



DISCOVERY OF NEW HIGH-FREQUENCY MAGNETIC MATERIALS ENABLED BY ARTIFICIAL INTELLIGENCE

This project will harness artificial intelligence (AI) to develop new high-frequency magnetic materials in support of the development of more resilient electrical grid components. Using AI in both the identification and synthesis of these new materials will dramatically shorten the time needed to develop these materials.

THE CHALLENGE

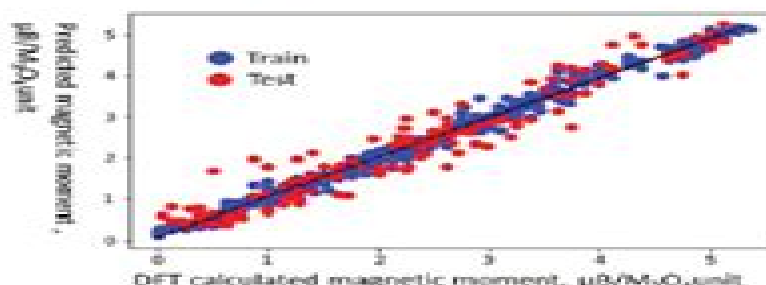
Solid-state transformers are a promising approach to making the electrical grid more resilient. Solid-state transformers can be more resistant to attack, and they can be more easily replaced than the massive, foreign-made, grid-scale transformers that are currently used. The optimum solid-state transformer would take advantage of the high switching speeds that are enabled by ultrawide bandgap switches, but unfortunately, current inductor materials have magnetic hysteresis losses that are too high at these frequencies. We need better high-frequency inductors to realize the potential of solid-state transformers.

The goal of this project is to use artificial intelligence to identify and synthesize new high-frequency ferrites to support new electrical architectures in power systems (such as solid-state transformers). This will dramatically shorten the time to develop new materials and allow us to test them in circuits within a three-year project period.

APPROACH

We are attacking this problem using artificial intelligence (AI) in all stages of the work from initial identification of target materials to the synthesis and characterization of the materials. We will train AI to identify new materials that have improved high-frequency magnetic properties using density functional theory (DFT) calculations. DFT calculations are generally extremely accurate, but are too time-consuming to effectively search the massive number of unknown ferrite phases. So, a series of DFT calculations can be used to train AI to find candidate material more

quickly and efficiently. The new materials identified by AI can then be subjected to full DFT calculations. If the AI is accurate, the materials will be synthesized.



AI being trained to determine the magnetic moment of unknown magnetic ferrites. Red dots represent the AI determinations; the closer they are to the black line, the more accurate the determination.

Synthesizing new materials can be as challenging as identifying materials that should be synthesized. Simply knowing the ultimate materials' components and structures doesn't mean they can be synthesized. We will use the DFT simulations to calculate the X-ray diffraction (XRD) pattern of each desired material. Then, when we attempt to synthesize the material we will collect XRD in real time and compare the patterns to the pattern of the desired product in real time using AI. The AI can adjust the reaction conditions and monitor the output of the reaction until the correct phase is synthesized. In time, the AI will become more efficient at synthesizing new, unknown phases as it learns the influence of the synthetic parameters such as time, concentrations, and temperature.

These reactions will be designed to produce nanoparticles, which leads to rapid reactions that produce materials that remain in solution, easing the collection of real-time XRD. Once we successfully produce the desired nanoparticles, the nanoparticles can undergo warm compaction to create toroidal inductors that can be wound with wire to test the inductors in the circuits of interest.

High Frequency Magnetic Materials

Hock Lim, Serguei Matitsine



High Frequency Magnetic Materials:

High-frequency Magnetic Materials, Their Characteristics and Principal Applications W. J. Polydoroff, 1960

High Frequency Processes In Magnetic Materials Andrei N Slavin, Gopalan Srinivasan, 1995-08-31 This review volume deals with recent advances in topics of importance to scientists and engineers involved in research and device development utilizing magnetic oxides and multilayers The subject matter covered includes linear and nonlinear high frequency magnetic excitations and interaction between magnons and photons In particular this book contains detailed discussion on the detection of magnons by Brillouin light scattering and photothermal spectroscopy interaction between spin waves and optical guided modes microwave solitons and spin wave instabilities Recent advances in traditional characterization techniques such as ferromagnetic and antiferromagnetic resonance and in studies on magnetic order in noncrystalline oxides are also presented

