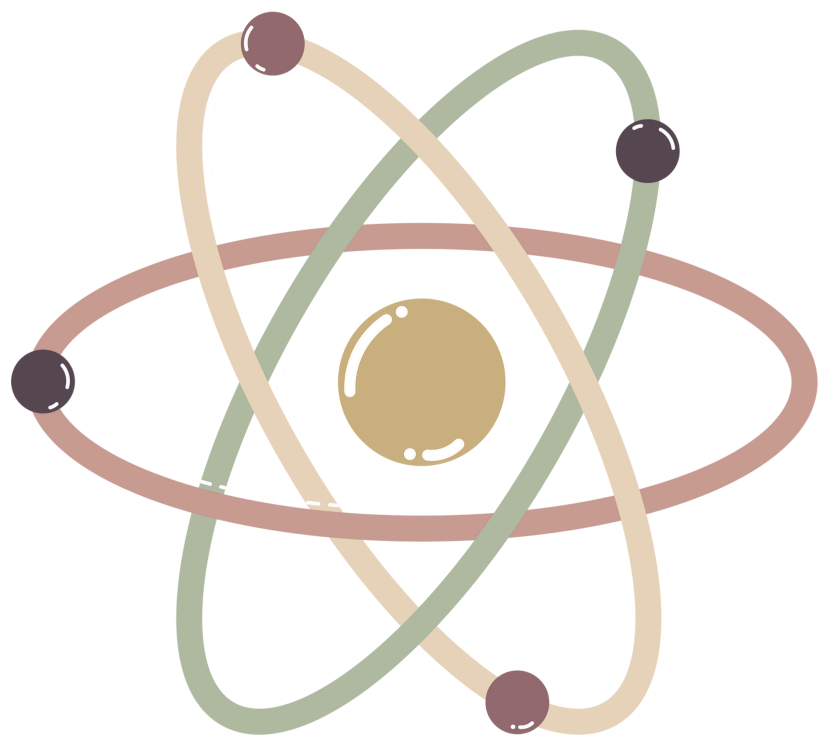
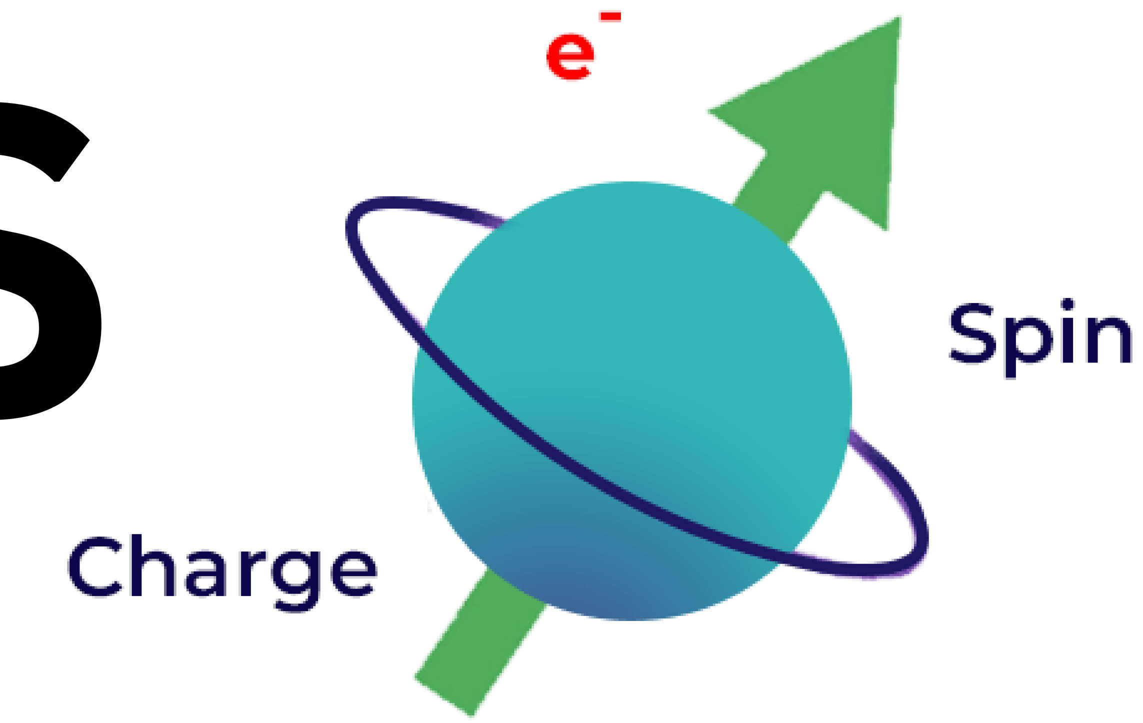


SPINTRONICS



Introduction

Spintronics is the study of the spin of electrons at the nanoscale for information processing, data storage, and computation power with lower energy consumption. Spintronics can help reduce power consumption and improve the speed of data processing. This allows for lower operational costs and efficient data management.

