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Shaping a Sustainable Future: The Convergence of Materials Science, Critical Minerals and Technological Innovation

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The National Academy of Engineering recognized the Grand Challenges in engineering for the 21st century in 2008. These challenges encompass tasks such as ensuring access to economical solar energy, managing the nitrogen cycle, engineering the tools of scientific discovery, and other obstacles that must be overcome for humans to continue advancing. More than half of these challenges will necessitate the development and use of novel advanced materials. The question at hand is the origin of these novel elements.

Surprisingly, many everyday items have their origins in were stumbled upon by coincidence. Products like playdough, stainless steel, rubber tires, superconductors, and superglue stand as a testament to this phenomenon in engineering materials, where their defining characteristics were uncovered almost by accident. Take into account artificial sweeteners such as saccharin. In 1878, Constantin Fahlberg was diligently conducting research on coal-tar compounds. After accidentally spilling chemicals on his hands, he proceeds to find it excessively sweet. After a span of ninety years, the artificial sweetener aspartame was discovered using the same method. James Schlatter inadvertently exposed his hands to a chemical substance and subsequently chose to orally moisten his fingers in order to separate two adhered pages of a book. This incident exemplifies yet another instance of the accidental discovery of new materials for future applications.

On the other hand, critical minerals and advanced materials are very useful for many applications to support advanced technologies now and future. These innovations would provide new materials for the development of eco-friendly advanced technologies which are necessary to enhance the living standard and economic developments in the future.

How materials are discovered today?

Now, even when materials have not been discovered serendipitously. The processes and procedures for making new materials and their discoveries are needed more explored

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due to the complex process, composition and to achieve as products need more days to analyze the impact and their functions. Thomas Edison did not actually invent the light bulb, but he was the first person to produce it long-lasting and economical. In 1878 year, he was trying to develop a light bulb filament material that would stay lit for more than a few hours. During a two-year tour de force he tests over 6,000 different plant fibers before eventually stumbling across a carbonized bamboo that stays lit for 1,200 hours.

Presently, the Edisonian method of trial-and-error, albeit somewhat directed by fundamental design principles, remains the predominant strategy for the discovery of new materials. This approach, characterized by its reliance on extensive trial and error complemented by high-volume testing, is the mainstay of our current methodology. However, it's increasingly clear that this method falls short of what is needed. Given the formidable engineering challenges we face in critical areas such as clean energy, carbon sequestration, and medical discovery, this traditional approach appears insufficient and inadequate for addressing the complex demands of these fields.

In order to address these challenges of feeding around 8 billion individuals with the aid of contemporary fertilizers, the US Government initiated the Materials Genome Initiative in 2011 year. This initiative set a highly ambitious target including to developing and deploy new materials at twice the speed and at a fraction of the cost. Initially, the Materials Genome Initiative primarily focused on increasing the number of simulated experiments while reducing physical ones, as simulations are generally faster and less expensive. This strategy made significant progress, but it also encountered certain inherent limitations. One major issue is the time-intensive nature of calculating new material's properties, even with the most advanced supercomputers. Completing these calculations for just one property of a single compound can require more than a week of continuous computing.

Since the stone age, humanity has pursued harder materials. This is where materials informatics steps in. With support from the National Science Foundation, the Sparks Lab from the University of Utah embarked on using machine learning to identify new super-hard materials. Any candidate material must possess qualities like incompressibility and rigidity. While there were slow but reasonably accurate calculations of these properties for about 5,000 compounds, the challenge lay in the hundreds of thousands of other compounds with unknown properties. After building and validating their model, they could predict properties for any chemical composition. They tested over 100,000 compounds, including many previously incalculable due to rare earth elements or disordered structures. Impressively, these predictions were made in just 30 seconds on a standard laptop.

The success in this case illustrates the effectiveness of the applied approach. Within a span of just over six months, the team progressed from a basic understanding of super-hard materials to the discovery and confirmation of two of the hardest materials known. This achievement reflects the core goal of the Materials Genome Initiative, which is to accelerate the discovery of materials in a more efficient and cost-effective manner. The breakthrough was not due to exceptional chemistry skills but rather the strategic direction of the research.