High-Frequency Magnetic Components Marian K. Kazimierczuk, 2011-08-24 If you are looking for a complete study of the fundamental concepts in magnetic theory read this book No other textbook covers magnetic components of inductors and transformers for high frequency applications in detail This unique text examines design techniques of the major types of inductors and transformers used for a wide variety of high frequency applications including switching mode power supplies SMPS and resonant circuits It describes skin effect and proximity effect in detail to provide you with a sound understanding of high frequency phenomena As well as this you will discover thorough coverage on integrated inductors and the self capacitance of inductors and transformers with expressions for self capacitances in magnetic components criteria for selecting the core material as well as core shape and size and an evaluation of soft ferromagnetic materials used for magnetic cores winding resistance at high frequencies expressions for winding and core power losses when non sinusoidal inductor or transformer current waveforms contain harmonics Case studies practical design examples and procedures using the area product method and the geometry coefficient method are expertly combined with concept orientated explanations and student friendly analysis Supplied at the end of each chapter are summaries of the key concepts review questions and problems the answers to which are available in a separate solutions manual Such features make this a fantastic textbook for graduates senior level undergraduates and professors in the area of power electronics in addition to electrical and computer engineering This is also an inimitable reference guide for design engineers of power electronics circuits high frequency transformers and inductors in areas such as SMPS and RF power amplifiers and circuits

High-frequency Magnetic Materials(their Characteristics And Principal Applicat.) W.J. Polydoroff, *High-frequency Magnetic Materials* Wladimir John Polydoroff, 1960

Magnetic Material for Motor Drive Systems Keisuke Fujisaki, 2019-11-29 This book focuses on how to use magnetic material usefully for electrical motor drive system especially electrical vehicles and power electronics The contents have been selected in such a way that engineers in other fields might find some of the ideas difficult to grasp but they can easily acquire a general or basic understanding of related concepts if they acquire even a rudimentary

understanding of the selected contents The cutting edge technologies of magnetism are also explained From the fundamental theory of magnetism to material equipment and applications readers can understand the underlying concepts Therefore a new electric vehicle from the point of view of magnetic materials or a new magnetic material from the point of a view of electric vehicles can be envisioned that is magnetic material for motor drive systems based on fusion technology of an electromagnetic field Magnetic material alone does not make up an electric vehicle of course Other components such as mechanical structure material semiconductors fuel cells and electrically conductive material are important and they are difficult to achieve However magnetic material involves one of the most important key technologies and there are high expectations for its use in the future It will be the future standard for motor drive system researchers and of magnetic material researchers as well This book is a first step in that direction

High-frequency Magnetic Materials, Etc Wladimir John Polydoroff, 1961 **Direct-current Magnetic Measurements for Soft Magnetic Materials** American Society for Testing and Materials. Committee A-6 on Magnetic Properties, 1970 □□□□□□□□□□(21□□□□□□□□□□□□□□1

□) David J. Sellmyer, 2005 **High-Frequency Magnetic Components** Dr. Marian K. Kazimierczuk, 2009-11-02 If you are looking for a complete study of the fundamental concepts in magnetic theory read this book No other textbook covers magnetic components of inductors and transformers for high frequency applications in detail This unique text examines design techniques of the major types of inductors and transformers used for a wide variety of high frequency applications including switching mode power supplies SMPS and resonant circuits It describes skin effect and proximity effect in detail to provide you with a sound understanding of high frequency phenomena As well as this you will discover thorough coverage on integrated inductors and the self capacitance of inductors and transformers with expressions for self capacitances in magnetic components criteria for selecting the core material as well as core shape and size and an evaluation of soft ferromagnetic materials used for magnetic cores winding resistance at high frequencies expressions for winding and core power losses when non sinusoidal inductor or transformer current waveforms contain harmonics Case studies practical design examples and procedures using the area product method and the geometry coefficient method are expertly combined with concept orientated explanations and student friendly analysis Supplied at the end of each chapter are summaries of the key concepts review questions and problems the answers to which are available in a separate solutions manual Such features make this a fantastic textbook for graduates senior level undergraduates and professors in the area of power electronics in addition to electrical and computer engineering This is also an inimitable reference guide for design engineers of power electronics circuits high frequency transformers and inductors in areas such as SMPS and RF power amplifiers and circuits

Additive Manufacturing of Magnetic Materials Moataz Attallah, Abdelmoez Hussein, 2025-08-01 Additive Manufacturing of Magnetic Materials Techniques Materials Applications Opportunities and Challenges outlines different 3D printing techniques that can be employed to create an array of different magnetic materials along with how these materials

can be effectively applied The book discusses the additive manufacturing AM of soft magnets permanent hard magnets 4D magnetic shape memory alloys magnetocaloric materials and rare earth based magnetic alloys Different AM techniques are covered including laser powder bed fusion directed laser deposition binder jetting cold spray and the different influences of these techniques on the microstructure of the material produced Common challenges are highlighted with solutions also provided and applications covered include magnetic shielding actuators sensors robotics and magnetic heat exchangers for solid state heat pumps Presents various additive manufacturing techniques the different types of magnetic materials produced and their applications Discusses soft and permanent hard magnets 4D magnetic shape memory alloys magnetocaloric materials and rare earth based magnetic alloys Highlights the common microstructural defects associated with different manufacturing techniques Covers applications such as magnetic shielding actuators sensors robotics and magnetic heat exchangers for solid state heat pumps

