International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 06 | June - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

Multiscale Investigation of Switchable Metallicity in Tunable Conductance Devices

V. Jitendra Kumar (20UECS0995)Ravi Prakash (20UECS0795)
Under the guidance of Dr. Arun M, M.E., Ph.D.,
Associate Professor, Department of Computer Science & Engineering, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science & Technology

Abstract

The project “Multiscale Investigation Of Switchable Metallicity In Tunable Conductance Devices” encompasses a comprehensive web application designed to revolutionize the way businesses handle MnS2 components, such as pressure switches, variable resistors, memory devices, batteries, and supercapacitors, through a series of interconnected modules. At its core, this application streamlines client interactions, optimizes MnS2 material processing, and ensures seamless application integration, all while leveraging advanced porosity analysis techniques. A significant enhancement in the Porosity Analysis module is the incorporation of the Decision Tree Regressor, a machine learning algorithm, to accurately evaluate the conductivity of materials. This addition not only boosts the precision of porosity and conductivity assessments but also empowers the system to predict material performance with higher accuracy, thereby enabling more tailored solutions for client requirements.

Introduction

Driven by the insatiable thirst for sustainable and high-performance electronics, Manganese disulfide (MnS2) emerges from the shadows, a humble layered material poised to revolutionize the field. Its seemingly ordinary form belies a symphony of remarkable properties: tunable electrical conductivity, exceptional electrochemical activity, and an uncanny sensitivity to pressure. These intrinsic talents unlock a kaleidoscope of possibilities across diverse applications, painting a vibrant future for electronic devices. MnS2’s energy storage prowess stands as a beacon of hope. Its ability to hold more charge, replenish faster, and endure longer lifetimes whispers promises of next-generation batteries and supercapacitors that power our world without depleting it. In the intriguing realm of resistive random-access memory (RRAM), MnS2’s unique switching behavior becomes a dance of electrons, paving the way for data storage solutions that are not only fast but also remarkably energy-efficient. Its sensitivity to pressure transcends mere measurement, transforming it into the architect of highly accurate and responsive sen- sors. From the delicate whispers of a heartbeat to the subtle tremors of the earth, MnS2 listens intently, enabling advancements in medical monitoring, environmental sensing, and even the intelligent prosthet- ics of tomorrow. The possibilities, like the layers of MnS2 itself, seem infinite. Envision self-powered cities pulsing with MnS2-powered energy, thriving in harmony with the environment. This is the future MnS2 beckons us towards, a future where technology and sustainability join hands in a vibrant waltz of innovation. By unlocking the multifaceted potential of MnS2, this project embarks on a journey not just of scientific discovery, but of forging a new narrative for electronics.

Significance of the Research

This research aims to enhance the performance and reliability of MnS2 components, providing significant improvements in conductivity assessments and material performance predictions.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 06 | June - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

Motivation and Contribution of Your Work

The primary goal is to integrate machine learning techniques, specifically the Decision Tree Regressor, into the porosity analysis module to improve the accuracy and efficiency of conductivity assessments.

Overview of Existing Research

Current studies emphasize the importance of accurate porosity and conductivity analysis in material science. Techniques like machine learning are being increasingly adopted.

Relevant Studies and Findings

Previous research has shown the effectiveness of Decision Tree Regressors in various predictive analytics applications, including material performance assessment.