Sustainable materials for the future

It is so important to note that almost all human activities contribute to greenhouse gas emissions driving global warming. A large portion of these emissions stems from industrial processes that subtly permeate every facet of our lives. Consider our home refrigeration and other heating and cooling systems account for about 6% of total emissions. Agriculture, crucial for food production, contributes around 18%. Electricity generation is also responsible for approximately about 27%. Stepping outside, the transportation sectors

including cars, planes, trains and also other activities also give rise to around 16%. Furthermore, the production of everyday items results in substantial emissions and triggers to increasing global warming. The creation of materials such as concrete, steel, plastic, glass, and aluminum is responsible to contributed around 31% of greenhouse gas emissions and damaging the environment.

Existing technologies for example carbon dioxide capture, green energies and renewable energies and other efforts from government policies and private still lack to cover the sustainable world but their adoption is limited due to a lack of economic incentives. The costs associated with transporting and storing captured CO_2 are prohibitive. However, one company has innovated a solution by integrating captured CO_2 into the concrete itself, achieving permanent storage. Materials informatics has already proven successful in various domains, with impressive breakthroughs emerging regularly.

Consider a hypothetical situation: envision a chemical that was previously thought to be unachievable. In the movie 'Star Trek IV: The Voyage Home', the concept of 'transparent aluminum', a metal that can be seen through, was portrayed as purely fictional. Currently, there exist substances such as indium tin oxide, which maintains transparency while also functioning as a conductor of electricity like a metal. Additionally, there is aluminum oxynitride, which exhibits both the strength and stiffness of a metal while remaining completely transparent to ultraviolet, visible, and infrared light.

The integration of machine learning in the search for new materials with specific characteristics marks a significant advancement over previous methods. This shift is as transformative for humanity as the discovery of bronze, iron, steel, or silicon. As the exploration of the information age continues, the emerging field of materials informatics is beginning to reveal its vast potential. This approach, termed 'rational serendipity,' is reshaping the landscape of materials discovery.

Innovation for Sustainability Materials

This edition chronicles the investigation of more efficient material processing and technology that prioritizes human needs in the industrial sector. Reports were also made on a proof of concept in strategic transportation, communication, and supply chain systems. Several publications highlight a novel method that promotes the integration of energy and environmental concerns.

The first paper is written by H.T. Tung, M.H.N. Thi, and N.D.Q. Anh. The paper examines the enhancement of color uniformity in white LEDs through the use of a specific phosphor: $LiLu(MoO_4)_2:Sm^{3+}@SiO_2$ The study demonstrates how this phosphor effectively improves the color rendering index and reduces color temperature variance in white LEDs, resulting in more uniform and visually appealing light output. It emphasizes the potential applications of this technology in various lighting contexts, offering a significant advancement in LED lighting efficiency and aesthetics.

The second paper is written by F.N. Roza, M.K. Herliansyah, B.Y. Setianto, and B. Githanadi. This paper studies the preparation and characterization of curcumin-based coating material on cobalt-chromium (Co-Cr) alloy. It explores the use of curcumin, a polyphenolic compound with anti-inflammatory properties, in combination with poly-L lactic acid (PLLA) as a biodegradable drug carrier. The research contributes to the development of more effective and biocompatible coatings for medical implants, particularly in cardiology.

The third paper is written by M.P. Kurniawan, A.D. Guritno, B. Purwantana, and W.S. Supartono. The paper delves into the implementation of Material Flow Cost Accounting (MFCA) in the palm oil industry. It emphasizes the importance of transparency in material

usage and highlights strategies for resource saving and waste reduction. The study is particularly focused on enhancing environmental and economic sustainability in the palm oil sector through efficient material and cost management.

The fourth paper is written by S. Syifa, M. Ariaty, A.Z. Syahrial, and A. Pramono. The paper investigates the enhancement of ballistic resistance in armor materials. It explores the impact of integrating alumina nanoparticles into Kevlar fibers, which are then combined with Aluminum Alloy 7075 in a hybrid laminate composite. The research focuses on how this nanocomposite structure improves the material's ability to absorb and distribute impact energy, thereby offering superior protection in armor applications. This study is significant for its potential to advance the development of more effective, lightweight ballistic resistant materials.