Problem Statement

The main problem currently plaguing spintronics is the power consumption within changing the spin state of a electron. Electrons act as tiny magnets when interacting with ferromagnetic materials. Using this interaction allows us to store and process information based on the spin of the electron. The problem occurs with the amount of torque to change the direction of the spin requires a lot of energy. This high power consumption makes far less viable as an alternative to CMOS data manipulation.

Risk Assessment

Spintronics faces several significant risk factors:

- **Energy Inefficiency** – Current devices consume significant energy to alter spin states.
- **Material Stability** – Lack of durable and scalable materials for spintronic applications.
- **Resource Dependency** – Dependence on materials can cause concern about supply chain vulnerabilities and cost.
- **Environmental Impact** – Extraction and use of non-renewable materials could result in ecological harm.

Implementation Plan

Our implementation plan to address the power consumption challenges in spintronics will focus on using antiferromagnetic materials in conjunction with voltage-controlled magnetization (VCMA) for spin manipulation. VCMA uses electric fields to efficiently manipulate spin states in antiferromagnetic materials, offering a low-energy alternative to traditional magnetic field-based methods.

Phase	Description	Duration	Milestones
Phase 1: Research	Investigate optimal antiferromagnetic materials and refine VCMA techniques	6 – 9 Months	Successful identification of suitable materials with high spin propagation efficiency and low damping factors, precise theoretical models for spin dynamics including VCMA and in said materials
Phase 2: Prototype Development	Fabricate functional prototypes to gauge feasibility (Nanoscale components; STT, SOT)	12 – 18 Months	Validation of possible practical application for theoretical models, especially material compatibilities
Phase 3: Testing	Evaluate prototypes' performance and reliability under varied conditions as well as conduct benchmarking against existing CMOS counterparts	9 Months	Iterative improvement until the technology is true to its word and a proper alternative to CMOS in relevant areas
Phase 4: Production	Transition to mass distribution of Spintronic devices for commercial usage	18 – 24 Months	Establishment of a manufacturing process compatible with semiconductor industry standards and high yield rates

Mitigation Strategies

Proposed mitigation strategies:

- Voltage-Controlled Magnetization (VCMA) offers a solution for reducing power consumption by using electric fields to manipulate spin states efficiently.
- Adoption of two-dimensional materials can enhance device performance, provide greater scalability, and reduce dependence on expensive critical resources.

Benefits and Imapcts

This technology is proven to provide many significant benefits and impacts across numerous areas such as Healthcare, the Automotive Industry, Telecom, Quantum Computing, Consumer Electronics, Energy Sector, Space and Aerospace, and even Military Defense, due to their sharply improved efficiency, durability and unique capabilities that traditional electronics struggle to match, especially where portable devices are concerned. There is no place that would benefit from it more than IT, though, with its heavy emphasis on data transfer and minaturization. Spintronics could eventually grow to become a major factor in the advancement for all things IT if it supplants CMOS data manipulation.

Conclusion

Spintronic technology has the ability to transform industries with its powerful and energy-efficient potential, but there are still some challenges to overcome. By using solutions such as VCMA and experimenting with more sustainable materials, we can solve these problems. With these improvements, we believe that spintronics could lead the way to more efficient and reliable applications in data storage, IT, and more.

References

Puebla, J., Kim, J., Kondou, K., & Otani, Y. (2020). Spintronic devices for energy-efficient data storage and energy harvesting. Communications Materials, 1(1), 1–9. https://doi.org/10.1038/s43246-020-0022-5

Breakthrough for efficient and high-speed spintronic devices. (2022). In Canada NewsWire. PR Newswire Association LLC.

Yakout, S. M. (2020). Spintronics: Future Technology for New Data Storage and Communication Devices. Journal of Superconductivity and Novel Magnetism, 33(9), 2557–2580. https://doi.org/10.1007/s10948-020-05545-8

Dieny, B., Prejbeanu, I. L., Garello, K., Gambardella, P., Freitas, P., Lehndorff, R., Raberg, W., Ebels, U., Demokritov, S. O., Akerman, J., Deac, A., Pirro, P., Adelmann, C., Anane, A., Chumak, A. V., Hiroata, A., Mangin, S., Mehmet Cengiz Onbasli, Aquino, M. d, ... Bortolotti, P. (2019). Opportunities and challenges for spintronics in the microelectronic industry. arXiv.Org.

Palomino, A. Marty, J. Auffret, S. Joumard, I. Sousa, R.C. Prejbeanu, I.L. Ageron, B. Dieny, B. (2021). Evaluating critical metals contained in spintronic memory with a particular focus on Pt substitution for improved sustainability. Sustainable Materials and Technologies. Volume 28. https://doi.org/10.1016/j.susmat.2021.e00270

Liu, Y., Zeng, C., Zhong, J., Ding, J., Wang, Z. M., & Liu, Z. (2020). Spintronics in Two-Dimensional Materials. Nano-Micro Letters, 12(1), 93–93. https://doi.org/10.1007/s40820-020-00424-2