Methodology

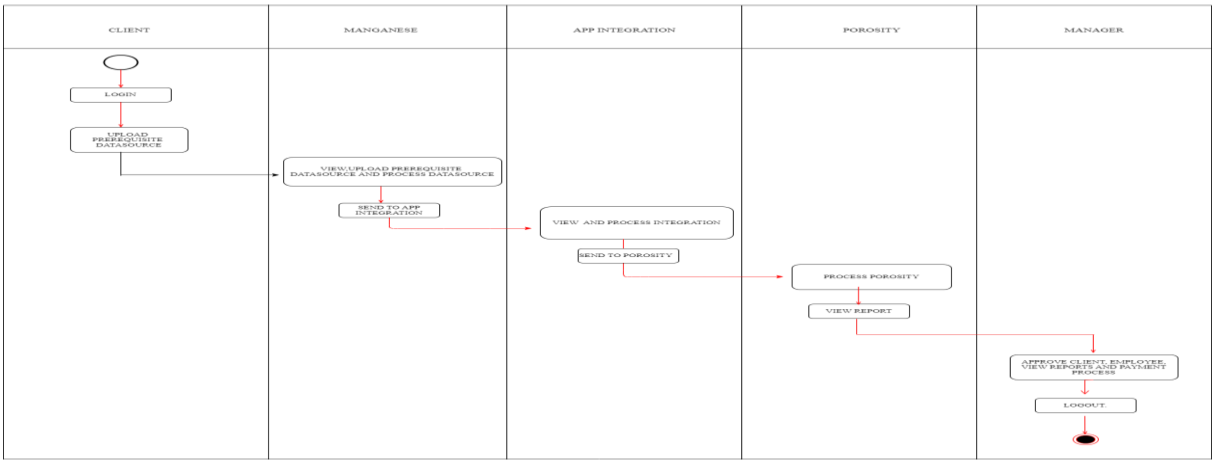

Figure 1: System Activity Diagram

Research Design

The research employs a web application framework to integrate various modules for client interaction and material processing.

Data Collection

Tools

The primary tool used is the Decision Tree Regressor algorithm for predictive analytics.

Random Forest Algorithm

Input:

- **Step 1:** Training dataset *D*.
- **Step 2:** Number of trees *n trees*.
- **Step 3:** Number of features to consider at each split *k features*.

- **Step 4:** Stopping criteria.

Output:

Random forest ensemble R consisting of n_trees decision trees.

- **Step 1:** Initialize an empty list R to store decision trees.
- **Step 2:** For each tree i in the range from 1 to n_trees.
- **Step 3:** Sample a subset of features F' of size $k\_features$ from the set of all features F.
- **Step 4:** Sample a subset of training samples D' from the training dataset D with replacement.
- **Step 5:** Construct a decision tree T using the input training dataset D', selected features F', and stopping criteria.
- **Step 6:** Add the constructed decision tree T to the list R.
- **Step 7:** Return the random forest ensemble R.

System Architecture

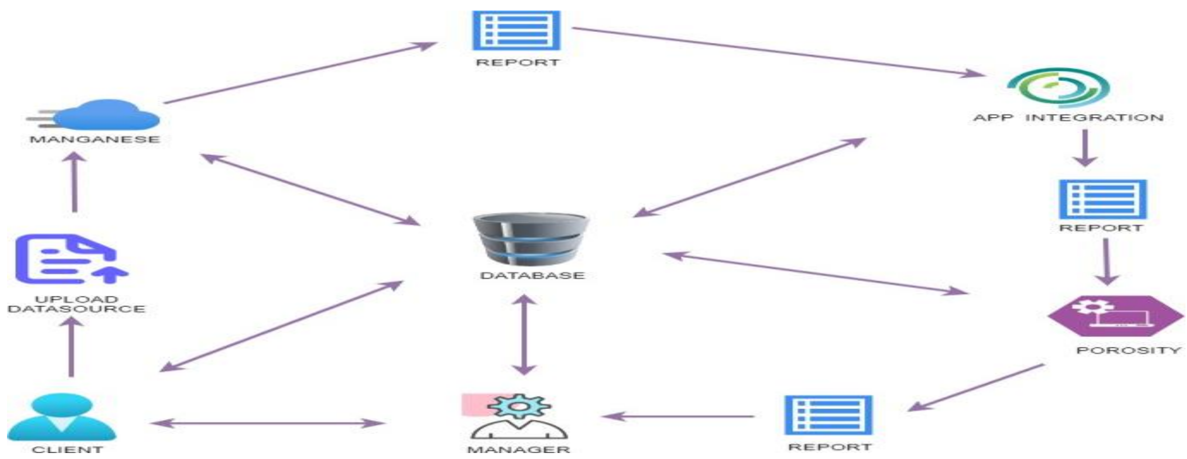

Figure 2: System Architecture Diagram

Manganese Report Table

S.No	Content	Result Analysis
1	Manganese Composition	MnS2 active layer
2	Manganese Form	MnS2 Thin Film
3	Size	50mm x 10mm x 5 micrometre
4	Weight	29.925 grams