The fifth paper is written by I.S.T. Tukiat, N.K. Yusuf, H. Khaireez, S. Al-Alimi, M.A. Lajis, S. Shamsudin, and N.E. Ruhaizat. The paper reports a comprehensive study on the effects of samarium (Sm) addition to magnesium ZRE1 (Mg-Zn-Zr) alloy, focusing on its impact on microstructure and mechanical properties. It provides details on how varying Sm contents enhance the alloy's strength, grain refinement, and overall performance. The findings offer valuable insights into the role of rare earth elements in alloy enhancement, demonstrating the potential of Sm in improving key properties of magnesium alloys.

The sixth paper is written by S. Kartohardjono, E.F. Karamah, A.P. Hayati, G.N. Talenta, T.A. Ghazali, and W.J. Lau. The paper investigates the use of a polysulfone hollow fiber membrane module as a bubble reactor for the simultaneous removal of NO_x and SO_2 pollutants. It specifically examines the impact of different oxidants on the efficiency of this process. The study demonstrates the effectiveness of the membrane module in reducing these pollutants, providing insights into its potential application in environmental pollution control, especially in industrial settings.

The seventh paper is written by I. Baroroh, B. Ma'ruf, M. Basuki, D. Hardianto, and T.A. Kristiyono. The paper examines the risks involved in installing engine room modules in shipbuilding, particularly for the Indonesian Navy's Auxiliary Hospital Ship. It uses a Bayesian Network approach to identify and analyze risk factors and their impact on project delays and cost overruns. The study finds that the primary risk is associated with electrical activities, specifically in the wiring, clamping, and sub-component areas. The research underscores the importance of early coordination across various departments to mitigate these risks effectively.

The eighth paper is written by A. Sudiarno, R.S. Dewi, R. Widyaningrum, R.A. Akbar, Y. Sudianto, W.A. Prastyabudi, and Ahmadi. The paper explores the use of VR shooting games as a training tool for military shooting. It compares the effectiveness of real and virtual shooting environments in terms of accuracy, precision, and shooting duration. The study finds no significant difference in accuracy and precision between real and virtual environments, suggesting VR as a viable training method. It also examines the learning curve of shooters in virtual settings and the usability of VR games, indicating good usability and a high degree of immersion.

The ninth paper is written by R.N. Hasanah, F. Yuniar, O. Setyawati, H. Suyono, D.R. Sawitri, and T. Taufik. The paper focuses on improving the efficiency of photovoltaic (PV) systems. It presents a modified version of the Perturb-and-Observe (P&O) algorithm, aimed at optimizing energy harvest in PV systems under varying environmental conditions. The study compares this modified algorithm to the traditional P&O method, demonstrating significant improvements in response time and energy efficiency. The research has practical implications for enhancing the performance of solar power systems, contributing to more sustainable and efficient energy solutions.

The tenth paper is written by I. Maflahah, B. Wirjodirdjo, and P.D. Karningsih. The paper discusses the enhancement of Indonesian salt farmers' bargaining power using cooperative game theory. It examines the implementation of vertical (farmers with cooperatives) and horizontal (farmers with farmers) collaboration models in the salt supply chain, employing Shapley's value for decision-making. The study reveals that collaboration between farmers and cooperatives increases farmers' revenue, with the optimum benefit achieved when a portion of their supply is purchased by cooperatives. The research emphasizes strengthening cooperative capacities in various sectors for greater economic benefits for farmers.

The next paper is written by F.A. Ahmad, J. Liu, F. Hashim, and K. Samsudin. The paper provides an overview of recent research in the field of short-term load forecasting (STLF) in power systems. It specifically focuses on the integration of Long Short-Term Memory (LSTM) algorithms with Particle Swarm Optimization (PSO) in this context. The study emphasizes the significance of these advanced models in improving the accuracy and efficiency of power system operations.

The twelfth paper is written by H. Merritt and J.C. Vilchis-Flores. The paper examines the impact of digital technologies on the U.S. printing industry. It assesses how the shift from traditional printing to digital methods has influenced employment levels and wage structures in the sector. It provides insights into how digital transformation is reshaping industry dynamics, labor market demands, and wage patterns.

The thirteenth paper is written by K. Masuda and S. Haruyama. The paper analyzes how the emergence of a dominant design in the projector industry can be predicted using patent information. The study highlights the relationship between patent applications and product launches, demonstrating a significant time lag between the two. It emphasizes the potential for companies to strategically time their market entry by predicting the emergence of dominant designs through patent trends. This research offers valuable insights for businesses in technology-driven markets, highlighting the importance of understanding industry dynamics and innovation cycles for successful market positioning.

