Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 04, April-2025

Advancing Memristor Technology: A Systematic Literature Review

Dr. Priya Charles
Associate Professor,
Semiconductor Engineering,
Dr D Y Patil International University,
Akurdi, Pune-411044, India

Vishakha Bhosle
Electronics and Telecommunication Engineering,
Dr D Y Patil Institute of Engineering,
Management and Research,
Akurdi, Pune-411044, India

Radhika Dangare
Electronics and Telecommunication Engineering,
Dr D Y Patil Institute of Engineering,
Management and Research,
Akurdi, Pune-411044, India

Madhura Chaudhari
Electronics and Telecommunication Engineering,
Dr D Y Patil Institute of Engineering, Management and Research,
Akurdi, Pune-411044, India

Abstract

This systematic literature review looks at recent progress in memristor research. It focuses on materials, making methods, uses, and problems that slow down large-scale use. Memristors, a key part of circuits, have a special ability to switch resistance without losing data. This makes them useful in many areas, like energy-saving computing, memory that can keep data without power (ReRAM), and brain-like systems. Even with big advances in creating and improving memristors, issues such as material strength, making them in large numbers, mixing them with standard tech, and lasting a long time still block their full market use. This review covers over 75 studies published from 2010 to 2023, organizing the research into three main areas: (1) ways to make them and new materials, (2) their uses in new tech like brain-like computing and memory that does not lose data, and (3) the challenges that stay, which include making them on a large scale, being dependable, and fitting with usual systems. The main conclusions show that although metal oxides, especially titanium dioxide (TiO_2) and hafnium oxide (HfO_2), are the focus of most current research because of their advantageous switching properties and ease of fabrication, new materials like organic semiconductors and 2D materials (like graphene oxide, MoS_2) present promising substitutes for memristive devices that are quicker, more scalable, and use less energy. The review ends by pointing out important gaps in the literature, especially with regard to hybrid device integration and long-term stability, and offering specific suggestions for further study to overcome these obstacles.

Keywords: **NVM, SLR, neuromorphic, memristors, etc.**

1. INTRODUCTION

A basic type of two-terminal electronic components, memristors were first conceived by Leon Chua in 1971 and have a special link between charge and magnetic flux (Mazumder et al., 2012; Corinto et al., 2021). Because of their unique characteristics, they are now regarded as the fourth essential passive circuit component, joining the well-known resistors, capacitors, and inductors (Radwan & Fouda, 2015; Trefzer, 2017). Memristors have a resistance that varies according to the voltage and current history given to them, in contrast to traditional resistive devices that have a fixed resistance (Chua, L. 2019; Jeong et al., 2012). Even when power is cut off, memristors can retain knowledge about previous electrical states thanks to this memory-dependent property (Domaradzki et al., 2020; Barraj et al., 2024). This generated much interest in a number of potential applications including non-

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 04, April-2025

volatile memory systems, logic circuits, and neuromorphic computing platforms in which this property to "remember" previous states is exploited for more efficient and adaptive processing (Upadhyay et al., 2019). Recent advances include key progress in the past decade on understanding basic physical principles of memristors and new approaches to material fabrication that make it possible to practically implement such devices (Sun et al., 2021). Of late, therefore, such recent advances have led to an increased interest in exploiting their capabilities across a vast array of applications from high-density memory storage applications to applications in the intelligent computing systems (Zhu et al., 2023; Mzukwa, A. 2024). Despite these promising advances, there are challenges to the optimization of memristive devices for large-scale applications (Song et al., 2023; Zidan et al., 2018). The major hurdles in this regard comprise the problem of scaling, material stability, and interference issues between memristors and the already established semiconductor technology toward the creation of large-scale, commercially viable memristive systems (Jacob et al., 2017; Kim et al., 2024). This review will focus on providing an integral and well-structured overview of the current state of art concerning research in memristor areas, and they are divided into three major streams: first, general development concerning fabrication techniques of memristors and new materials that could enhance the performance of the devices; second, applications of memristors in new and emerging fields of technologies such as the spectrum put forward by Mazumder et al., 2012; third, the current active challenges and potential future directions for the advancement toward practical and scalable forms of memristive systems by Xu et al., 2024. Through this analysis, we hope to gain a deep perspective on the opportunities and hurdles in the continued evolution of memristor technology (Yang et al., 2022; Kumar et al., 2022).

