

Biocompatible Control: The Integration of Graphene-Based Neural Interfaces and Adaptive AI Systems

Yash Srivastav^{1*}, Ankit Kumar¹, Vikas Kumar¹, Salim¹, Ankur Bajpai¹, Nitin Mishra¹,
Shivani Singh¹

¹D.K.R.R Pharmacy College, Amberpur, Sitapur (Uttar Pradesh), India

*Corresponding Email: yashsrv.108@gmail.com

Abstract:

The fusion of graphene neural interfaces with adaptive artificial intelligence (AI) systems has become a critical breakthrough in human-centred neurotechnologies and personalised healthcare. Graphene has an outstanding electrical conductivity, flexibility, transparency, light architecture and biocompatibility, making it an ideal material for wearable and implantable neural devices. At the same time, artificial intelligence systems that adapt their performance benefit the interpretation of the neural signals, learning in real time, signal recognition, and performance of rehabilitation. This review covers the structural and functional characteristics of graphene neural interfaces, adaptive AI in neural signal processing, and the synergy and application of both to brain-computer interfaces (BCIs), neuroprosthetics, assistive communication systems, and personalized neurotherapy. Humans studies show that graphene-AI systems have boosted the stability of neural signals, motor control, speech decoding and rehabilitation efficiency, as well as neural monitoring and remote healthcare. The review also covers critical issues like long-term biocompatibility, privacy of neural data, algorithmic transparency, cybersecurity, and regulatory approval. While small-scale clinical trials and the absence of standardized frameworks pose challenges, the potential applications of graphene-AI combination in neurological rehabilitation and intelligent healthcare systems are promising.

Keywords: Graphene Neural Interfaces; Adaptive Artificial Intelligence; Brain-Computer Interfaces; Neuroprosthetics; Personalized Neurotherapy; Neural Signal Processing; Biocompatibility; Human-Centered Neurotechnology

Received: Feb. 11, 2026

Revised: March 18, 2026

Accepted: April 14, 2026

Published: May 18, 2026

DOI: <https://doi.org/10.64063/3049-1681.vol.3.issue5.12>

<https://aktpublication.com/index.php/jprims/issue/archive>

This is an Open Access article distributed under the terms of the Creative Commons Attribution (CC BY NC), which permits unrestricted use, distribution, and reproduction in any medium, as long as the original authors and source are cited. No permission is required from the authors or the publishers. (<https://creativecommons.org/licenses/by-nc/4.0/>)

1. INTRODUCTION

The recent developments in the field of neurotechnology and artificial intelligence have revolutionized human-centred healthcare and neural engineering. Graphene, one of the emerging biomaterials, has been the focus of high scientific interest because of its remarkable electrical conductivity, mechanical flexibility, light weight, transparency, and biocompatibility. Because of these special characteristics, graphene is particularly promising for neural interface technologies such as brain-computer interaction (BCI), wearable neural sensors, neuroprostheses, and

cognitive monitoring devices. Meanwhile, adaptive artificial intelligence (AI) systems have enhanced the understanding and handling of complex neural signals via machine learning and real-time adaptive learning methods [1]. The integration of graphene neural interfaces and adaptive AI systems is a promising interdisciplinary strategy that holds the potential to significantly advance the field of neural communications, improve signal fidelity, and develop personalized healthcare solutions.

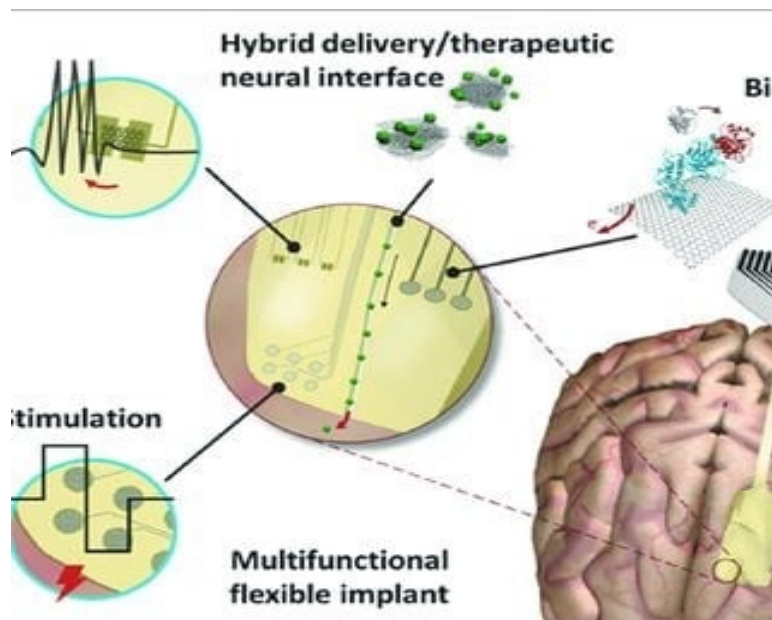


Figure 1: Graphene-Based Neural Interfaces [2]

