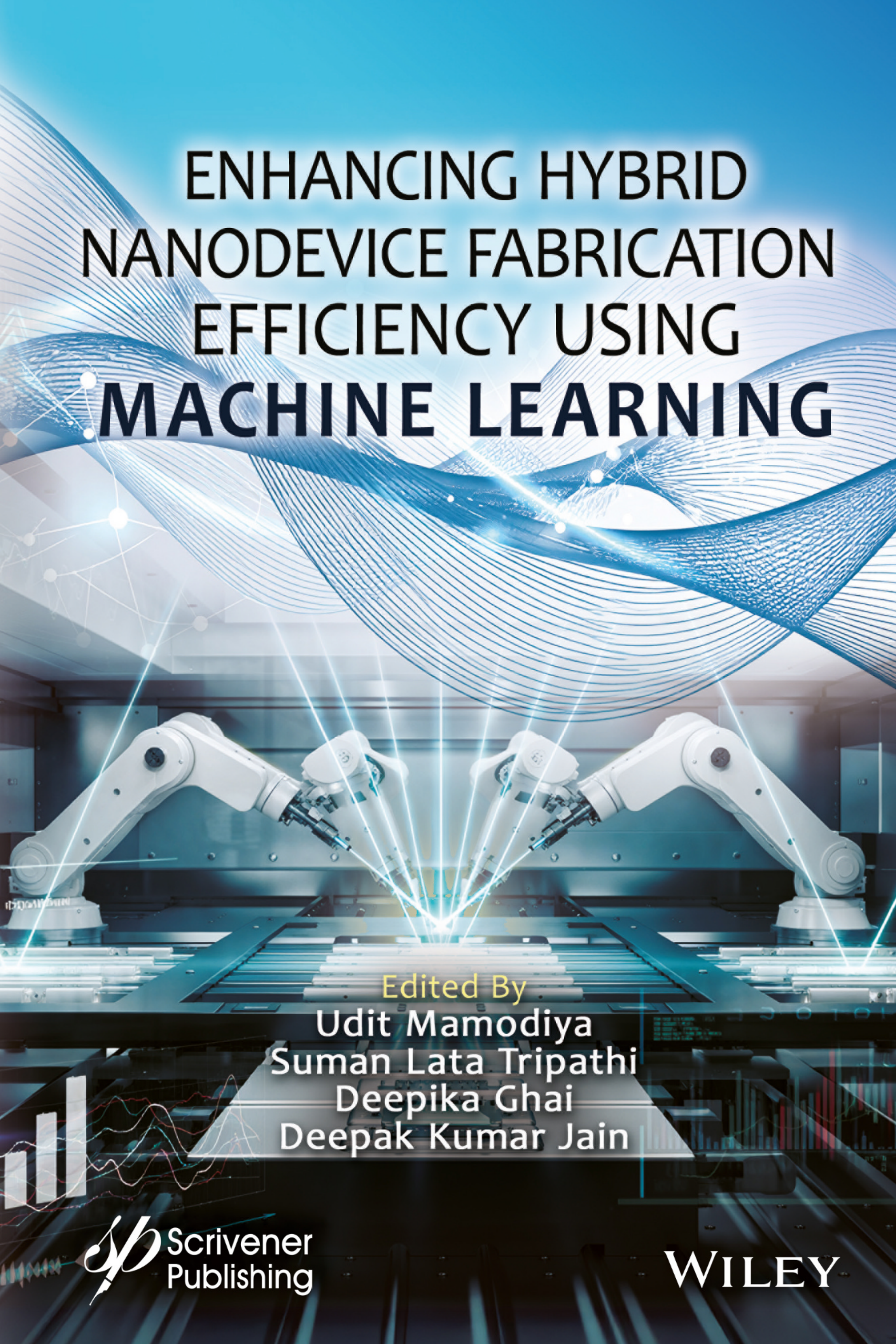

ENHANCING HYBRID NANODEVICE FABRICATION EFFICIENCY USING MACHINE LEARNING

Edited By

Udit Mamodiya
Suman Lata Tripathi
Deepika Ghai
Deepak Kumar Jain

Scrivener Publishing

WILEY

Enhancing Hybrid Nanodevice Fabrication Efficiency Using Machine Learning

Scrivener Publishing
100 Cummings Center, Suite 541J
Beverly, MA 01915-6106

Publishers at Scrivener
Martin Scrivener (martin@scrivenerpublishing.com)
Phillip Carmical (pcarmical@scrivenerpublishing.com)