Electromagnetic Materials Hock Lim, Serguei Matitsine, 2003

Electromagnetic materials have both civilian and defence applications such as novel antenna designs and protection against high power transients in densely packed printed circuits For certain applications the materials may be required to have special frequency response or polarization response to meet the component or system specifications An in depth understanding of the responses of materials to electromagnetic waves may even enable us to design and fabricate materials with properties not found in nature This book constitutes the proceedings of the Symposium on Electromagnetic Materials which provided a forum for scientists and engineers to report the latest research findings to exchange ideas and information and to establish research links

Handbook of Advanced Magnetic Materials Yi Liu, D.J. Sellmyer, Daisuke Shindo, 2008-11-23

In December 2002 the world's first commercial magnetic levitation super train went into operation in Shanghai The train is held just above the rails by magnetic levitation maglev and can travel at a speed of 400 km/hr completing the 30km journey from the city to the airport in minutes Now consumers are enjoying 50 GB hard drives compared to 0.5 GB hard drives ten years ago Achievements in magnetic materials research have made dreams of a few decades ago reality The objective of the four volume reference Handbook of Advanced Magnetic Materials is to provide a comprehensive review of recent progress in magnetic materials research Each chapter will have an introduction to give a clear definition of basic and important concepts of the topic The details of the topic are then elucidated theoretically and experimentally New ideas for further advancement are then discussed Sufficient references are also included for those who wish to read the original work In the last decade one of the most significant thrust areas of materials research has been nanostructured magnetic materials There are several critical sizes that control the behavior of a magnetic material and size effects become especially critical when dimensions approach a few nanometers where quantum phenomena appear The first volume of the book Nanostructured Advanced Magnetic Materials has therefore been devoted to the recent development of nanostructured magnetic materials emphasizing size effects Our understanding of magnetism has advanced with the

establishment of the theory of atomic magnetic moments and itinerant magnetism Simulation is a powerful tool for exploration and explanation of properties of various magnetic materials Simulation also provides insight for further development of new materials Naturally before any simulation can be started a model must be constructed This requires that the material be well characterized Therefore the second volume Characterization and Simulation provides a comprehensive review of both experimental methods and simulation techniques for the characterization of magnetic materials After an introduction each section gives a detailed description of the method and the following sections provide examples and results of the method Finally further development of the method will be discussed The success of each type of magnetic material depends on its properties and cost which are directly related to its fabrication process Processing of a material can be critical for development of artificial materials such as multilayer films clusters etc Moreover cost effective processing usually determines whether a material can be commercialized In recent years processing of materials has continuously evolved from improvement of traditional methods to more sophisticated and novel methods The objective of the third volume Processing of Advanced Magnetic Materials is to provide a comprehensive review of recent developments in processing of advanced magnetic materials Each chapter will have an introduction and a section to provide a detailed description of the processing method The following sections give detailed descriptions of the processing properties and applications of the relevant materials Finally the potential and limitation of the processing method will be discussed The properties of a magnetic material can be characterized by intrinsic properties such as anisotropy saturation magnetization and extrinsic properties such as coercivity The properties of a magnetic material can be affected by its chemical composition and processing route With the continuous search for new materials and invention of new processing routes magnetic properties of materials cover a wide spectrum of soft magnetic materials hard magnetic materials recording materials sensor materials and others The objective of the fourth volume Properties and Applications of Advanced Magnetic Materials is to provide a comprehensive review of recent development of various magnetic materials and their applications Each chapter will have an introduction of the materials and the principles of their applications The following sections give a detailed description of the processing properties and applications Finally the potential and limitation of the materials will be discussed **Ferrite**

Nanostructured Magnetic Materials Jitendra Pal Singh, Keun Hwa Chae, Ramesh Chandra Srivastava, Ovidiu Florin Caltun, 2023-04-28 Ferrite Nanostructured Magnetic Materials Technologies and Applications provides detailed descriptions of the physical properties of ferrite nanoparticles and thin films Synthesis methods and their applications in numerous fields are also included And since characterization methods play an important role in investigating the materials phenomena various characterization tools applied to ferrite materials are also discussed To meet the requirements of next generation characterization tools in the field of ferrite research synchrotron radiation based spectroscopic and imaging tools are thoroughly explored Finally the book discusses current and emerging applications of ferrite nanostructured materials in

industry health catalytic and environmental fields making this comprehensive resource suitable for researchers and practitioners in the disciplines of materials science and engineering chemistry and physics Reviews the fundamentals of ferrite materials including their magnetic electrical dielectric and optical properties Includes discussions on the most relevant and emerging synthesis and optimization of ferrite nanostructured materials for a diverse range of morphologies Provides an overview of both the most relevant and emerging applications of ferrite magnetic materials in industry health energy and environmental remediation **High-Frequency Magnetic Materials: Their Characteristics and Principal Applications** Wladimir John POLYDOROFF,1960 **Introduction to Magnetism and Magnetic Materials** David Jiles,2015-09-18 A long overdue update this edition of Introduction to Magnetism and Magnetic Materials is a complete revision of its predecessor While it provides relatively minor updates to the first two sections the third section contains vast updates to reflect the enormous progress made in applications in the past 15 years particularly in magnetic recording