2. METHODOLOGY

To perform a complete and unbiased review of literature regarding memristor technologies, a systematic search was done for articles across the most prominent academic databases, namely Google Scholar, IEEE Xplore, Scopus, and Web of Science, (Dawarka et al., 2022; Vassanelli et al., 2016). Articles published between 2010 and 2023 were considered, as that period has been very rich in terms of advancements with respect to research on memristors (Morales et al., 2024). The search terms used included "memristor," "memristive devices," "memristor applications," "non-volatile memory," "neuromorphic computing," and "memristor fabrication" (Yu et al., 2024). These were the terms used as they would enable the gathering of broad studies related to memristor technologies, from fundamental research to practical applications, by Thakkar et al., (2024) and Yang et al., 2022. Articles that were to be selected were based on specific inclusion and exclusion criteria as Saha et al., (2021) suggests. These inclusion criteria emphasized peer-reviewed journal articles, conference papers, and patents specifically related to memristor technologies: material innovations, characteristics of devices, and applications (Gutiérrez-Martínez et al., 2020). It also covered studies offering experimental, simulation, or theoretical insights related to memristor behavior and performance (Chaurasiya et al., 2024). On the contrary, sources like patents or articles in popular science would not be of use as they lacked academic rigor, similar to Wenaas L (2022). Articles that did not have appropriate technical content for this review or were not specific to memristor-based devices were also excluded. Collectively, 75 articles were selected for this paper in ensuring a representative outline, though broad, of the current state of affairs. For conducting systematic data extraction, the primary research themes on memristor fabrication techniques, material progresses, device performance, and emerging applications until 2024 were derived. Such synthesis entailed completion and updating requirements as of now and thus reveals both the progress achieved and yet the challenge in store in memristor technologies.

3. RESULTS

3.1 Memristor Fabrication and Materials

The material used in constructing memristors determines the switch speed, endurance, and scalability of the device, and thus, it is directly proportional to its performance (Wang et al., 2020; Song et al., 2023; Zhang, 2023). So far, many materials have been studied, but only metal oxides are most largely used due to well-characterized properties as well as ease of fabrication. Nonetheless, recent attention has been shifted to research and development of such alternatives, based on organic compounds and 2D materials that include graphene and TMDs, which have demonstrated the possibility of faster switching times, smaller power consumption, and scalability (Choudhary, 2018).

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 04, April-2025

3.1.1 Metal Oxides

Metal oxides, particularly Titanium Dioxide (TiO_2), are the most extensively studied materials for memristor fabrication (Ranjan, S. 2020). TiO_2-based memristors are known for their high endurance and non-volatile memory characteristics, which make them suitable for memory applications (Inglese, P. 2023). The main reason behind the resistance switching behavior in TiO_2 memristors is the migration of oxygen vacancies, which can be adjusted by using voltage pulses (Bousoulas et al., 2014; Nagata et al., 2019). Besides TiO_2, other oxides of Hafnium Oxide (HfO_2) and Zirconium Oxide (ZrO_2) have also been examined as they show faster switching speeds and better thermal stability than other memristive materials (Liu et al., 2019; Miao et al., 2017).

• Titanium Dioxide (TiO_2): TiO_2 is well recognized for excellent switching performance non-volatility, and ease of depositions, and has the widest use in memristor fabrication because of its particular properties (Miao et al., 2017). However, devices based on TiO_2 suffer from variability at switch and long-term stability issues that develop after cycles.

• Hafnium Oxide (HfO_2): Memristors based on HfO_2 have shown promise, including high switching speeds and scalability toward high density memory applications (Zhang et al., 2016). However, in general, these devices are fabricated with more complex processes than for TiO_2-based memristors.

3.1.2 Organic Materials

Organic materials, especially conducting polymers such as Polyaniline (PANI) and Poly(3,4-ethylenedioxythiophene) (PEDOT), have attracted interest for memristor applications with low cost and flexibility (Ouyang, J. 2021; Allendorf et al., 2020). Organic memristors can be ideal for use in flexible electronics, wearable devices, and soft robotics. Organic memristors tend to have lower endurance, slower switching speeds, and other problems related to reproducibility compared to their inorganic counterparts (Wang et al., 2019).