Enhancing Hybrid Nanodevice Fabrication Efficiency Using Machine Learning

Edited by

Udit Mamodiya

Suman Lata Tripathi

Deepika Ghai

and

Deepak Kumar Jain

Scrivener
Publishing

WILEY

This edition first published 2026 by John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, USA and Scrivener Publishing LLC, 100 Cummings Center, Suite 541J, Beverly, MA 01915, USA

For more information about Scrivener publications please visit www.scrivenerpublishing.com.

Wiley Global Headquarters
111 River Street, Hoboken, NJ 07030, USA

For details of our global editorial offices, customer services, and more information about Wiley products visit us at www.wiley.com.

The manufacturer's authorized representative according to the EU General Product Safety Regulation is Wiley-VCH GmbH, Boschstr. 12, 69469 Weinheim, Germany, e-mail: Product_Safety@wiley.com.

Library of Congress Cataloging-in-Publication Data

ISBN 9781394355280

Cover image: Generated with AI using Adobe Firefly
Cover design by Russell Richardson

Set in size of 11pt and Minion Pro by Manila Typesetting Company, Makati, Philippines

Printed in the USA

10 9 8 7 6 5 4 3 2 1

Contents

Preface

Enhancing Hybrid Nanodevice Fabrication Efficiency using Machine Learning explores the intersection of advanced manufacturing techniques and machine learning (ML) applications in the field of nanotechnology, specifically focusing on hybrid nanodevices for integrated circuits (ICs). This book aims to provide a comprehensive understanding of how ML algorithms and techniques can optimize the fabrication processes of hybrid nanodevices, thereby improving their efficiency, reliability, and performance in IC applications. The presented book begins with an introduction to the fundamentals of hybrid nanodevice fabrication and the role of ML in enhancing these processes. It then delves into various ML algorithms and models used for process optimization, quality control, and predictive maintenance in IC fabrication. Case studies and practical examples illustrate real-world applications of ML in improving yield, reducing costs, and accelerating time-to-market for hybrid nanodevices. The integration of machine learning into hybrid nanodevice fabrication processes is crucial for advancing semiconductor technology. Traditional methods often struggle with optimizing complex fabrication processes at the nanoscale level, where precision and consistency are paramount. ML offers a promising solution by enabling automated decision-making, pattern recognition, and predictive analytics that can significantly enhance fabrication efficiency and yield.

This book addresses the pressing need for a comprehensive guide on ML applications in nanodevice fabrication. It provides researchers, engineers, and industry professionals with practical insights into implementing ML techniques to tackle challenges such as variability reduction, defect detection, and process optimization. By bridging the gap between theory and practice, the book equips readers with the knowledge and tools necessary to leverage ML for competitive advantage in the semiconductor industry. This book is intended for professionals and researchers working in semiconductor manufacturing, nanotechnology, and integrated circuit design. It is also suitable for graduate students and academics interested in the application of machine learning in advanced manufacturing processes. The content is designed to be accessible yet informative, catering to both newcomers and experienced practitioners seeking to enhance their understanding and implementation of ML in hybrid nanodevice fabrication.