The integration of graphene and adaptive AI has demonstrated promising applications in assistive communication devices, robotic prosthetics, rehabilitation technologies, and neurological disorder management. Graphene-based electrodes offer cleaner and more stable neural recordings, and adaptive AI systems provide better signal classification, motor control and real-time response based on individual neural patterns. These technologies can increase the quality of life of people who are paralyzed, have neurodegenerative diseases, speech problems, and mobility issues [3]. Yet, these developments have created other challenges, such as long-term biocompatibility, data privacy in the brain, transparency of algorithms and clinical regulation, which need to be further explored. Hence, future research is needed across various disciplines to develop safe, ethical, and effective graphene-AI neural systems for healthcare applications.

1.1 Background Information and Context

The recent advances in neurotechnology, nanomaterials, and Artificial Intelligence (AI) have significantly changed the brain-computer interface (BCI), neuroprosthetics and intelligent healthcare systems development. Graphene has attracted significant interest as an emerging nanomaterial, owing to its outstanding electrical conductivity, mechanical flexibility, transparency, light weight and biocompatibility and is a promising material for neural interface applications. At the same time, adaptive artificial intelligence (AI) systems have improved the ability to interpret and process complex neural signals via machine learning and real-time

adaptive learning ^[4]. The combination of graphene-based neural interfaces with adaptive AI systems is a groundbreaking interdisciplinary effort that seeks to enhance the connectivity between neural and artificial systems, facilitate human-machine interaction, and develop personalized neurorehabilitation solutions. The human-centered studies have shown potential in neural monitoring, prosthetic control, assistive communication devices, and cognitive assessment devices.

1.2 Objectives of the Review

This review aims to examine:

- To examine the structural, functional, and biocompatible properties of graphene-based neural interfaces in human-centered neurotechnology applications.
- To analyze the role of adaptive artificial intelligence systems in neural signal processing, brain-computer interfaces, and neuroprosthetic control.
- To evaluate the integration of graphene neural interfaces with adaptive AI for improving rehabilitation, assistive healthcare, and personalized neurotherapy.
- To investigate the clinical safety, ethical concerns, neural data privacy, and regulatory challenges associated with graphene-AI neural systems.
- To identify current limitations, future research directions, and opportunities for the development of advanced human-centered neurotechnological solutions.

1.3 Importance of the Topic

Incorporating graphene nanotechnology with adaptive AI could transform healthcare, neurological rehabilitation, and assistive technology, potentially creating more responsive, adaptive, and personalized neural systems. These technologies have the potential to greatly enhance the quality of life for people with mobility challenges, speech difficulties, neurodegenerative diseases, and paralysis. In addition, graphene-AI systems can enable long-term monitoring of brain activity, smart prosthetic systems, and even enhanced brain health services ^[5]. While these achievements have been made, significant issues of long-term safety, neural data privacy, algorithmic transparency, and regulatory approval still need to be addressed, underscoring the need for further interdisciplinary research and ethical clinical trials in this rapidly developing area.

2. GRAPHENE NEURAL INTERFACES AND ADAPTIVE AI: ADVANCEMENTS IN HUMAN-CENTERED NEUROTECHNOLOGY

Neural interfaces and adaptive AI systems, when combined with graphene technology, mark a significant milestone in the advancement of neurotechnology and human-centric healthcare. Excellent electrical conductivity, flexibility, biocompatibility and stable neural signal recording properties make graphene to be very suitable for wearable and implantable neural devices. Simultaneously, adaptive AI systems enhance the interpretation of neural signals, real-time learning, speech decoding, control of prosthetics, and brain-computer interface performance ^[6].

2.1 Graphene-Based Neural Interfaces

Structural and Functional Properties of Graphene

The properties graphene has made its use highly suited to neural interface application:

- Ability to conduct electricity efficiently, allowing neural signals to be transmitted effectively.
- Biointegrated shape and size for conformal contact with brain tissue
- Optical transparency to assist simultaneous imaging and recording
- The resistance to chemical reactions and corrosion.
- Lightweight ultra-thin architecture
- High surface area and high sensitivity of electrodes.

Graphene is widely used by human-centered wearable neural sensors because it is able to record bioelectrical signals for extended periods and while the sensor is in motion.

Types of Graphene Neural Interfaces

- **Implantable Graphene Electrodes:** Flexible graphene electrodes have been studied for human neurosurgical recordings of the cortex. These interfaces show less tissue irritation and better signal resolution than stiff metal electrodes.
- **Wearable Graphene Sensors:** EEG systems based on graphene are also considered as non-invasive neural monitoring systems that can be used in wearable devices. There are no conductive gels required in dry graphene electrodes, which not only enhance patient comfort but are also user-friendly for long-term applications [7].
- **Transparent graphene neural array:** 2D transparent graphene neural array for simultaneous neural recording and optical imaging for multimodal brain monitoring in clinical neuroscience research.

Human-Based Research Findings

Clinical and pilot studies have been carried out to establish that graphene electrodes can perform:

- Lower electrode-skin impedance
- More stable EEG signals
- Results in improved comfort for long-term monitoring.
- Enhanced flexibility for wearable applications.
- Increased flexibility for wearable applications.
- Lower inflammatory reactions in short-term studies of implants

Most of the studies with humans, however, are still small and at the pilot scale.

2.2 Adaptive AI Systems in Neural Control

AI-Based Neural Signal Processing

Adaptive AI systems rely on machine learning algorithms for deciphering the patterns of neural activity. Common AI Methodologies are:

- Artificial neural networks (ANNs)
- Convolutional neural networks (CNNs)
- Recurrent neural networks (RNNs)

- Reinforcement learning
- Deep learning classifiers
- Transfer learning algorithms

These techniques allow the decoding of neural signals in real-time for communication and motor control.

Real-Time Adaptive Learning

One of the major advantages of adaptive AI systems is their ability to continuously learn from user-specific neural patterns. Unlike static algorithms, adaptive AI can adjust the algorithms of decoding based on changes in neural activity, fatigue, emotional state or environment [8].

Adaptive BCIs have been shown to lead to greater accuracy in human studies for:

- Speech decoding
Cursor control
- Robotic arm movement
- Prosthetic limb coordination
- Cognitive workload assessment

2.2.3 Strengths and Weaknesses of AI Integration

Strengths

- **Personalized Neural Decoding:** Adaptive AI is able to analyze neural activity individually from one person and customize their decoding process based on their neural signatures uniquely. In addition to that, adaptive AI increases the efficiency and effectiveness of BCIs and neuroprosthetics as well. This technology will be greatly beneficial for humans, as it can learn to adapt to individual differences between people.
- **Faster Response Times:** Artificial intelligence-based neural networks are able to process extensive neural data sets in real-time, making it possible for them to be interpreted and executed instantaneously. This speed in computation is especially crucial for practical uses like robotic prostheses, communicative technology, and mobility assistance systems [9].
- **Improved Signal Classification Accuracy:** Modern machine learning and deep learning models have the capacity to detect sophisticated neural patterns in a highly accurate manner. The use of adaptive artificial intelligence technologies allows for better classification of electroencephalography (EEG) and other neural signals through noise reduction and separation of relevant neural processes from irrelevant ones.

Weaknesses

- **High Computational Requirements:** Deep Learning models and other forms of adaptive AI algorithms need powerful computational capabilities to process information from the brain. The addition of high-performance computer chips might cause more

complications concerning portability, energy use, and costs. This issue could have negative implications for wearable or implantable devices in the field of neural engineering.

- **Big Datasets Needing Extensive Amounts of Time:** AI-based programs generally require large sets of data for training purposes. The collection of relevant data from human neural activity is challenging and costly. Insufficient data for training would make the algorithm unreliable, thereby limiting its application among a wider population of patients ^[10].
- **Bias in Neural Decoding Algorithms:** AI technologies have a possibility of being biased depending on the quality of training data used. The bias generated by the algorithm can make the technology perform poorly among people with varied neurological problems, age differences, or cognitive traits.

3. ADVANCEMENTS, SAFETY, AND ETHICAL PERSPECTIVES IN GRAPHENE-BASED ADAPTIVE NEURAL SYSTEMS

Neural interfacing of graphene material with adaptive artificial intelligence technology has made significant advancements in neurotechnology that is more geared towards humans by enhancing brain-computer interfaces, neuro-prosthetics, and assistive healthcare technologies ^[11]. Graphene ensures quality neural interfacing with flexibility and bio-compatibility whereas adaptive artificial intelligence improves interpretation and analysis of brain signals. However, several issues still need to be addressed such as safety, security, privacy, and regulation.