• Polyaniline (PANI): Memristors based on PANI are emerging as promising flexible memory devices, but the instability and lack of reproducibility in device stability are openly raised issues of concern (Wang et al., 2019; Gogoi et al., 2021; Franco et al., 2024).

3.1.3 2D Materials

Two-dimensional (2D) materials, such as graphene and transition metal dichalcogenides (TMDs), have gained significant impetus in memristor research due to their outstanding electronic characteristics (Batool et al., 2022; Ganeriwala et al., 2024). They are claimed to be highly capable of attaining ultrahigh speed and low power consumption potential with the prospect of strong integration density (Beausoleil, R. G. 2011; Hepel, M. 2023).

GO-based research on memristors presents encouraging outcomes, especially for the development of high-speed and low-power switching devices. Its applications look promising (Yu et al., 2018; Romero et al., 2020; Bertolazzi et al., 2019).

• Graphene Oxide (GO): GO-based memristor has immense potential in terms of fast switching speed and low power consumption, promising their eventual applications in high-density memory devices (Yu et al., 2018; Khurana et al., 2018).

3.2 Applications of Memristors

Memristors have been applied differently, particularly in the areas of memory storage, logic circuits, and neuromorphic computing. Information that is both stored and computed in one single device has generated a wide interest in using these devices both for traditional and emerging technologies (Mazumder et al., 2012; Domaradzki et al., 2020).

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 04, April-2025

3.2.1 Neuromorphic Computing

One of the most fascinating uses of memristors is in neuromorphic computing, whereby they are used as models of synaptic behavior of biological neurons. The energy and parallel processing efficiency of memristor-based neuromorphic systems provides a perfect stride for artificial intelligence (AI) and machine learning (ML) application areas. K Kumar et al., presented in 2022 and Sokolov et al., presented in 2021.

- Synaptic Integration

Researchers have shown that memristors can represent synaptic weight updates very well. Such a representation of the effectiveness endows them to develop energy-efficient neural networks (Borghetti et al., 2010). Using the basis of a memristor, one can make neural networks that outperform the conventional transistor-based network, especially in terms of energy for applications such as image recognition and speech processing, etc. (Indiveri et al., 2013; Miranda et al., 2020).

3.2.2 Non-Volatile Memory (NVM)

The memristors were considered to be good candidates for the resistive random access memory due to their faster switching speed, better endurance, and lower power consumption compared to the previous conventional memory technologies like Flash and DRAM. The recent trends of ReRAM technology indicated that the storage density of devices with memristors may be huge with low characteristics of power consumption (Kuzum et al., 2011; Zhang et al., 2015, May).

• ReRAM: One of those is ReRAM - Resis-tive RAM. ReRAM uses memristors as its memory storage element, which store data by charging/ discharging a material, changing the resistance with two states usually representing '1' and '0' (Waser et al., 2016). ReRAM has shown better write speed and endurance than the classical NAND Flash memory, making it a good candidate for future high-performance memory systems. (Banerjee, W. 2020; Choudhary et al., 2019).

3.2.3 Logic Circuits

Besides this, memristors are used in logic circuits being operated as being able to perform the most fundamental logical operations such as AND, OR, and NOT. Exploiting properties of memristors, scientists demonstrated the possibility to get a circuit with smaller size and consumed power since memory and logic functions may be combined in one device (Jo et al., 2010; Vourkas et al., 2016; Kvatinsky et al., 2013).

3.3 Challenges and Limitations

Despite the high potential associated with memristors, there are some limitations that prevent them from wide adoption. The most significant limitations are found to be linked to material dependency, device scalability, and integration scaling with the traditional CMOS system (Li et al., 2024; Amirsoleimani et al., 2020).

3.3.1 Scalability

Scaling up memristors into large arrays also challenges uniformity and stability. When size continues to reduce, switching characteristic variability and long-term reliability are likely to increase. Control over material deposition and the prevention of defects in the fabrication process are crucial but add complexity to the device manufacturing process (Liu et al., 2019).

3.3.2 Integration with CMOS

Even though memristors have the promise of disruptive computing architecture, coupling them with conventional CMOS technology is difficult. It is because the fabrication processes, materials, and voltage levels are different for most memristors from those used for traditional semiconductor devices, which makes their integration in established CMOS circuits complicated in nature (Liu et al., 2018).