Key topics covered include:

- Fundamentals of hybrid nanodevice fabrication techniques
- Introduction to machine learning and its applications in manufacturing
- ML algorithms for process optimization and quality assurance in IC fabrication
- Predictive modeling and maintenance strategies for hybrid nanodevice production
- Case studies and industry examples showcasing ML-driven improvements in efficiency
- Future trends and challenges in integrating ML with nanodevice fabrication technologies

Author(s)
Udit Mamodiya
Suman Lata Tripathi
Deepika Ghai
Deepak Kumar Jain

1

Challenges and Limitations in Implementation: Nanodevice Fabrication Efficiency Using Machine Learning

Amit Kumar Jain[1]*, Tarun Mishra[1] and Mohamed M. Awad[2]

[1]Dept. of Electrical & Electronics Engineering, Poornima University, Rajasthan, India
[2]Mechanical Power Engineering Department, Faculty of Engineering, Mansoura University, Mansoura, Egypt

Abstract

This chapter thus provides a brief summary of the critical issues and constraints relating to the integration of machine learning (ML) in the production of hybrid nanodevices and the technical and business difficulties that surround the mainstreaming of the technology. One of the primary issues with ML application in nanodevice fabrication is that the data used are often low quality and limited in availability. Nanofabrication is a sophisticated process that is characterized by variations in characteristics of materials and conditions, which allow a huge volume of high-quality data to be collected for model training for ML. For effectiveness of procedures used in fabrication, minimum accuracy comes from noisy or inadequate data, which leads to wrong predictions. Additionally, the computational costs remain high for higher-level algorithms; more so, the deep learning algorithms demand significant computing power for the handling of simulations as well as large dataset. This is because by increasing the cost of the production process, it becomes difficult for research laboratories and manufacturing facilities to purchase these technologies for extensive use. Nevertheless, the future of ML in hybrid nanodevice fabrication remains possibly challenging but promising. Some of the current limitations can be handled using transfer learning, edge computing, and self-learning systems, among others. Moreover, due to improvements in nanotechnology and ML, data generation will be more effective as well as computational approaches, and integration with the existing environments will be less challenging.

**Corresponding author:* jain.2102@gmail.com

Udit Mamodiya, Suman Lata Tripathi, Deepika Ghai and Deepak Kumar Jain (eds.)
Enhancing Hybrid Nanodevice Fabrication Efficiency Using Machine Learning, (1–22) © 2026 Scrivener Publishing LLC

***Keywords*:** Machine learning (ML), hybrid nanodevices, nanofabrication, data quality, model interpretability, deep learning, computational costs

1.1 Introduction

1.1.1 Overview of Hybrid Nanodevice Fabrication

Nanotechnology at present has achieved fast progress and has thereby prompted the emergence of enhanced nanodevices and nanoscale devices that possess new characteristics in physics, chemistry, and even biology. Nanoscale electrical sensors are nowadays the backbone of the most electrical products, including circuits, energy systems, and medical and environmental applications because of their sensitivity, selectivity, and scale integration. Novel nanoscale devices that can consist of at least two materials and provide at least two functionalities are especially interesting because of multiple benefits such as their efficiency. For example, within electronics, there may be a synergism where a hybrid nanodevice contains both semiconductor material with conductive polymers that are used in making superior sensors or transistors. The biomedical standing of these composites gets seen in metal–polymer hybrid nanostructures working toward better drug delivery technologies with controllable release capabilities.

1.1.2 Role of Machine Learning in Nanodevice Fabrication

Machine learning (ML) provides a revolutionary solution to these fabrication challenges as it will improve fabrication efficiency, accuracy, and scale. Because ML algorithms follow the data patterns to analyze and learn the likely outcomes, fabrication parameters can be modeled using ML to predict data results that can simplify fabrication processes. Conventional manufacturing techniques rely on modifying the fabrication conditions "by guess and by golly" a slow and expensive way of doing things that also has fixed boundaries to improvement. Specifically, although artificial neural networks can be trained using the large banks of materials properties and fabrication conditions, the successful outcome can be well dictated with high accuracy, and often the identification of optimal fabrication parameter combination for given devices' characteristics is possible [1–3].

ML applications in nanodevice fabrication can be broadly categorized into several areas: