindrical nanostructures exhibiting exceptional mechanical strength, electrical conductivity, and biocompatibility. These properties position them at the forefront of material science research with vast potential for biomedical applications. This proposal investigates the feasibility of utilizing CNTs for neural applications, specifically focusing on their role in peripheral nerve regeneration and as neural interface components.

II. Background

Peripheral nerve injuries (PNI) disrupt nerve signal transmission, leading to functional loss and disability. Current treatments for PNI have limitations, highlighting the need for novel therapeutic strategies. Neural interfaces offer promising avenues for prosthetics, neurorehabilitation, and treatment of neurological disorders by facilitating communication between the nervous system and external devices.

III. Literature Review

Extensive research explores the unique properties of CNTs. Their biocompatibility makes them suitable for interacting with living tissues. Additionally, their exceptional electrical conductivity allows for efficient transmission of electrical signals, a crucial aspect of neural interfaces.

Studies have demonstrated the positive effects of CNTs on neurite outgrowth, a critical step in nerve regeneration (see Table 1). In vitro research suggests CNT-based scaffolds can provide a supportive microenvironment for nerve cell growth.

Table 1: Effect of CNTs on Neurite Outgrowth

CNT Type	Cell Line	Neurite Outgrowth (%)	Reference
MWCNT	PC12	170%	[6]
SWCNT	DRG neurons	150%	[7]

Abbreviations: MWCNT (multi-walled carbon nanotube), SWCNT (single-walled carbon nanotube), PC12 (rat pheochromocytoma cell line), DRG (dorsal root ganglion).

The development of biocompatible and functional neural interfaces is another active area of research. CNTs have emerged as promising candidates for neural electrode fabrication due to their ability to record and stimulate neural activity.

This graph highlights the exceptional electrical conductivity of CNTs compared to traditional electrode materials like copper, aluminum, and steel. This superior conductivity is crucial for efficient signal transmission in neural interfaces.

IV. Hypothesis

We hypothesize that CNTs possess favorable properties for neural applications due to their biocompatibility and electrical conductivity. This research project aims to evaluate the potential of CNTs for:

- Promoting peripheral nerve regeneration as nerve conduit materials.
- Functioning as neural electrodes for recording and stimulating neural activity.

V. Objectives

1. Investigate the biocompatibility of CNTs with neural cells.

International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 8, Issue 4, pp 363-366, April-2024

https://doi.org/10.47001/IRJIET/2024.804058

2. Evaluate the electrical properties of CNTs and their ability to promote neural adhesion and growth.

3. Design and fabricate CNT-based scaffolds with structures suitable for nerve regeneration.

4. Test the efficacy of CNT-based conduits in promoting peripheral nerve regeneration in animal models.

5. Develop and test CNT-based microelectrodes for recording and stimulating neural activity.

VI. Methodology

In-vitro Studies

- Assess the biocompatibility of CNTs with neural cells using viability and adhesion assays.
- Evaluate the electrical properties of CNTs and their influence on neural cell growth.

Scaffold Design and Fabrication

- Design and fabricate CNT-based scaffolds with appropriate porosity and architecture to support nerve regeneration.

In-vivo Testing

- Evaluate the efficacy of CNT-based conduits in promoting peripheral nerve regeneration in animal models.

Microelectrode Development

- Develop and test CNT-based microelectrodes for recording and stimulating neural activity in vitro and potentially in vivo.

VII. Expected Outcomes

This research is expected to contribute to the field of neural regeneration and neural interfaces by:

- Providing a comprehensive understanding of CNT biocompatibility with neural tissues.
- Demonstrating the potential of CNT-based scaffolds for promoting peripheral nerve regeneration.
- Evaluating the feasibility of CNT-based microelectrodes for neural recording and stimulation.

VIII. Significance

The successful development of CNT-based technologies for neural applications could have a significant impact on various fields. In peripheral nerve regeneration, CNT-based conduits could offer a novel therapeutic approach to improve functional recovery after nerve injuries. Additionally, advancements in CNT-based neural interfaces hold promise for the development of next-generation prosthetics and improved treatment strategies for neurological disorders.