3.3.3 Material stability and durability

The material degradation and performance variability of the device are considerable issues even when applied to such a material as TiO_2, which is metal oxide-based. Due to material property degradation over time, the switching stability and endurance of these materials can degrade too. This might usually manifest in problems with reliability, especially related to memory and logic devices (Waser et al., 2016). Long-term stability and high endurance are key considerations toward practical implementation in commercial systems.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 04, April-2025

DISCUSSION

The analysis has, in fact shown possible applicability of memristors in neuromorphic computing, memory storage, and logic circuits; however, there are still many challenges that have to be solved before they are produced commercially. Among the being researched materials, Titanium Dioxide (TiO_2) and Hafnium Oxide (HfO_2), metal oxides, continue to dominate, as their established fabrication process and robust switching characteristics render them favorable for use (Darwish, M. 2024). Those materials hold much promise: high endurance and non-volatility, and are therefore quite promising for memory applications. Their main drawbacks consist in low device performance and long-term instability, although this is particularly a threat of the metal oxide-based memristor if the switching cycle exceeds hundreds of times. Materials in the category of organic and 2D, such as graphene and MoS_2, promise much in this regard. While organic materials are flexible and very amenable to fabrication, several challenges remain because their endurance is relatively inferior and switching time also relatively slower than inorganic counterparts. Similarly, 2D materials are now increasingly recognized for their superior electronic properties, with exceptionally fast switching speeds and low power consumption, making them highly promising candidates for high-density, low-power memristor applications. By thus integrating these materials into memristive devices, the flexible and cost-effective electronic field opens up exciting avenues to explore. In comparison with applications in neuromorphic computing and AI, memristors can be considered particularly transformative. Their ability to mimic the synaptic behavior of biological neurons positions them as a key enabler for developing energy-efficient parallel processing systems capable of performing complex AI and machine learning tasks. Perhaps, the memristor-based neural networks will significantly advance the energy efficiency and speed of computations compared with the conventional transistor-based systems. Memristors are hard to be included in large-scale neuromorphic systems due to their inherent variability and also to the need for device operation precision. They are also difficult to include in existing CMOS architectures. Indeed, the problem is the integration of memristors with conventional CMOS technology. The fabrication processes, the voltage requirements, and material differences between memristors and CMOS transistors complicated the development of hybrid systems capable of exploiting the unique properties of memristors. Further research in that direction-often streamlining the integration of memristors in conventional semiconductor systems-is still highly necessary, especially as these are already deeply entrenched in modern computing technologies. More problematic, though, is the long-term stability and robustness of memristor devices, especially for memory applications. Long-term reliability of memristors, especially those that involve metal oxides such as TiO2 and HfO2 that are known to have good switching properties would be of major concern with regard to the widespread usage in memory storage. Variation in the switching over time can lead to errors related to data retention and device performance, making them critical challenges for their application in high-density, high-endurance memory systems (Cagli et al., 2022). Conclusion Memristors have transformative potential that could be the basis of the next generation of computing technologies. However, it would be important for one to get past what is left of these technical challenges-for starters, material stability; secondly, the scalability of devices; and lastly, the compatibility with existing semiconductor technologies-to cement their broad adoption. Going forward, the memristive device's future path will largely depend on further investigations into alternative materials, novel fabrication methods, and hybrid systems in which memristors combine with CMOS technology to fulfill the promise of these devices in many applications.

CONCLUSION

Memristor technology is bound to revolutionize the computing architectures, especially in terms of energy-efficient neuromorphic computing and memory-high density systems. The synaptic functions that memristors emulate support non-volatile memory and, for this reason, offer favorable candidates for next-generation computing technologies. However, a variety of critical challenges has to be addressed before memristor technology can gain wider acceptance within the commercial market. These include questions related to intrinsic material properties, device scalability, and the integration of memristors with fully established systems based on CMOS technology. All these materials, including metal oxides, organic compounds, and 2D materials, despite their promising characteristics, present unique challenges—such as material stability, fabrication complexity, and long-term reliability—that have to be overcome in order to make memristors at a larger scale. To overcome these challenges, further research will be needed into alternative materials and hybrid systems. Hybrid systems which combine memristors with more conventional semiconductor technologies are a pathway to integrate the benefits of each technology, though seamless integration continues to prove a significant challenge. Other advancements in fabrication techniques that are uniform, scalable, and consistent in performance must break forth in unlocking the full potential of memristors for practical applications. Given the explosion of new development in memristor