3.1 Integration of Graphene Interfaces with Adaptive AI

The combination of graphene electrodes with adaptive AI models has greatly enhanced the efficiency of BCIs ^[12]. As a result of the superior electrical conductivity and flexibility of graphene, as well as its high biocompatibility, graphene electrodes make possible clearer and more consistent neural signal recording than traditional electrodes do. Such a high-quality input enables the AI system to analyze neural activity much more precisely. For instance, experiments using BCIs have achieved faster information transfer, increased ability to recognize motor imagery, lower noise levels, and higher usability. Adaptive AI models can adapt to changes in the neural activity that occur because of motion, emotions, or tiredness, among other reasons ^[13].

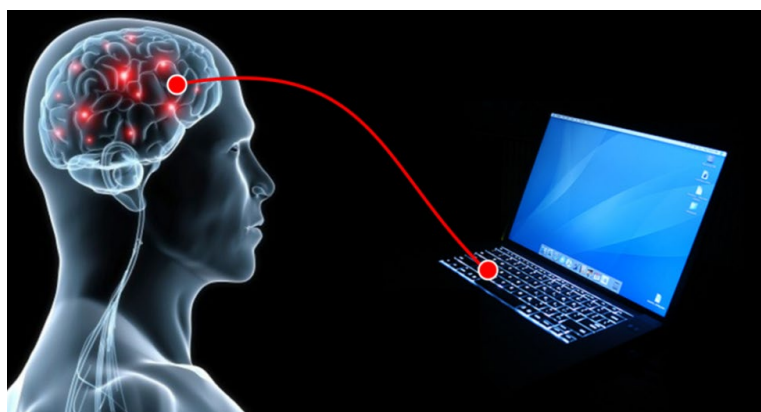


Figure 2: Brain–Computer Interfaces (BCIs) ^[14]

The use of adaptive AI in combination with graphene is also very promising in neuroprosthetics and assistive technologies ^[15]. Neural instructions detected by means of graphene interfaces and processed using artificial intelligence will be able to result in accurate movements performed by an AI-controlled prosthetic limb. Some examples of clinical application can be intelligent prosthetic arms, communication aids for people with speech impairments, exoskeletons controlled by artificial intelligence, and mobility aid devices. Graphene sensors provide additional advantages in terms of flexibility and accuracy, whereas adaptive AI increases precision and responsiveness of movements ^[16].

3.2 Biocompatibility and Safety Considerations

There are many features of graphene that help it become an ideal candidate for use in neural interfaces ^[17]. First, the ultra-thinness and flexibility of the material allow avoiding mechanical incongruity between the material and the soft neural tissues and, hence, ensuring comfort and preventing additional stresses on neighboring cells while recording neural signals from within the brain. The existing research carried out on humans indicates that graphene-based interfaces have the ability to prevent inflammation, irritation, improve conformability, and ensure stable functioning of electrodes.

Despite these advantages, many clinical safety issues persist that need to be addressed. These issues involve the potential side effects of the biodegradation process in graphene materials, the risk of nanomaterial accumulation in the human body, inconsistent synthesis techniques for graphene materials, and inconsistent quality control processes when manufacturing devices. Furthermore, there has been no clinical validation on the long-term effects of graphene neural interfaces after implantation in the human brain. Most of the research that supports this topic involves short-term testing among humans ^[18].

3.3 Ethical and Regulatory Challenges

AI-aided neural networks produce vast amounts of extremely sensitive neurologically and cognitively personal information, thus creating neural data privacy issues from an ethical point of view ^[19]. The leakage of this kind of information could have a severe effect on personal autonomy and privacy of cognitive states, especially where continuous brain monitoring is required. The risks here include potential brain surveillance, data ownership ambiguities, cybersecurity threats, and difficulties achieving full informed consent from users of the technology. As the brain information is likely to contain thoughts, emotions, behaviors, or cognitive intent, there must be effective ways to secure the information.

An additional issue that exists is related to the transparency in the algorithms used for adaptation in artificial intelligence applications ^[20]. The reason is that many AI applications function through black-box methods, where the decision-making procedure is not easy to understand. The problem with the above-mentioned issue is that it might create difficulties when validating the neural interpretations or treatment plans made by such algorithms. In medical settings, the inability to interpret algorithms can negatively affect the trust levels between practitioners, patients, and machines ^[21].

The combination of graphene nanomaterials with adaptive AI technologies also poses difficult regulatory issues [22]. These issues include the setting of regulatory pathways for medical approvals, the undertaking of thorough safety testing, the delineation of AI responsibility criteria, and the adherence to international rules on biomedical devices. Regulatory bodies will need to consider not only the safety of graphene-based neural interface devices but also the ethical considerations in relation to AI decision-making systems [23]. Nevertheless, full regulatory guidelines for such hybrid graphene-AI neurotechnologies are currently being formulated.

4. HUMAN-CENTERED CLINICAL TRANSLATION AND PERSONALIZED NEUROTHERAPY

The incorporation of graphene-based neural interfaces in conjunction with adaptive AI technologies has been playing a key role in advancing personalized neurotherapeutic options that can benefit the health care industry [24]. The aim here is to transition neurotechnologies from laboratories to patient-oriented technologies, which are aimed at advancing neurological diagnosis, rehabilitation, and treatments. Individualized neurotherapy involves neural modulation, personalized rehabilitation techniques, and advanced patient monitoring [25].



Figure 3: Neurotherapy [26]

Graphene-based neural devices have great potential to be translated into clinical practice thanks to their flexibility, lightweight nature, and enhanced electrical sensitivity [27]. They enable non-invasive continuous neural monitoring, which results in better tolerance in humans. Furthermore, once integrated with an adaptive AI system, these devices will allow for the analysis of neural activity in each patient, leading to personalized treatment based on the results obtained.

An adaptive AI system is capable of learning from the reactions of patients throughout the therapy process, making it possible to make adaptive changes in the degree of stimulation, movement support, or even the interpretation of language signals [28].

In addition to that, it is important to note the possibility for remote healthcare monitoring by using graphene-based neuro-devices. Patients would be able to have their brain activity assessed

without leaving hospitals, which allows for early diagnosis of neuro disorders and helps avoid unnecessary workload [29].

However, even with all these advancements, there are some limitations that come with the clinical application of neurotechnology. First, most research has been performed within lab settings using only a few human subjects. Issues related to device stability, regulation, standardization, and ethical handling of neural information persist as obstacles to its adoption [30].

Table 1: Summary of Literature on Graphene-Based Biocompatible and Neural Interface Technologies [31]

Author(s) & Year	Study Focus	Methodology/Approach	Key Findings
Rodríguez Meana (2023) [32]	Biocompatibility and functionality of graphene-based neural interfaces in biomedical applications	Review-based analysis of graphene neural interface technologies and biomedical performance	Reported that graphene exhibited excellent electrical conductivity, flexibility, and neural tissue compatibility. The study found reduced inflammatory responses and improved signal transmission compared to conventional electrodes, while emphasizing surface modification for long-term implant stability and safety.
Sabet & Sabet (2025) [33]	Biocompatible graphene-polymer composites for biomedical and environmental applications	Literature review of graphene-polymer composite fabrication and applications	Identified enhanced mechanical strength, thermal stability, antimicrobial activity, and conductivity in graphene-polymer composites. The study highlighted applications in tissue engineering, biosensors, drug delivery, water purification, and pollutant removal, while discussing challenges related to toxicity and sustainability.
Sarkar et al. (2025) [34]	Graphene-hydrogel biointerfaces and translational	Comparative review of graphene-hydrogel design frameworks and	Demonstrated that graphene-hydrogel systems improved flexibility,

	biomedical pathways	biomedical integration	conductivity, hydration, and cellular compatibility. The study reported enhanced cell adhesion, tissue regeneration, and neural communication, while identifying translational barriers such as manufacturing complexity and regulatory concerns.
Tabish et al. (2025) ^[35]	Low-dimensional nanoarchitectonics for neurochemical sensing and neurological modulation	Review of nanoscale engineering approaches for neurotechnology applications	Found that graphene-based nanostructures significantly improved neurochemical sensing sensitivity, selectivity, and real-time monitoring. The study emphasized applications in neural modulation, brain-machine interfaces, and personalized neurological therapies with improved biocompatibility.
Tariq et al. (2022) ^[36]	Synthesis and applications of graphene and graphene-based nanocomposites using conventional and AI-assisted approaches	Comprehensive review of graphene synthesis techniques and AI integration	Reported exceptional physicochemical properties of graphene nanocomposites, including high conductivity, surface area, and durability. The study highlighted the role of artificial intelligence in optimizing synthesis, characterization, and performance prediction, thereby accelerating graphene technology development.

Future innovations in personalized neurotherapy will certainly involve the convergence of explainable AI algorithms, secure cloud computing of neural data, low-power wearables, and reproducible methods of graphene manufacturing^[37]. It will also be necessary to maintain close cooperation between healthcare practitioners, neuroscientists, biomedical engineers, and AI experts in order to deliver safe neurotechnology solutions.

5. DISCUSSION

Combining the capabilities of graphene-enabled neural interfaces with adaptive artificial intelligence technologies has been very beneficial for both neurotechnology and personalized medicine. This is because of the superior qualities provided by graphene such as conductivity, flexibility, biocompatibility, and neural signal recording, combined with adaptive algorithms that facilitate better signal decoding and improve real-time learning as well as the effectiveness of rehabilitation therapies [38].

5.1 Interpretation and Analysis of the Findings

As shown by the results of this review, the use of graphene-based neural interface integration with adaptive AI systems is considered an important achievement in the field of human-centric neurotechnology and personalized medicine. Graphene materials exhibit outstanding characteristics, including high electrical conductivity, flexibility, light weight, transparency, and biocompatibility, thus making them ideal candidates for development of neural interface implants. Human-centric research shows that the application of graphene electrodes is effective in enhancing neural signal quality, reducing electrode-skin impedance, ensuring comfort while using them, and achieving stable neural recording. Meanwhile, adaptive AI systems have helped in improving neural signal analysis via machine learning, deep learning, and adaptive real-time processing.

5.2 Implications and Significance

Graphene and adaptive AI have a number of significant clinical and technical implications in modern medicine. Neural systems powered by adaptive artificial intelligence will help people who suffer from paralysis, neurodegeneration, speech disabilities, and other conditions with fast and accurate signal processing, neural decoding, more precise motor control, and adaptability during rehabilitation [39]. Adaptive AI and graphene materials can be used in wearable technologies that will enable continuous neural monitoring and remote medical care to create new tele-neurology and neurotherapy systems. Graphene materials can improve patient comfort and adaptability of medical devices to individual patients through increased sensitivity and flexibility. At the same time, adaptive AI technology can respond differently depending on the individual's neural activity and surrounding environment.

5.3 Research Gaps and Future Direction

However, there are still many limitations that need to be addressed. Firstly, most of the existing human-focused studies suffer from having too small sample sizes, short-term experiments and being at a prototype stage, which restricts their applicability to real-life scenarios. Further studies should explore long-term issues such as biocompatibility and biodegradation of nanoparticles, nanomaterial accumulation and the safety of prolonged implants through clinical trials [40]. Additionally, ethical issues associated with neural data protection, cybersecurity, informed consent and transparency of artificial intelligence algorithms should not be overlooked. Furthermore, an absence of regulation makes the translation of these neural networks into clinical use problematic.

6. CONCLUSION

This review demonstrates that the combination of graphene-based neural interfaces with adaptive artificial intelligence technology is the great breakthrough in neurotechnology and personalized healthcare based on human-centered technology. Graphene can be used successfully in wearables and implantable neural devices because of its unique electrical properties, flexibility, transparency, lightness, and biocompatibility, whereas adaptive artificial intelligence increases the efficiency in interpreting neural signals, real-time learning, personalized signal decoding, and rehabilitation results. The review shows that the technologies described above have found their use in brain-computer interface devices, neuroprosthetics, assistive speech technologies, and personalized neurotherapy. The technologies allow enhancing brain monitoring, motion control, speech decoding, and rehabilitation results. In addition, the technologies under consideration can significantly improve people's quality of life with such conditions as paralysis, neurodegenerative diseases, speech disorders, and locomotion disabilities. Still, this review emphasizes the challenges associated with long-term biocompatibility, neural data security issues, cybersecurity, algorithm transparency, and regulatory approval that should be explored further. Thus, the continuous research from various disciplines, human trials, governance, and technology standardization are crucial for safe and efficient future healthcare innovations.

REFERENCES

1. Ai, Q., Zhao, M., Chen, K., Liu, Q., He, D., Li, Z., & Ma, L. (2024). Development and application of graphene sensors in human-computer interaction: a review. *IEEE Sensors Journal*, 24(6), 7406-7419.
2. Alahi, M. E. E., Rizu, M. I., Tina, F. W., Huang, Z., Nag, A., & Afsarimanesh, N. (2023). Recent advancements in graphene-based implantable electrodes for neural recording/stimulation. *Sensors*, 23(24), 9911.
3. Ayad, A. (2025). Bioinspired NeuroPods: AI-Enhanced 4D Composite Bioprinting Revolutionizing Brain-on-Chip and Neural Regeneration. Preprint, July, 23, 10-20944.
4. Bhardwaj, S. K., Mujawar, M., Mishra, Y. K., Hickman, N., Chavali, M., & Kaushik, A. (2021). Bio-inspired graphene-based nano-systems for biomedical applications. *Nanotechnology*, 32(50), 502001.
5. Bramini, M., Alberini, G., Colombo, E., Chiacchiarretta, M., DiFrancesco, M. L., Maya-Vetencourt, J. F., ... & Cesca, F. (2018). Interfacing graphene-based materials with neural cells. *Frontiers in systems neuroscience*, 12, 358913.
6. Cai, M., Sun, H., Yang, T., Hu, H., Li, X., & Jia, Y. (2025). Continuous monitoring with AI-enhanced BioMEMS sensors: a focus on sustainable energy harvesting and predictive analytics. *Micromachines*, 16(8), 902.
7. Cui, T., Li, D., Hirtz, T., Xu, J., Qiao, Y., Xu, H., ... & Ren, T. L. (2024). Graphene-based sensors for human-machine interaction. *Carbon Future*, 1(1), 9200005-1.
8. Das, S., Mazumdar, H., Khondakar, K. R., & Kaushik, A. (2025). Machine learning integrated graphene oxide-based diagnostics, drug delivery, analytical approaches to empower cancer diagnosis. *BMEMat*, 3(1), e12117.

9. Debnath, S., Debnath, T., Moni, M. A., & Paul, M. (2025). Biocompatibility of graphene-based materials. In *Graphene in Wearable Sensors for Health Monitoring* (pp. 51-62). Singapore: Springer Nature Singapore.
10. Esan, A. O., Akinsanmi, O., Ayeoribe, O. P., Omodunbi, B. A., & Ayeoribe, A. E. (2025). ELECTRONIC GRAPHENE AND GOLD NANOPARTICLE BIOMEDICAL ELECTRODES FOR IMPROVED CLINICAL SIGNAL QUALITY. *International Journal of Electronics, AI & Robotics*, 1(1), 43-52.
11. Feng, Z. (2025). Multidisciplinary integration and application in Brain-Computer Interface (BCI) technology. *Science and Technology of Engineering, Chemistry and Environmental Protection*, 1(1).
12. Gou, S., Yang, S., Cheng, Y., Yang, S., Liu, H., Li, P., & Du, Z. (2024). Applications of 2D nanomaterials in neural interface. *International Journal of Molecular Sciences*, 25(16), 8615.
13. Gungordu Er, S., & Edirisinghe, M. (2025). Graphene for self-powered biosensors: a perspective. *Journal of The Royal Society Interface*, 22(233).
14. Guo, X., Zhang, Z., Ren, Z., Li, D., Xu, C., Wang, L., ... & Lee, C. (2025). Advances in Intelligent Nano-Micro-Scale Sensors and Actuators: Moving Toward Self-Sustained Edge AI Microsystems. *Advanced Materials*, 37(50), e10417.
15. Huang, M., Li, Z., & Zhu, H. (2022). Recent advances of graphene and related materials in artificial intelligence. *Advanced Intelligent Systems*, 4(10), 2200077.
16. Karbalaee Akbari, M., Siraj Lopa, N., Shahriari, M., Najafzadehkhoe, A., Galusek, D., & Zhuiykov, S. (2023). Functional two-dimensional materials for bioelectronic neural interfacing. *Journal of Functional Biomaterials*, 14(1), 35.
17. Khondakar, K. R., Tripathi, D., Mazumdar, H., Ahuja, K., & Kaushik, A. (2024). Tailored MXenes and graphene as efficient telemedicine platforms for personalized health wellness. *Materials Advances*, 5(10), 4091-4111.
18. Kim, Y., Lee, H., Lee, J., Shin, M., & Son, D. (2025). Tissue-like bioelectronic material strategies for personalized closed-loop neuroprostheses. *ACS nano*, 19(27), 24621-24652.
19. Kumar, R., Rauti, R., Scaini, D., Antman-Passig, M., Meshulam, O., Naveh, D., ... & Shefi, O. (2021). Graphene-based nanomaterials for neuroengineering: recent advances and future prospective. *Advanced Functional Materials*, 31(46), 2104887.
20. Li, M., Mao, A., Guan, Q., Xu, Y., Li, C., Lu, G., & Saiz, E. (2025). Nature-Inspired Innovation in Electrical Engineering Technologies and Applications. *Advanced Science*, 12(48), e12250.
21. Liu, G., Lv, Z., Batool, S., Li, M. Z., Zhao, P., Guo, L., ... & Han, S. T. (2023). Biocompatible material-based flexible biosensors: from materials design to wearable/implantable devices and integrated sensing systems. *Small*, 19(27), 2207879.
22. Liu, S., Li, X., Gan, L., Liu, S., Luo, H., Du, X., ... & Li, C. (2024). Carbon-based implantable bioelectronics. *Applied Physics Reviews*, 11(3).
23. Lopes, V., Moreira, G., Bramini, M., & Capasso, A. (2024). The potential of graphene coatings as neural interfaces. *Nanoscale Horizons*, 9(3), 384-406.