IX. Uses in the Medical Field

The use of CNTs in drug delivery and biosensing technology has the potential to revolutionize medicine. Functionalization of single-walled nanotubes (SWNTs) has proven to enhance solubility and allow for efficient tumor targeting/drug delivery. It prevents SWNTs from being cytotoxic and altering the function of immune cells.

Cancer, a group of diseases in which cells grow and divide abnormally, is one of the primary diseases being looked at with regard to how it responds to CNT drug delivery. Current cancer therapy primarily involves surgery, radiation therapy, and chemotherapy. These methods of treatment are usually painful and kill normal cells in addition to producing adverse side effects. CNTs as drug delivery vehicles have shown potential in targeting specific cancer cells with a dosage lower than conventional drugs used, which is just as effective in killing the cells, however, does not harm healthy cells and significantly reduces side effects.

Current blood glucose monitoring methods by patients with diabetes are normally invasive and often painful. For example, one method involves a continuous glucose sensor integrated into a small needle which must be inserted under the skin to monitor glucose levels every few days. Another method involves glucose monitoring strips to which blood must be applied. These methods are not only invasive but they can also yield inaccurate results. It was shown that 70 percent of glucose readings obtained by continuous glucose sensors differed by 10 percent or more and 7 percent differed by over 50 percent. The high electrochemically accessible surface area, high electrical conductivity, and useful structural properties have demonstrated the potential use of single-walled nanotubes (SWNTs) and multi-walled nanotubes (MWNTs) in highly sensitive noninvasive glucose detectors.

X. CNTs in Drug Delivery and Cancer Therapy

Drug delivery is a rapidly growing area that is now taking advantage of nanotube technology. Systems being used currently for drug delivery include dendrimers, polymers, and liposomes, but carbon nanotubes present the opportunity to work with effective structures that have high drug-loading capacities and good cell penetration qualities. These nanotubes function with a larger inner volume to be used as the drug container, large aspect ratios for numerous functionalization attachments, and the ability to be readily taken up by the cell. Because of their tube structure, carbon nanotubes can be made

International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 8, Issue 4, pp 363-366, April-2024

https://doi.org/10.47001/IRJIET/2024.804058

with or without end caps, meaning that without end caps the inside where the drug is held would be more accessible.

Right now with carbon nanotube drug delivery systems, problems arise like the lack of solubility, clumping occurrences, and half-life. However, these are all issues that are currently being addressed and altered for further advancements in the carbon nanotube field. The advantages of carbon nanotubes as nano vectors for drug delivery remain where cell uptake of these structures was demonstrated efficiently where the effects were prominent, showing the particular nanotubes can be less harmful as nanovesicles for drugs. Also, drug encapsulation has been shown to enhance water dispersibility, better bioavailability, and reduced toxicity. Encapsulation of molecules also provides a material storage application as well as protection and controlled release of loaded molecules. All of these result in a good drug delivery basis where further research and understanding could improve upon numerous other advancements, like increased water solubility, decreased toxicity, sustained half-life, increased cell penetration, and uptake, all of which are currently novel but undeveloped ideas.

XI. CNT Network Bio-stress Sensors

A single nanotube experiences a change in electrical resistance when experiencing stress or strain. This piezoresistive effect changes the current flow through the nanotube, which can be measured in order to accurately quantify the applied stress. A semi-random positioning of many overlapping nanotubes forms an electrically conducting network composed of many piezoresistive nanotubes. If the variance of the tube lengths and angles is known and controllable during manufacture, an eigensystem approach can be used to determine the expected current flow between any two points in the network. The tube network is embedded within orthopedic plates, clamps, and screws and in bone grafts to determine the state of bone healing by measuring the effect of a load on the plate, clamp, screw, or other fixation device attached to the bone. A healed bone will bear most of the load while a yet unhealed bone will defer the load to the fixation device wherein the nanotube network may measure the change in resistivity. Measurement is done wirelessly by electrical induction. This allows the doctor to accurately assess patient healing and also allows the patient to know how much stress the affected area may safely tolerate. Wolff's law indicates that bone responds positively to safe amounts of stress, which may be applied to yet-unhealed bones in order to build strength without compromising healing.

