

Advanced Materials in Engineering: A Bibliometric Review

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ABSTRACT

This bibliometric review examines the field of advanced materials in engineering, focusing on the evolution, key trends, and future directions. By applying bibliometric techniques such as citation analysis, co-authorship networks, and keyword co-occurrence, this study identifies influential papers, authors, and research themes in the domain. The findings reveal the growing prominence of sustainable materials, energy storage technologies, and biomedical applications, with energy-related materials, such as lithium-ion batteries, receiving significant attention. The increasing integration of computational methods, including machine learning and density functional theory, highlights the role of data-driven approaches in accelerating material discovery. Additionally, the study underscores the importance of interdisciplinary collaborations across engineering, chemistry, and biology to address global challenges. This review offers valuable insights for researchers and professionals, pointing to emerging trends in advanced materials research and their potential impact on technological and societal advancements.

Keywords: *Advanced Materials, Bibliometric Analysis, Energy Storage, Tissue Engineering, Computational Techniques*

1. INTRODUCTION

The field of advanced materials in engineering has experienced substantial growth over the past few decades, driven by rapid technological advancements, evolving industrial demands, and a greater focus on sustainability. Advanced materials, which encompass a wide range of substances, from nanomaterials and composites to smart materials and biomaterials, play a pivotal role in modern engineering applications [1], [2]. These materials exhibit superior performance characteristics, such as high strength-to-weight ratios, enhanced conductivity, responsiveness to external stimuli, and environmental sustainability, making them essential in industries such as aerospace, automotive, electronics, renewable energy, and healthcare.

The significance of advanced materials in engineering extends beyond their fundamental properties. They are at the heart of innovations that drive progress in various sectors, ranging from cutting-edge technologies to sustainable solutions for addressing global challenges. As such, understanding the trends, evolution, and impact of research in this domain is crucial for guiding future developments and for making informed decisions about material selection and design [3], [4].

Bibliometric analysis, a powerful tool for mapping the intellectual structure of a field, offers valuable insights into the evolution of scientific research. Through citation analysis, co-authorship networks, and keyword analysis, bibliometric methods allow for the identification of key contributors, influential papers, emerging themes, and collaborative relationships. This review leverages bibliometric techniques to examine the body of research on advanced materials in engineering, offering a comprehensive overview of the field's development, its current state, and its future directions [5], [6].

This paper aims to explore the academic landscape of advanced materials in engineering by conducting a bibliometric review of published research. The objectives are threefold: to identify the most productive authors, institutions, and countries in the field; to map the primary research themes and their evolution over time; and to assess the collaboration patterns that have shaped the field. By

analyzing a large corpus of literature, the review provides a broad understanding of the current state of research in advanced materials, offering insights into both the strengths and gaps in the field.

The importance of this review lies not only in its analysis of existing literature but also in its potential to guide future research. By highlighting emerging trends and key challenges, the study aims to provide recommendations for future investigations in advanced materials that could address critical issues such as energy efficiency, material sustainability, and the development of next-generation technologies. As such, this review serves as a valuable resource for researchers, engineers, policymakers, and industry professionals looking to stay abreast of the latest developments and contribute to the continued evolution of advanced materials in engineering.

2. METHODS

This bibliometric review employs a comprehensive bibliometric analysis to examine the research landscape of advanced materials in engineering. The methodology consists of systematic data collection, citation analysis, co-authorship network analysis, and keyword co-occurrence analysis, which together provide a multidimensional view of the academic progression in this field. The data for this review was sourced from the Scopus and Web of Science databases, which are two of the most authoritative and widely used repositories for scholarly articles. These databases encompass a broad range of research publications from peer-reviewed journals, conference proceedings, and academic books, ensuring that the analysis covers a representative sample of the field. The time frame for the analysis spans from the inception of advanced materials research to the present day, with a particular focus on publications from the past two decades.

To identify the most influential works in the field, citation analysis was conducted, evaluating the frequency and impact of articles published on advanced materials. This analysis helps in understanding the evolution of key research themes and recognizing seminal works that have shaped the development of the field. Citation analysis also reveals the academic impact of these papers, as highly cited articles are often considered as cornerstone studies within their respective areas. Additionally, co-authorship network analysis was utilized to determine collaboration patterns among researchers, institutions, and countries. This method maps the relationships between authors and identifies the most active and influential research groups. It also highlights international collaborations and how these partnerships contribute to the exchange of knowledge and expertise across borders.

