Journal of Artificial Intelligence Practice (2023)
Clausius Scientific Press, Canada

DOI: 10.23977/jaip.2023.060309
ISSN 2371-8412 Vol. 6 Num. 3

Applications and challenges of hybrid artificial intelligence in chip age testing: a comprehensive review

Cong Xu, Wensheng Chen, Mingkuan Lin, Jianli Lu, Yunghsiao Chung, Jiahui Zou, Ciliang Yang

Global ETS. LLC, 2631 Success Dr, Odessa, Florida, 33556, USA

Keywords: Artificial intelligence, Convolutional Neural Networks, Recurrent Neural Networks, Genetic Algorithms, Genetic Algorithms

Abstract: As technology rapidly advances, semiconductor devices play a crucial role in various fields. However, these devices experience aging over time, leading to performance degradation, failure, or system crashes. Real-time aging detection of semiconductor devices is essential. This paper presents a real-time aging detection technique for semiconductor devices, combining deep learning and evolutionary algorithms, effectively assessing and predicting device aging states using Convolutional Neural Networks (CNN) and Recurrent Neural Networks (RNN). These features are then input into evolutionary algorithm frameworks, such as Genetic Algorithms (GA) and Genetic Algorithms (PSO), to identify and predict aging trends. The adaptation of evolutionary algorithms ensures good generalization for various semiconductor devices. Through extensive experimental data analysis, the proposed technique demonstrates excellent accuracy and real-time performance compared to traditional aging detection methods. In addition, it also monitors their operation in real-time, providing valuable support for maintenance and management personnel. The findings contribute to improving semiconductor device reliability and stability, providing a robust foundation for intelligent and automated maintenance.

1. Introduction

With the continuous advancement of technology, artificial intelligence (AI) has become an important driving force for social development today. Hybrid AI technology effectively overcomes the limitations of single methods by integrating various AI methods such as machine learning, deep learning, knowledge graphs, natural language processing, and computer vision, providing new solutions for the development of multiple fields. At the same time, with the rapid development of electronic technology, chips have a pivotal position in various fields. Effective testing and prediction of chip lifespan and aging are of significant importance to ensure their reliability and security.

As an interdisciplinary research direction, hybrid AI technology has achieved remarkable results in recent years, owing to the rapid development of computer hardware, the rise of big data technology, and the emergence of new algorithms (Xie, 2023). The development of hybrid AI technology provides a technical foundation for achieving chip lifespan and aging testing.

The lifespan and aging issues of chips significantly affect their performance and reliability. However, with the continuous miniaturization of chip manufacturing processes, chip lifespan and

aging testing face many challenges, such as data quality, fault location, and testing efficiency. Therefore, researching how to leverage hybrid AI technology to address these challenges and improve the accuracy and efficiency of chip lifespan and aging testing has important theoretical and practical value.

This study aims to provide a comprehensive review of the research and application of hybrid AI in chip lifespan and aging testing. Firstly, the basic concepts and development history of hybrid AI are outlined. Secondly, the application of hybrid AI technology in the field of chip lifespan and aging testing is analyzed. Then, the current challenges and future development trends are discussed. Finally, the prospects of hybrid AI in chip lifespan and aging testing are summarized and predicted. In conclusion, this article provides a valuable reference and inspiration for relevant researchers, aiming to promote the development of hybrid AI in the field of chip lifespan and aging testing by comprehensively reviewing its research and application, analyzing the current challenges and future development trends[1-4].

2. Hybrid Artificial Intelligence

Hybrid Artificial Intelligence (Hybrid AI), which is an integrated approach to Artificial Intelligence (AI) that combines different AI technologies to achieve more efficient and intelligent solutions. Hybrid AI leverages the strengths of various AI technologies to overcome the limitations of individual techniques, thereby offering broader applicability to solve practical problems.

2.1 Components of Hybrid AI

Hybrid AI comprises several different technologies, including Machine Learning (ML), Deep Learning (DL), Knowledge Graphs, Natural Language Processing (NLP), and Computer Vision (CV). ML is a data-driven AI technology that automatically discovers patterns and relationships from large volumes of data using algorithmic models. The primary methods of ML include Supervised Learning, Unsupervised Learning, Semi-supervised Learning, and Reinforcement Learning. DL is a neural network-based machine learning method that abstractly represents and processes data through multiple layers of neural networks. DL has made breakthroughs in Computer Vision and NLP, providing effective solutions for complex problems. Knowledge Graphs are a structured representation of knowledge that describes entities and their relationships through graph structures. Knowledge Graphs can provide structured knowledge backgrounds for Hybrid AI, improving the accuracy of reasoning and decision-making. NLP is an important branch of AI that aims to achieve computer understanding and generation of natural language. NLP techniques can help Hybrid AI systems better understand and process textual information, thereby improving the system's level of intelligence. CV is the field of research that focuses on making computers "see" and understand images or video information. CV technology plays a critical role in Hybrid AI systems by providing robust support for decision-making through the analysis and processing of image information.