XII. Conclusion

In conclusion, the exploration of carbon nanotubes (CNTs) for neural applications holds immense potential for advancing medical science and technology. CNTs' unique properties, such as exceptional electrical conductivity, mechanical strength, and biocompatibility, position them as promising candidates for both peripheral nerve regeneration and neural interfaces. By addressing the current limitations in nerve injury treatments and enhancing neural interface technologies, this research could pave the way for significant breakthroughs in prosthetics, neurorehabilitation, and the treatment of neurological disorders. The proposed investigation into the biocompatibility, electrical properties, and design of CNT-based scaffolds and microelectrodes aims to validate their efficacy in real-world applications. The successful implementation of CNT-based technologies can revolutionize neural regeneration and neural interfaces, ultimately improving the quality of life for individuals affected by nerve injuries and neurological conditions. Continued research and development in this field are essential for realizing the full potential of CNTs in biomedical applications, promising a future where advanced materials significantly contribute to medical advancements and patient care.

REFERENCES

[1] Bekyarova, E., Ni, Y., Malarkey, E. B., Montana, V., McWilliams, J. L., Haddon, R. C., & Parpura, V. (2005). Applications of carbon nanotubes in biotechnology and biomedicine. *Journal of Biomedical Nanotechnology, 1*(1), 3-17.

[2] Kam, N. W. S., & Dai, H. (2006). Carbon nanotubes as intracellular protein transporters: Generality and biological functionality. *Journal of the American Chemical Society, 128*(3), 351-358.

[3] Mattson, M. P., Haddon, R. C., & Rao, A. M. (2000). Molecular functionalization of carbon nanotubes and use as substrates for neuronal growth. *Journal of Molecular Neuroscience, 14*(3), 175-182.

[4] Pantarotto, D., Partidos, C. D., Graff, R., Hoebeke, J., Briand, J. P., Prato, M., & Bianco, A. (2003). Synthesis, structural characterization, and immunological properties of carbon nanotubes functionalized with peptides. *Journal of the American Chemical Society, 125*(20), 6160-6164.

[5] Rudge, S. R., Kurtz, T. L., Vesely, C. R., Catterall, L. G., & Williamson, D. L. (2000). Preparation, characterization, and performance of magnetic iron-carbon composite microparticles for biomedical applications. *Journal of Biomedical Materials Research, 50*(1), 70-80.

[6] Saito, N., Usui, Y., Aoki, K., Narita, N., Shimizu, M., Hara, K.,.. & Kato, H. (2009). Carbon nanotubes: Biomaterial applications. *Chemical Society Reviews, 38*(7), 1897-1903.

ISSN (online): 2581-3048
Volume 8, Issue 4, pp 363-366, April-2024
https://doi.org/10.47001/IRJIET/2024.804058

[7] Smart, S. K., Cassady, A. I., Lu, G. Q., & Martin, D. J. (2006). The biocompatibility of carbon nanotubes. *Carbon, 44*(6), 1034-1047.
[8] Wang, Y., Iqbal, Z., & Mitra, S. (2006). Rapidly functionalized, water-dispersed carbon nanotubes at high concentrations. *Journal of the American Chemical Society, 128*(1), 95-99.
[9] Yang, W., Thordarson, P., Gooding, J. J., Ringer, S. P., & Braet, F. (2007). Carbon nanotubes for biological and biomedical applications. *Nanotechnology, 18*(41), 412001.
[10] Zhang, Y., Ali, S. F., Dervishi, E., Xu, Y., Li, Z., Casciano, D., & Biris, A. S. (2010). Cytotoxicity effects of graphene and single-wall carbon nanotubes in neural phaeochromocytoma-derived PC12 cells. *ACS Nano, 4*(6), 3181-3186.

AUTHORS BIOGRAPHY

Rithik Vinay P.S,
Department of Student Research, SSVM World School, Coimbatore, Tamilnadu, India.

Shashank Sivakumar,
Department of Student Research, SSVM World School, Coimbatore, Tamilnadu, India.

Citation of this Article:

Rithik Vinay P.S, Shashank Sivakumar, Prof. Dr. Saibol Ray, “Carbon Nanotubes for Neural Applications”, Published in *International Research Journal of Innovations in Engineering and Technology - IRJIET*, Volume 8, Issue 4, pp 363-366, April 2024. Article DOI https://doi.org/10.47001/IRJIET/2024.804058

****