24. Lu, Y., Liu, X., & Kuzum, D. (2018). Graphene-based neurotechnologies for advanced neural interfaces. *Current Opinion in Biomedical Engineering*, 6, 138-147.
25. Ma, J., Yang, S., Yang, Z., He, Z., & Du, Z. (2025). Functional nanomaterials for advanced bioelectrode interfaces: recent advances in disease detection and metabolic monitoring. *Sensors*, 25(14), 4412.
26. Mahalakshmi, M., Diana, D. C., Ramachandran, R., Ravva, S. K., Illuri, B., Johannah, J. J., ... & Anand, A. J. (2025). Review on carbon-based micro and nano electro-mechanical systems for biotechnological application. *Recent Patents on Nanotechnology*, 19(4), 468-482.
27. Molokanova, E., Zhou, T., Vasupal, P., Cherkas, V. P., Narute, P., Ferraz, M. S., ... & Savchenko, A. (2025). Non-genetic neuromodulation with graphene optoelectronic actuators for disease models, stem cell maturation, and biohybrid robotics. *Nature Communications*, 16(1), 7499.
28. Mudhulu, S., Channegowda, M., Balaji, S., Khosla, A., & Sekhar, P. (2023). Trends in graphene-based e-skin and artificial intelligence for biomedical applications—a review. *IEEE Sensors Journal*, 23(17), 18963-18976.
29. Pang, J., Peng, S., Hou, C., Zhao, H., Fan, Y., Ye, C., ... & Cuniberti, G. (2023). Applications of graphene in five senses, nervous system, and artificial muscles. *ACS sensors*, 8(2), 482-514.
30. Prakash, G., Kumar, K., Parmar, B., Sharma, A., Vyas, A., Goel, A., ... & Bhatia, D. (2025). DNA and Graphene-Based Nanomaterial Applications in Stem Cell Therapeutics and Regeneration. *ACS Biomaterials Science & Engineering*, 11(11), 6386-6400.
31. Rawat, S., Phogat, P., Sharma, S., Jha, R., & Singh, S. (2025). Smart and Adaptive Bionanocomposite Materials Processing and Fabrication. In *Advanced Bionanocomposite Materials: Innovations for Sustainable Development* (pp. 125-179). Singapore: Springer Nature Singapore.
32. Rodríguez Meana, B. (2023). Biocompatibility and functionality of graphene-based neural interfaces.
33. Sabet, M., & Sabet, S. (2025). Biocompatible graphene polymer composites: New frontiers in biomedical and environmental applications. *Polymer-Plastics Technology and Materials*, 64(9), 1282-1314.
34. Sarkar, G., Bhowmick, K., Acharya, P., Adak, N. C., Chakraborty, M., Chattopadhyay, D., & Ghosh, T. K. (2025). Graphene–hydrogel biointerfaces: Comparative design frameworks and translational pathways in biomedicine. *Next Bioengineering*, 1, 100005.
35. Tabish, M., Malik, I., Akhtar, A., & Afzal, M. (2025). A review on low-dimensional nanoarchitectonics for neurochemical sensing and modulation in responsive neurological outcomes. *Biomolecules*, 15(10), 1405.
36. Tariq, W., Ali, F., Arslan, C., Nasir, A., Gillani, S. H., & Rehman, A. (2022). Synthesis and applications of graphene and graphene-based nanocomposites: Conventional to artificial intelligence approaches. *Frontiers in Environmental Chemistry*, 3, 890408.
37. Ullah, A., Kim, D. Y., Lim, S. I., & Lim, H. R. (2025). Hydrogel-Based Biointerfaces: Recent Advances, Challenges, and Future Directions in Human–Machine Integration. *Gels*, 11(4), 232.

38. Wang, C., He, T., Zhou, H., Zhang, Z., & Lee, C. (2023). Artificial intelligence enhanced sensors-enabling technologies to next-generation healthcare and biomedical platform. *Bioelectronic Medicine*, 9(1), 17.
39. Yang, G., Zheng, Y., & Tian, B. (2025). Perspective on Nano-Enabled Photostimulation Biointerfaces. *ACS nano*, 19(23), 21189-21205.
40. Youvan, D. C. (2025). Quantum Intelligence-Driven Nano-Cyborgs: Integrating Advanced Qubit Materials for Next-Generation Bio-Computing and Medical Applications.