Keyword co-occurrence analysis was used to identify the main research themes and track the emergence of new topics within the field of advanced materials in engineering. By analyzing the frequency of keyword pairs that appear together in publications, this approach reveals trends in the types of materials being studied (such as nanomaterials, composites, and biomaterials), as well as the application areas (e.g., aerospace, energy, and electronics). The analysis also enables the identification of hot topics and gaps in the literature, offering a roadmap for future research. The findings from these analyses were then synthesized to provide a comprehensive view of the current state of research in advanced materials, shedding light on the most prominent contributors, the evolution of key research areas, and the collaborative dynamics that drive the field forward.

3. RESULT AND DISCUSSION

3.1 Author Collaboration Analysis

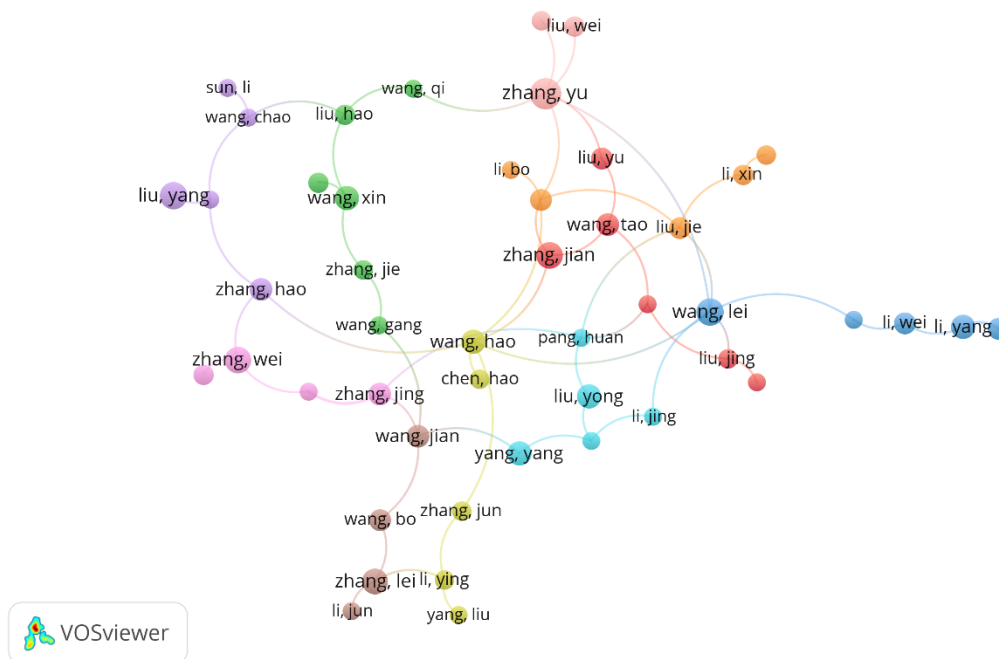


Figure 1. Author Visualization

Source: Data Analysis

Figure 1 illustrates the co-authorship network of researchers in the field of advanced materials in engineering, as visualized through VOSviewer. Each node represents an author, with the size of the node indicating the author's research influence or contribution to the field. The color of the nodes denotes different research clusters, showing how authors are grouped based on their collaborative work. The edges connecting the nodes signify co-authorship relationships, highlighting the interconnectedness between researchers. Notably, the figure demonstrates a strong network of collaboration, with several tightly-knit clusters formed around influential authors such as Zhang Yu, Liu Wei, Wang Tao, and others. This visualization reflects the collaborative nature of research in advanced materials, where cross-disciplinary efforts and international partnerships play a crucial role in advancing the field. The network also reveals emerging research groups and possible areas of synergy for future investigations, offering insights into potential collaboration opportunities within the academic community.