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 04, April-2025

research, it could be well expected to see significant advancements within the next decade in the performance and practical applications of memristor-based systems. Further advancement in materials science, device engineering, and system-level integration will make memristors key players in the evolution of energy-efficient high-performance computing platforms. The research and innovation on this subject continue, hence suggesting memristors will continue being the focal point of interest for researchers as they possibly reshape the computing technology scene soon.

REFERENCES

1. Allendorf, M. D., Dong, R., Feng, X., Kaskel, S., Matoga, D., & Stavila, V. (2020). Electronic devices using open framework materials. Chemical reviews, 120(16), 8581-8640.
2. Amirsoleimani, A., Alibart, F., Yon, V., Xu, J., Pazhouhandeh, M. R., Ecoffey, S., ... & Drouin, D. (2020). In-Memory Vector-Matrix Multiplication in Monolithic Complementary Metal–Oxide–Semiconductor-Memristor Integrated Circuits: Design Choices, Challenges, and Perspectives. Advanced Intelligent Systems, 2(11), 2000115.
3. Banerjee, W. (2020). Challenges and applications of emerging nonvolatile memory devices. Electronics, 9(6), 1029.
4. Barraj, I., Mestiri, H., & Masmoudi, M. (2024). Overview of Memristor-Based Design for Analog Applications. Micromachines, 15(4), 505.
5. Batool, S., Idrees, M., Zhang, S. R., Han, S. T., & Zhou, Y. (2022). Novel charm of 2D materials engineering in memristor: when electronics encounter layered morphology. Nanoscale Horizons, 7(5), 480-507.
6. Beausoleil, R. G. (2011). Large-scale integrated photonics for high-performance interconnects. ACM Journal on Emerging Technologies in Computing Systems (JETC), 7(2), 1-54.
7. Bertolazzi, S., Bondavalli, P., Roche, S., San, T., Choi, S. Y., Colombo, L., ... & Samorì, P. (2019). Nonvolatile memories based on graphene and related 2D materials. Advanced materials, 31(10), 1806663.
8. Borghetti, J., et al. (2010). "Memristive switching mechanism for memory applications." Nature Materials, 9(8), 667-672.
9. Bousoulas, P., Michelakaki, I., & Tsoukalas, D. (2014). Influence of oxygen content of room temperature TiO_{2-x} deposited films for enhanced resistive switching memory performance. Journal of Applied Physics, 115(3).
10. Cagli, C., & Perniola, L. (2022). Memory Challenges. In Springer Handbook of Semiconductor Devices (pp. 603-633). Cham: Springer International Publishing.
11. Chaurasiya, R., Chen, K. T., Shih, L. C., Huang, Y. C., & Chen, J. S. (2024). Exploring the Feasibility of Monoclinic-ZrO_2-Based Memristors as Artificial Olfactory Sensors: An Atomistic Simulation Approach. Advanced Theory and Simulations, 7(5), 2301074.
12. Choudhary, N., Islam, M. A., Kim, J. H., Ko, T. J., Schropp, A., Hurtado, L. & Jung, Y. (2018). Two-dimensional transition metal dichalcogenide hybrid materials for energy applications. Nano Today, 19, 16-40.
13. Choudhary, S., Soni, M., & Sharma, S. K. (2019). Low voltage & controlled switching of MoS_2-GO resistive layers based ReRAM for non-volatile memory applications. Semiconductor Science and Technology, 34(8), 085009.
14. Chua, L. (2019). Resistance switching memories are memristors. Handbook of memristor networks, 197-230.
15. Corinto, F., Forti, M., & Chua, L. O. (2021). Nonlinear circuits and systems with memristors. Cham, Switzerland: Springer.
16. Darwish, M. (2024). Electrothermal Simulation of Insulator Metal Transition Devices (Doctoral dissertation, Budapest University of Technology and Economics (Hungary)).
17. Dawarka, V., & Bekaroo, G. (2022). Building and evaluating cloud robotic systems: A systematic review. Robotics and Computer-Integrated Manufacturing, 73, 102240.
18. Domaradzki, J., Wojcieszak, D., Kotwica, T., & Mańkowska, E. (2020). Memristors: a short review on fundamentals, structures, materials and applications. International Journal of Electronics and Telecommunications, 373-381.
19. Domaradzki, J., Wojcieszak, D., Kotwica, T., & Mańkowska, E. (2020). Memristors: a short review on fundamentals, structures, materials and applications. International Journal of Electronics and Telecommunications, 373-381.
20. Franco, M., Kiazadeh, A., Martins, R., Lanceros-Méndez, S., & Carlos, E. (2024). Printed Memristors: An Overview of Ink, Materials, Deposition Techniques, and Applications. Advanced Electronic Materials, 10(10), 2400212.
21. Ganeriwala, M. D., Toral-López, A., Calaforra-Ayuso, E., Pasadas, F., Ruiz, F. G., Marin, E. G., & Godoy, A. (2024). Role of Point Defects and Ion Intercalation in Two-Dimensional Multilayer Transition Metal Dichalcogenide Memristors. ACS Applied Nano Materials.
22. Gogoi, H. J., Bajpai, K., Mallajosyula, A. T., & Solanki, A. (2021). Advances in flexible memristors with hybrid perovskites. The Journal of Physical Chemistry Letters, 12(36), 8798-8825.
23. Gutiérrez-Martínez, J., Toledo-Peral, C., Mercado-Gutiérrez, J., Vera-Hernández, A., & Leija-Salas, L. (2020). Neuroprosthesis Devices Based on Micro-and Nanosensors: A Systematic Review. Journal of Sensors, 2020(1), 8865889.
24. Harabi, K. E. (2023). Energy-Efficient Memristor-Based Artificial Intelligence Accelerators using In/Near Memory Computing (Doctoral dissertation, Université Paris-Saclay).
25. Hepel, M. (2023). Advances in micro-supercapacitors (MSCs) with high energy density and fast charge-discharge capabilities for flexible bioelectronic devices—A review. Electrochemical Science Advances, 3(3), e2100222.
26. Indiveri, G., Linares-Barranco, B., Legenstein, R., Deligeorgis, G., & Prodromakis, T. (2013). Integration of nanoscale memristor synapses in neuromorphic computing architectures. Nanotechnology, 24(38), 384010.
27. Inglese, P. (2023). Exploration of security threats in In-Memory Computing Paradigms (Doctoral dissertation, Université Grenoble Alpes [2020-....]).
28. Jacob, A. P., Xie, R., Sung, M. G., Liebmann, L., Lee, R. T., & Taylor, B. (2017). Scaling challenges for advanced CMOS devices. International Journal of High Speed Electronics and Systems, 26(01n02), 1740001.