Magnetic Components for Power Electronics Alex Goldman,2012-12-06 Magnetic Components for Power Electronics concerns the important considerations necessary in the choice of the optimum magnetic component for power electronic applications These include the topology of the converter circuit the core material shape size and others such as cost and potential component suppliers These are all important for the design engineer due to the emergence of new materials changes in supplier management and the examples of several component choices Suppliers using this volume will also understand the needs of designers Highlights include Emphasis on recently introduced new ferrite materials such as those operating at megahertz frequencies and under higher DC drive conditions Discussion of amorphous and nanocrystalline metal materials New technologies such as resonance converters power factors correction PFC and soft switching Catalog information from over 40 magnetic component suppliers Examples of methods of component choice for ferrites amorphous nanocrystalline materials Information on suppliers management changes such as those occurring at Siemens Philips Thomson and Allied Signal Attention to the increasingly important concerns about EMI This book should be especially helpful for power electronic circuit designers technical executives and material science engineers involved with power electronic components *Technical News Bulletin* United States. National Bureau of Standards,1952 Comprehensive Energy Systems Ibrahim Dincer,2018-02-07 Comprehensive Energy Systems Seven Volume Set provides a unified source of information covering the entire spectrum of energy one of the most significant issues humanity has to face This comprehensive book describes traditional and novel energy systems from single generation to multi generation also covering theory and applications In addition it also presents high level coverage on energy policies strategies environmental impacts and sustainable development No other published work covers such breadth of topics in similar depth High level sections include Energy Fundamentals Energy Materials Energy Production Energy Conversion and Energy Management Offers the most comprehensive resource available on the topic of energy systems Presents an authoritative resource authored and

edited by leading experts in the field Consolidates information currently scattered in publications from different research fields engineering as well as physics chemistry environmental sciences and economics thus ensuring a common standard and language The Canadian Patent Office Record and Register of Copyrights and Trade Marks ,1926

High Frequency Magnetic Materials Book Review: Unveiling the Magic of Language

In a digital era where connections and knowledge reign supreme, the enchanting power of language has been apparent than ever. Its capability to stir emotions, provoke thought, and instigate transformation is truly remarkable. This extraordinary book, aptly titled "**High Frequency Magnetic Materials**," written by a highly acclaimed author, immerses readers in a captivating exploration of the significance of language and its profound affect on our existence. Throughout this critique, we will delve to the book's central themes, evaluate its unique writing style, and assess its overall influence on its readership.

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Table of Contents High Frequency Magnetic Materials

1. Understanding the eBook High Frequency Magnetic Materials
 - The Rise of Digital Reading High Frequency Magnetic Materials
 - Advantages of eBooks Over Traditional Books
2. Identifying High Frequency Magnetic Materials
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an High Frequency Magnetic Materials
 - User-Friendly Interface
4. Exploring eBook Recommendations from High Frequency Magnetic Materials
 - Personalized Recommendations
 - High Frequency Magnetic Materials User Reviews and Ratings
 - High Frequency Magnetic Materials and Bestseller Lists
5. Accessing High Frequency Magnetic Materials Free and Paid eBooks

- High Frequency Magnetic Materials Public Domain eBooks
- High Frequency Magnetic Materials eBook Subscription Services
- High Frequency Magnetic Materials Budget-Friendly Options
- 6. Navigating High Frequency Magnetic Materials eBook Formats
 - ePub, PDF, MOBI, and More
 - High Frequency Magnetic Materials Compatibility with Devices
 - High Frequency Magnetic Materials Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of High Frequency Magnetic Materials
 - Highlighting and Note-Taking High Frequency Magnetic Materials
 - Interactive Elements High Frequency Magnetic Materials
- 8. Staying Engaged with High Frequency Magnetic Materials
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers High Frequency Magnetic Materials
- 9. Balancing eBooks and Physical Books High Frequency Magnetic Materials
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection High Frequency Magnetic Materials
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine High Frequency Magnetic Materials
 - Setting Reading Goals High Frequency Magnetic Materials
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of High Frequency Magnetic Materials
 - Fact-Checking eBook Content of High Frequency Magnetic Materials
 - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development

- Exploring Educational eBooks

14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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