2.2 Development and Trends of Hybrid AI

The development of Hybrid AI can be traced back to the 1950s, when researchers began exploring methods that combined symbolic and connectionist approaches. In recent years, Hybrid AI has made significant progress due to advances in computing power, the emergence of big data technology, and the advent of new algorithms. The trends in the development of Hybrid AI can be categorized into algorithm fusion, cross-modal learning, interpretability and transparency, adaptability and online learning, and security and privacy protection. Future Hybrid AI research will focus more on the fusion and collaboration of algorithms to create models with higher flexibility and robustness to address

more complex problems. Hybrid AI will further develop cross-modal learning methods to achieve information fusion among different modal data and improve the expressiveness and generalization ability of models. To enhance the reliability and trustworthiness of Hybrid AI, future research will pay more attention to the interpretability and transparency of models, making them more interpretable in complex scenarios. With the increasing demand for dynamic environments and real-time data, Hybrid AI will place greater emphasis on adaptability and online learning methods to maintain high efficiency and stability in ever-changing environments. With the growing awareness of data security and privacy protection, Hybrid AI will strengthen its research in security and privacy protection to provide safer technological guarantees for practical applications[5-7].

Hybrid AI is a technology with broad application prospects, and its development trends indicate the direction of future AI research. By integrating various AI technologies, Hybrid AI will play a greater role in fields such as chip life and aging testing , as shown in Figure 1.

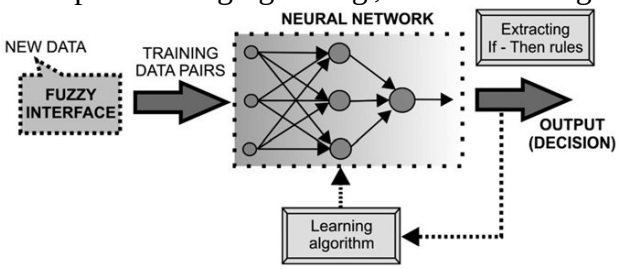

Figure 1: Sample Hybrid AI

3. Application of Hybrid Artificial Intelligence in Chip Lifetime and Burn-in Testing

Hybrid Artificial Intelligence (Hybrid AI) is increasingly being applied in chip lifetime and aging testing to improve test accuracy, reduce costs, and enhance production efficiency (Sahoo et al., 2022). Several specific applications and case studies are discussed below.

3.1 Lifetime Prediction Model

Hybrid AI can help build accurate chip lifetime prediction models. For example, in a recent study, researchers improved the accuracy of chip lifetime prediction by combining support vector machine (SVM) and artificial neural network (ANN) models, providing valuable reference information for designers and manufacturers (Manoharan et al., 2022). Chang et al. (2023) introduced how to reduce the training time of AI through grid search and parallel computing to improve the efficiency of electronic packaging technology. They combined verified finite element models with machine learning to enhance simulation accuracy and explored the optimization of hyperparameters with parallel computing in a case study of wafer-level chip-scale packaging (WLCSP) , as shown in Figure 2.

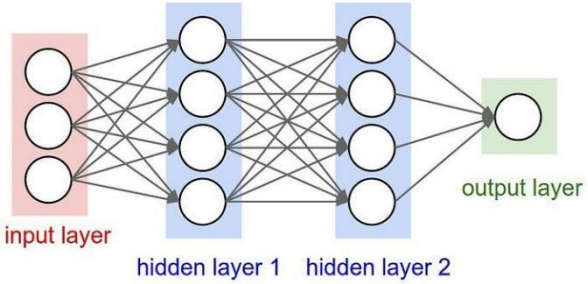

Figure 2: A diagram representing ANN (Zulu et al., 2023)

3.2 Aging Mechanism Research

Hybrid AI can be used to gain a deeper understanding of chip aging mechanisms. For instance, in a study, knowledge graph and natural language processing techniques were used to analyze literature data, revealing the critical factors and their interactions in chip aging and providing important references for further optimization of chip design. Dang et al. (2020) proposed a platform for thermal distribution, lifetime reliability prediction, and spare TSV insertion in 3D-IC stacking and explored different layouts and cooling strategies to address thermal dissipation issues in 3D-IC stacking[8-9].