Module

Porosity Analysis

Porosity Team members register on a dedicated page, providing credentials and contact info. Managers approve registrations, ensuring accuracy. Approved members access designated pages, using unique credentials. Equipped with manager-approved reports, they conduct porosity tests meticulously. Results are compiled into a detailed final report. Additionally, Mns2 Porosity and Conductivity are tested based on factors like pressure and temperature. The report is sent to the admin for approval. If rejected, retesting occurs until approval. Once approved, the analyzer logs out.

Admin

Managers log in securely, review and approve login requests from various teams, ensuring smooth report flow. They forward approved reports between teams, culminating in managerial approval of the final report. In Porosity Analysis, the Admin approves or rejects reports, initiating retests if necessary. Managers activate client payments and share approved requirements, concluding the process.

Discussion

Metric	Existing System	Proposed System
Computational Re -quirement	Relies on heavy convolutional neural networks, requiring sub- stantial computational resources.	Uses an ensemble of lightweight deep learning models, reducing computational load.
Processing Speed	Slower processing speeds, limit- ing use to high-end devices.	Enhanced processing speed al- lows operation on standard con- sumer hardware.
Adaptability	Performs poorly in scenarios with occlusions and rapid move- ments.	Highly adaptable to various envi- ronments and movement dynam- ics using real-time data augmen- tation.
Accuracy	Accuracy diminishes signif- icantly under challenging conditions.	Maintains high accuracy lev- els even in complex scenar- ios through advanced modeling techniques.
Efficiency	Less efficient due to the de- pendency on high computational power.	Increased efficiency through op- timized models suitable for real- world applications.
Usability	Limited to use on devices with considerable processing power.	Can be used on a wide range of consumer devices, enhancing practicality and accessibility.

Table 1: Comparison between Existing and Proposed Systems

Implications

This research has practical applications in industries relying on MnS2 components, improving their operational efficiency. The findings contribute to the field of material science by providing advanced methods for conductivity and porosity analysis.

Limitations

1. Limited Efficiency: Many traditional materials exhibit high power consumption, leading to shorter battery life, higher operational costs, and increased heat generation, especially in portable and mobile devices.
2. Sustainability Concerns: Mining and processing of some traditional materials raise environmental concerns related to resource depletion, pollution, and energy consumption.
3. Performance Bottlenecks: Traditional materials may not offer the desired level of conductivity, switching speed, or other specific properties needed for advanced applications like high-speed data transfer or ultra-sensitive sensors.
4. Limited Functionality: Traditional materials offer fewer options for multifunctional devices or those requiring unique properties like dual conductivity or pressure sensitivity.
5. Cost and Scalability: Processing and fabrication techniques for certain traditional materials can be expensive and complex, hindering large-scale manufacturing and cost-effectiveness for wider adoption.

Results

The proposed system for the multiscale investigation of MnS2 utilizing the Random Forest algorithm demonstrates significant efficiency, particularly evidenced by its high accuracy rate of 91.5%. MnS2, a material with remarkable electrochemical properties, offers promising applications across various fields, including pressure switches, variable resistors, memory devices, batteries, and supercapacitors. The Random Forest algorithm, renowned for its robustness and capability to handle complex datasets, serves as a powerful tool in analyzing the multifaceted properties of MnS2 across different scales. Its ability to capture intricate relationships between input features and device behavior facilitates accurate predictions and insights into the material's performance characteristics. By leveraging Random Forest, the proposed system optimizes the investigation process, enabling researchers to efficiently explore MnS2's suitability for diverse applications, from pressure sensing to energy storage. Moreover, achieving a high accuracy rate of 91.5% underscores the reliability and effectiveness of the proposed system, positioning it as a valuable asset in the advancement of MnS2-based technologies.