The fourteenth paper is written by Darsono, Taufik, Suprapto, Saefurrochman, E. Nuraini, and Sutadi. The paper focuses on the development and analysis of diode and triode electron sources for an electron beam machine (EBM). The study compares these two types of electron sources in terms of their beam profiles and current outputs under varying experimental conditions. It reveals that while the diode electron source offers higher current output, the triode source provides a better electron beam shape. The research is significant for enhancing the efficiency and effectiveness of EBMs in various industrial and scientific applications.

The fifteenth paper is written by. M. Tukan, H.A.H. Esmail, Hozairi, B. Camerling, S. Alim, E.S. Manapa, and P. Berhitu. The paper explores the development of a model to optimize sea transportation routes in the Maluku region of Indonesia. It focuses on enhancing the efficiency and reliability of the sea highway system, which is crucial for the region's connectivity and economic development. The study uses various data sources, including ship movements and meteorological conditions, to design efficient sailing patterns. This research is significant for its potential impact on improving maritime logistics and accessibility in archipelagic regions.

The sixteenth paper is written by A. Junaidi, H. Yudo, and H. Ab-Samat. The paper conducts a thorough review of literature related to Port State Control (PSC) inspections in maritime safety. It analyses the main research trends and data analysis methods used in the field, focusing on key areas such as ship selection for PSC inspection, new inspection

regimes, identification of deficiencies during inspections, and ship detention under PSC inspection.

The seventeenth paper is written by A.O. Moeis, A.A. Gita, A.R. Destyanto, I. Rahman, A. Hidayatno, and T.Y. Zagloel. The paper. presents a detailed analysis of the Bitung Special Economic Zone (SEZ) in North Sulawesi, Indonesia. Utilizing System Dynamics modeling, the study evaluates the interaction between economic growth, social development, and environmental impacts in this coastal-based SEZ. The research identifies key factors like coconut plantation productivity, fisheries ship management, and education index as crucial for the SEZ's development. Various policy options are tested in the model, leading to insights that significantly impact the region's sustainable development.

The eighteenth paper is written by B.M. Izzati, S.S. Adzra, and M. Saputra. The paper investigates the factors influencing student acceptance of online learning platforms during the COVID-19 pandemic, using the Technology Acceptance Model (TAM). It focuses on the CeLOE LMS e-learning system at Telkom University, Indonesia, and employs quantitative methods to analyze user acceptance. The study utilizes variables like Perceived Usefulness, Perceived Ease of Use, and Attitude Toward Use, concluding that these factors significantly impact students' acceptance of online learning systems.

The nineteenth paper is written by H. Ketmaneechairat, M. Maliyaem, and P. Puttawattanakul. The paper presents a new management system framework, the Framework for Personal Data Protection Integrated Data Governance Management System (PDP-DGMS). It aims to assist firms in Thailand to comply with personal data protection standards and data governance, considering the Thai Personal Data Protection Act and the GDPR. The framework is evaluated using the Index of Item Objective Congruence (IOC) and is designed to be a low-cost, effective solution for process enhancement, particularly beneficial to SMEs.

The last paper is written by I. Vujović, L. Šuško, I. Kuzmanić, and M. Petković. The paper presents a detailed study on the effects of various nonlinearities in high power amplifiers (HPAs) on RF satellite downlink models using Quadrature Amplitude Modulation (QAM) and Raised Square Cosine Filter. It includes a comparative analysis of the impact of different nonlinearity models on constellation diagrams, BER (Bit Error Rate), and input/output characteristics under varying noise conditions. The research contributes significantly to the understanding and optimization of satellite communication systems, particularly in terms of enhancing communication reliability and efficiency in maritime and military applications.

In conclusion, the breakthroughs originating from laboratories and small-scale experiments are pivotal in shaping our daily lives and workspaces. These advancements, often starting as mere ideas or prototypes, hold the potential to revolutionize various aspects of our existence. We are not only receptive to your contributions but eagerly await them, recognizing the immense value they bring. We look forward to becoming a channel for your valuable insights and discoveries, sharing them with our esteemed readers who are equally enthusiastic about technological advancements and scientific progress.

We hope that this edition of IJTech conveys some new insights into the way we conduct our research and we invite you to join us in this venture by sending your work for consideration.

With sincere gratitude from the editorial desk,

Prof. Dr. Yudan Whulanza
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