3.3 Aging Parameter Extraction and Analysis

Hybrid AI can effectively extract and analyze the key parameters of chip aging (Li et al., 2022). In a practical case, researchers used machine learning algorithms to analyze temperature, voltage, and other parameters of chips, established a model of the relationship between parameters and aging, and provided important references for chip lifetime prediction and aging testing. Hybrid AI can help automatically identify and locate chip fault modes. Researchers successfully detected fault locations by analyzing chip image data using computer vision technology, providing the basis for subsequent repairs , as shown in Figure 3.

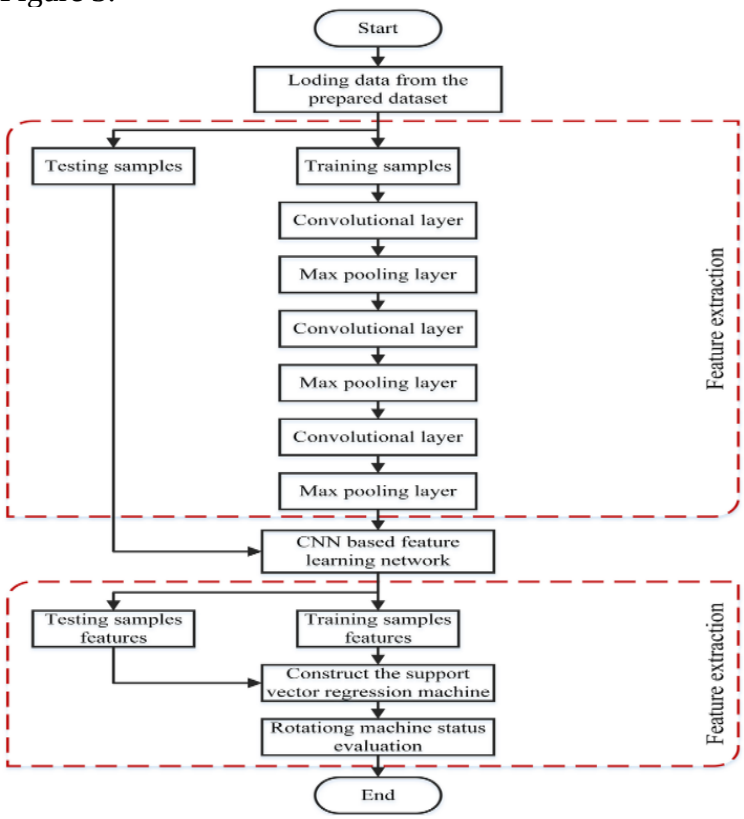

Figure 3: A model of the relationship between parameters and aging

3.4 Application of Automatic Test Equipment (ATE) in Lifetime and Aging Testing

Hybrid AI can improve the performance of automatic test equipment (ATE) in chip lifetime and aging testing (Ronald et al., 2022). By applying deep learning and knowledge graph technologies to the testing process, real-time processing, analysis, and decision-making of test data were achieved, significantly improving test efficiency and accuracy. Hybrid AI can be applied to real-time monitoring and predictive maintenance of chips. In a study at GLOBAL ETS LLC in the Florida Data

Research Center, researchers used Hybrid AI to analyze a large amount of data generated during chip operation, predicting possible faults and performing maintenance in advance, effectively prolonging chip life and reducing maintenance costs.

Hybrid AI has significant advantages in chip lifetime and aging testing (Lai et al., 2020). By combining multiple AI technologies, such as machine learning, deep learning, knowledge graphs, natural language processing, and computer vision, Hybrid AI can effectively improve test accuracy, reduce costs, and enhance production efficiency. As Hybrid AI technology continues to evolve, its application in the field of chip lifetime and aging testing will become more extensive and profound.

4. Future Research Directions on Hybrid Artificial Intelligence in Chip Lifespan and Aging Testing

With the continuous development of chip technology and hybrid artificial intelligence (AI) technology, the field of chip lifespan and aging testing is facing new challenges and opportunities. To address the increasingly complex chip designs and continuously improving performance requirements, future research requires more innovative hybrid AI algorithms and models. These new models will combine various AI technologies such as reinforcement learning, generative adversarial networks, etc., to improve the accuracy and efficiency of chip lifespan and aging testing. As the amount of chip testing data grows rapidly, future research needs to develop more effective data processing and feature extraction methods. These methods will utilize hybrid AI technologies such as automatic feature engineering and unsupervised learning to discover key information and potential patterns hidden in large amounts of data.

Future research will focus on developing end-to-end solutions for lifespan and aging testing, integrating various AI technologies at all stages. These solutions will include the entire process from data collection, pre-processing, feature extraction to lifespan prediction, fault diagnosis, and predictive maintenance, to achieve comprehensive monitoring and management of chip lifespan and aging. As hybrid AI technology is widely applied in the field of chip lifespan and aging testing, ethical, legal, and policy issues are also increasingly prominent. Future research needs to explore how to promote the development and application of hybrid AI technology while ensuring data security, protecting intellectual property rights, and complying with laws and regulations.