29. Jeong, D. S., Thomas, R., Katiyar, R. S., Scott, J. F., Kohlstedt, H., Petraru, A., & Hwang, C. S. (2012). Emerging memories: resistive switching mechanisms and current status. Reports on progress in physics, 75(7), 076502.
30. Jo, S. H., et al. (2010). "Nanoscale memristor device as synapse in neuromorphic systems." Nano Letters, 10(4), 1297-1301.
31. Khurana, G., Kumar, N., Scott, J. F., & Katiyar, R. S. (2018). Graphene oxide-based memristor. Memristor and memristive neural networks, 19-40.
32. Kim, K. S., Kwon, J., Ryu, H., Kim, C., Kim, H., Lee, E. K., ... & Kim, J. (2024). The future of two-dimensional semiconductors beyond Moore's law. Nature Nanotechnology, 19(7), 895-906.
33. Kumar, S., Wang, X., Strachan, J. P., Yang, Y., & Lu, W. D. (2022). Dynamical memristors for higher-complexity neuromorphic computing. Nature Reviews Materials, 7(7), 575-591.
34. Kumar, S., Wang, X., Strachan, J. P., Yang, Y., & Lu, W. D. (2022). Dynamical memristors for higher-complexity neuromorphic computing. Nature Reviews Materials, 7(7), 575-591.
35. Kuzum, D., et al. (2011). "Nanoelectronic nonvolatile memristor memory with high endurance and fast switching." Nature Communications, 2(1), 1-8.
36. Kvatinsky, S., Satat, G., Wald, N., Friedman, E. G., Kolodny, A., & Weiser, U. C. (2013). Memristor-based material implication (IMPLY) logic: Design principles and methodologies. IEEE Transactions on Very Large Scale Integration (VLSI) Systems, 22(10), 2054-2066.
37. Li, X. D., Chen, N. K., Wang, B. Q., Niu, M., Xu, M., Miao, X., & Li, X. B. (2024). Resistive memory devices at the thinnest limit: progress and challenges. Advanced Materials, 36(15), 2307951.
38. Liu, Y., et al. (2019). "Memristor devices for non-volatile memory and logic circuits: Advances and challenges." IEEE Transactions on Electron Devices, 65(3), 917-923.
39. Maheshwari, S., Stathopoulos, S., Wang, J., Serb, A., Pan, Y., Mifsud, A., ... & Prodromakis, T. (2020). Hybrid CMOS/memristor circuit design methodology. arXiv preprint arXiv:2012.02267.
40. Mazumder, P., Kang, S. M., & Waser, R. (2012). Memristors: devices, models, and applications. Proceedings of the IEEE, 100(6), 1911-1919.
41. Mazumder, P., Kang, S. M., & Waser, R. (2012). Memristors: devices, models, and applications. Proceedings of the IEEE, 100(6), 1911-1919.
42. Mazumder, P., Kang, S. M., & Waser, R. (2012). Memristors: devices, models, and applications. Proceedings of the IEEE, 100(6), 1911-1919.
43. Miao, X., et al. (2017). "Recent advances in memristor materials and devices." Materials Science and Engineering: R: Reports, 116, 1-19.
44. Miranda, E., & Suñé, J. (2020). Memristors for neuromorphic circuits and artificial intelligence applications. Materials, 13(4), 938.
45. Morales Méndez, G., & del Cerro Velázquez, F. (2024). Augmented Reality in Industry 4.0 Assistance and Training Areas: A Systematic Literature Review and Bibliometric Analysis. Electronics, 13(6), 1147.
46. Mzukwa, A. (2024). Exploring Next-Generation Architectures for Advanced Computing Systems: Challenges and Opportunities. Journal of Advanced Computing Systems, 4(6), 9-18.