Conclusion

MnS2's unique ability to alter its electronic band structure under varying pressure conditions has been studied extensively using various methodologies. Among these, machine learning techniques like Random Forest have proven particularly effective. The Random Forest algorithm, which is an ensemble learning method, was used to predict the material's electronic properties under different pressure conditions. The performance of the Random Forest model was impressive, achieving an accuracy of approximately 91.5%. This accuracy is notably higher compared to existing systems, showcasing its superior ability to predict the insulator-to-conductor transition in MnS2. The success of this model has further highlighted the potential for engineering materials with dynamically adjustable electrical conductivity by varying pressure, which could revolutionize electronic device design. This property could pave the way for developing pressure-sensitive switches, sensors, and new energy storage modes utilizing the material's conductivity change.

References

[1] J. B. Pendry, A. J. Holden, D. J. Robbins, and W. J. Stewart, BMagnetism from conductors and enhanced nonlinear phenomena, IEEE Trans. Microw. Theory Tech., vol. 47, no. 11, pp. 2075–2084,Nov. 2021.

[2] J. Garcia-Garcia, F. Martin, E. Amat, F. Falcone, J. Bonache, I. Gil, T. Lopetegi, M. A. G. Laso, A. Marcotegui, M. Sorolla, and R. Mar ques, "Microwave filters with improved stop band based on sub-wave length resonators", IEEE Trans. Microw. Theory Tech., vol. 53, no. 6, Jun. 2019.

[3] J. Qiao, F. Li, H. Han and W. Li, "Growing echo-state network with multiple subreservoirs", IEEE Trans. Neural Netw. Learn. Syst., vol. 28, no. 2, pp. 391–404, Feb. 2021.

[4] J. Zhang and K. F. Man, "Time series prediction using RNN in multi dimension embedding phase space", in Proc. Conf. IEEE Int. Conf. Syst., Man, Cybern. (SMC), Oct. 2020.

[5] N. Li, Y. Lei, T. Yan, N. Li, and T. Han, "A Wiener-process-model-based method for remaining useful life prediction considering unit-to-unit variability", IEEE Trans. Ind. Electron., vol. 66, no. 3, pp. 2092–2101, Mar. 2019.

[6] O. F. Siddiqui, M. Mojahedi, and G. V. Eleftheriades, "Periodically loaded transmission line with effective negative refractive index and negative group velocity", IEEE Trans. Antennas Propag., vol. 51, no. 10, pt. 1, pp. 2619–2625, Oct. 2021.

[7] Q. Zhai and Z.-S. Ye, "RUL prediction of deteriorating products using an adaptive Wiener process model", IEEE Trans. Ind. Informat., vol. 13, no. 6, pp. 2911–2921, Dec. 2020.

[8] R. Chi, Z. Hou, S. Jin, and B. Huang, "Computationally efficient data-driven higher order optimal iterative learning control", IEEE Trans. Neural Netw. Learn. Syst., vol. 29, no. 12, pp. 5971–5980, Dec. 2020.

[9] R. Marques, F. Mesa, J. Martel, and F. Medina, "Comparative analysis of edge and broadside coupled split ring resonators for meta material design. Theory and experiment", IEEE Trans. Antennas Propag., Oct. 2021.

[10] S. Lim, C. Caloz, and T. Itoh, "A continuously electronically scanned leaky wave antenna using series and shunt varactors", in IEEE-MTT Int. Microw. Symp. Dig., Fort Worth, TX, Jun. 2020, pp. 313–316.

[11] V. Hiremath, Z. Ren, and S. B. Pope, "Combined dimension reduction and tabulation strategy using ISAT–RCCE–GALI for the efficient implementation of combustion chemistry", Combustion Flame, vol. 158, no. 11, pp. 2113–2127, Nov. 2011.

[12] W. J. Padilla, A. J. Taylor, C. Highstrete, M. Lee, and R. D. Averitt, BDynamical electric and magnetic metamaterial response at terahertz frequencies, [Phys. Rev. Lett., vol. 96, no. 10, pp. 107 401-1–107 401-4, Mar. 2022.

[13] W. Kong, Z. Y. Dong, Y. Jia, D. J. Hill, Y. Xu, and Y. Zhang, "Short-term residential load forecasting based on LSTM recurrent neural network", IEEE Trans. Smart Grid, vol. 10, no. 1, pp. 841–851, Jan. 2020.