The research directions in the field of chip lifespan and aging testing will focus on innovation in hybrid AI technology, optimization of data processing and feature extraction methods, development of end-to-end solutions, and exploration of ethical, legal, and policy issues. These studies will help to promote technological progress in the field of chip lifespan and aging testing, improve chip performance and reliability, reduce production and maintenance costs, and provide critical support for the development of multiple industries such as information technology, communication, automotive, aerospace, and more.

At the same time, future research needs to focus on interdisciplinary integration and collaboration, combining hybrid AI technology with materials science, electronic engineering, reliability engineering, and other fields to comprehensively address various issues in chip lifespan and aging testing. In addition, strengthening international cooperation and information exchange, sharing research results and experiences, will also help to promote the development of hybrid AI in the field of chip lifespan and aging testing.

Talent cultivation and education, to cultivate more professionals with a background in hybrid AI technology in the field of chip lifespan and aging testing, to meet the needs of future industrial development. At the same time, raising awareness in society about the application of hybrid AI technology in chip lifespan and aging testing, increasing policy support and investment, will help to promote the research and application of relevant technologies, providing a strong driving force for

the development and innovation of the entire chip industry.

5. Conclusion

This paper has reviewed the research and applications of hybrid artificial intelligence in chip lifetime and aging testing. Hybrid artificial intelligence technology, by combining various artificial intelligence methods such as machine learning, deep learning, knowledge graphs, natural language processing, and computer vision, brings significant advantages to chip lifetime and aging testing. In aspects like lifetime prediction models, aging mechanism research, aging parameter extraction and analysis, and failure mode identification and localization, hybrid artificial intelligence technology has achieved remarkable results and has been successfully applied to real-world cases.

However, there are still many challenges and research directions, including the innovation of hybrid artificial intelligence algorithms and models, more effective data processing and feature extraction methods, end-to-end lifetime and aging testing solutions, and ethics, law, and policy research. Through continuous research and innovation, it is expected to address these challenges and promote the development of hybrid artificial intelligence applications in the field of chip lifetime and aging testing.

In summary, hybrid artificial intelligence technology has a broad application prospect and huge development potential in the field of chip lifetime and aging testing. With the continuous advancement of technology, hybrid artificial intelligence will play an increasingly important role in improving chip lifetime, reducing costs, and enhancing production efficiency, providing key support for the continuous development and innovation of the chip industry and its related fields.

References

[1] K. Dang, A. Benahmed, F. Rahman, B. Benabid and T. Tu, "Thermal Distribution, Lifetime Reliability Prediction and Spare TSV Insertion Platform for Stacking 3D-ICs," 2020 International Conference on Advanced Technologies for Communications (ATC), Hanoi, Vietnam, 2020, pp. 53-58, doi: 10.1109/ATC48548. 2020.9325085

[2] C. Y. Chang, C. H. Lee, and K. N. Chiang, "Using Grid Search Methods and Parallel Computing to Reduce AI Training Time for Reliability Lifetime Prediction of Wafer-Level Packaging," in 2023 24th International Conference on Thermal, Mechanical and Multi-Physics Simulation and Experiments in Microelectronics and Microsystems (EuroSimE), 2023, pp. 5-10.

[3] Lai Chunfeng, et al. "High luminous efficacy and enhanced stability of QDs via a network silica and methylphenyl silicone hybrid for the long-term operation of on-chip white light-emitting diodes with a wide color gamut." Applied Materials Today 20 (2020): 100739.

[4] Li Zongtao, et al. "Solid–Liquid Hybrid-State Organic Lens for Highly Efficient Deep Ultraviolet Light-Emitting Diodes." Advanced Photonics Research 3.5 (2022): 2100211.

[5] Larson Ronald B. "Controlling social desirability bias." International Journal of Market Research 61.5 (2019): 534-547.

[6] Manoharan Aaruththiran, et al. "Artificial neural networks, gradient boosting and support vector machines for electric vehicle battery state estimation: A review." Journal of Energy Storage 55 (2022): 105384.

[7] Sahoo Satyajeet, et al. "Artificial Deep Neural Network in Hybrid PV System for Controlling the Power Management." International Journal of Photoenergy 2022 (2022).

[8] Xie Haonan, et al. "IntelliSense technology in the new power systems." Renewable and Sustainable Energy Reviews 177 (2023): 113229.

[9] Zulu, Musawenkosi Lethumcebo Thanduxolo, Rudiren Pillay Carpanen, and Remy Tiako. "A Comprehensive Review: Study of Artificial Intelligence Optimization Technique Applications in a Hybrid Microgrid at Times of Fault Outbreaks." Energies 16.4 (2023): 1786.