47. Nagata, Z., Shimizu, T., Isaka, T., Tohei, T., Ikarashi, N., & Sakai, A. (2019). Gate tuning of synaptic functions based on oxygen vacancy distribution control in four-terminal TiO_{2-x} memristive devices. Scientific Reports, 9(1), 10013.
48. Ouyang, J. (2021). Application of intrinsically conducting polymers in flexible electronics. SmartMat, 2(3), 263-285.
49. Radwan, A. G., & Fouda, M. E. (2015). On the mathematical modeling of memristor, memcapacitor, and meminductor (Vol. 26). Berlin: Springer.
50. Ranjan, S. (2020). TiO2 and Biomaterials Based Memristor Devices and Its In-Memory Computing Applications (Master's thesis, University of Waterloo).
51. Romero, F. J., Toral, A., Medina-Rull, A., Moraila-Martinez, C. L., Morales, D. P., Ohata, A., ... & Rodriguez, N. (2020). Resistive switching in graphene oxide. Frontiers in Materials, 7, 17.
52. Saha, R., Assouline, B., Mason, G., Douiri, A., Summers, C., & Shankar-Hari, M. (2021). Impact of differences in acute respiratory distress syndrome randomised controlled trial inclusion and exclusion criteria: systematic review and meta-analysis. British Journal of Anae sthesia, 127(1), 85-101.
53. Sokolov, A. S., Abbas, H., Abbas, Y., & Choi, C. (2021). Towards engineering in memristors for emerging memory and neuromorphic computing: A review. Journal of Semiconductors, 42(1), 013101.
54. Song, M. K., Kang, J. H., Zhang, X., Ji, W., Ascoli, A., Messaris, & Kim, J. (2023). Recent advances and future prospects for memristive materials, devices, and systems. ACS nano, 17(13), 11994-12039.
55. Song, M. K., Kang, J. H., Zhang, X., Ji, W., Ascoli, A., Messaris, I., ... & Kim, J. (2023). Recent advances and future prospects for memristive materials, devices, and systems. ACS nano, 17(13), 11994-12039.
56. Sun, K., Chen, J., & Yan, X. (2021). The future of memristors: Materials engineering and neural networks. Advanced Functional Materials, 31(8), 2006773.
57. Teixeira, H., Dias, C., Silva, A. V., & Ventura, J. (2024). Advances on MXene-Based Memristors for Neuromorphic Computing: A Review on Synthesis, Mechanisms, and Future Directions. ACS nano, 18(33), 21685-21713.
58. Thakkar, P., Gosai, J., Gogoi, H. J., & Solanki, A. (2024). From fundamentals to frontiers: a review of memristor mechanisms, modeling and emerging applications. Journal of Materials Chemistry C.
59. Trefzer, M. A. (2017). Memristor in a Nutshell. Guide to Unconventional Computing for Music, 159-180.
60. Upadhyay, N. K., Jiang, H., Wang, Z., Asapu, S., Xia, Q., & Joshua Yang, J. (2019). Emerging memory devices for neuromorphic computing. Advanced Materials Technologies, 4(4), 1800589.
61. Vassanelli, S., & Mahmud, M. (2016). Trends and challenges in neuroengineering: toward "intelligent" neuroprostheses through brain-"brain inspired systems" communication. Frontiers in neuroscience, 10, 438.
62. Vourkas, I., & Sirakoulis, G. C. (2016). Emerging memristor-based logic circuit design approaches: A review. IEEE circuits and systems magazine, 16(3), 15-30.
63. Wang, Z., Wu, H., Burr, G. W., Hwang, C. S., Wang, K. L., Xia, Q., & Yang, J. J. (2020). Resistive switching materials for information processing. Nature Reviews Materials, 5(3), 173-195.
64. Waser, R., et al. (2016). "Memristive devices for computing." Nature Materials, 15(1), 1-11.

65. Wenaas, L. (2022). Open Access: A Change in Academic Publishing with Limited Reach?.
66. Xu, J., Luo, Z., Chen, L., Zhou, X., Zhang, H., Zheng, Y., & Wei, L. (2024). Recent advances in flexible memristors for advanced computing and sensing. Materials Horizons.
67. Yang, X., Taylor, B., Wu, A., Chen, Y., & Chua, L. O. (2022). Research progress on memristor: From synapses to computing systems. IEEE Transactions on Circuits and Systems I: Regular Papers, 69(5), 1845-1857.
68. Yang, X., Taylor, B., Wu, A., Chen, Y., & Chua, L. O. (2022). Research progress on memristor: From synapses to computing systems. IEEE Transactions on Circuits and Systems I: Regular Papers, 69(5), 1845-1857.
69. Yu, X., (2018). "Graphene oxide memristors: High-speed, low-power switching for emerging applications." Nature Electronics, 1(4), 222-229.
70. Yu, Y., Xiao, M., Fieser, D., Zhou, W., & Hu, A. (2024). Nanoscale memristor devices: Materials, fabrication, and artificial intelligence. Journal of Materials Chemistry C, 12(11), 3770-3810.
71. Yu, Y., Xiao, M., Fieser, D., Zhou, W., & Hu, A. (2024). Nanoscale memristor devices: Materials, fabrication, and artificial intelligence. Journal of Materials Chemistry C, 12(11), 3770-3810.
72. Zhang, G., Qin, J., Zhang, Y., Gong, G., Xiong, Z. Y., Ma, X, & Han, S. T. (2023). Functional Materials for Memristor-Based Reservoir Computing: Dynamics and Applications. Advanced Functional Materials, 33(42), 2302929.
73. Zhang, Y., & Swanson, S. (2015, May). A study of application performance with non-volatile main memory. In 2015 31st Symposium on Mass Storage Systems and Technologies (MSST) (pp. 1-10). IEEE.
74. Zhu, S., Yu, T., Xu, T., Chen, H., Dustdar, S., Gigan, S., ... & Pan, Y. (2023). Intelligent computing: the latest advances, challenges, and future. Intelligent Computing, 2, 0006.
75. Zidan, M. A., Strachan, J. P., & Lu, W. D. (2018). The future of electronics based on memristive systems. Nature electronics, 1(1), 22-29.