3.2 Country Contribution Analysis

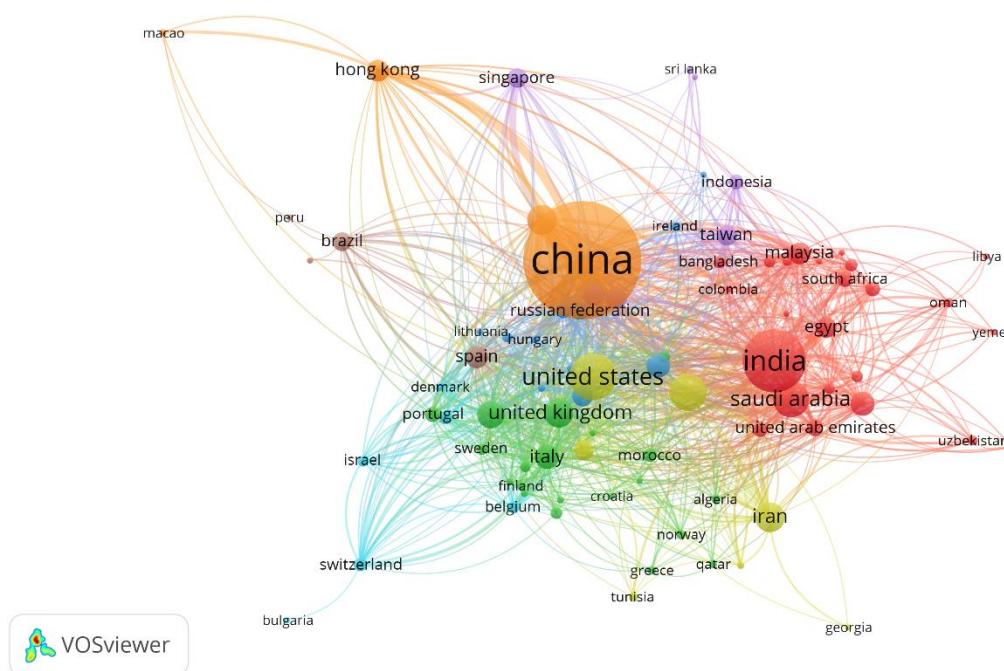


Figure 2. Country Visualization
Source: Data Analysis

Figure 2 presents a country-level co-authorship network in the field of advanced materials research, as visualized by VOSviewer. Each node represents a country, with the size of the node indicating the country's relative contribution to the field of study. The connections between countries, represented by the lines, highlight the collaborative relationships and research exchange between them. China, the United States, India, and the United Kingdom are among the largest nodes, indicating their significant roles in advanced materials research, followed by other countries like Japan, Germany, and Italy. The color coding further distinguishes clusters of countries with strong collaborative links, such as those from Asia (China, Hong Kong, India, and Singapore) and Europe (Germany, Italy, and the United Kingdom). This visualization underscores the global nature of research in advanced materials, with strong international partnerships forming the backbone of scientific progress in the field. The geographic distribution also reveals key research hubs, such as China and India, which are pivotal in driving new innovations in materials science, while countries in Europe and North America continue to contribute significantly through their research institutions and collaborative networks.

3.3 Citation Analysis: Influential Publications

Table 1. The Most Impactful Literatures

| Citations | Authors and year | Title |
|-----------|--|--|
| 3375 | Ligon, S.C.,Liska, R.,Stampfl, J.,Gurr, M.,Mülhaupt, R. (2017) | Polymers for 3D Printing and Customized Additive Manufacturing |
| 2899 | Lustig, W.P.,Mukherjee, S.,Rudd, N.D.,... Li, | Metal-organic frameworks: Functional luminescent and photonic materials for sensing applications |

| Citations | Authors and year | Title |
|-----------|---|--|
| | J.,Ghosh, S.K. (2017) | |
| 1903 | Jin, H.,Guo, C.,Liu, X.,... Zheng, Y.,Qiao, S.-Z. (2018) | Emerging Two-Dimensional Nanomaterials for Electrocatalysis |
| 1452 | Song, J.,Chen, C.,Zhu, S.,... Li, T.,Hu, L. (2018) | Processing bulk natural wood into a high-performance structural material |
| 1303 | Guimarães, C.F.,Gasperini, L.,Marques, A.P.,Reis, R.L. (2020) | The stiffness of living tissues and its implications for tissue engineering |
| 1176 | Hodges, B.C.,Cates, E.L.,Kim, J.-H. (2018) | Challenges and prospects of advanced oxidation water treatment processes using catalytic nanomaterials |
| 1156 | Chen, C.,Kuang, Y.,Zhu, S.,... Eichhorn, S.J.,Hu, L. (2020) | Structure–property–function relationships of natural and engineered wood |
| 1138 | Ray, T.R.,Choi, J.,Bandodkar, A.J.,... Ghaffari, R.,Rogers, J.A. (2019) | Bio-integrated wearable systems: A comprehensive review |
| 1084 | Zhang, W.,Liu, Y.,Guo, Z. (2019) | Approaching high-performance potassium-ion batteries via advanced design strategies and engineering |
| 1034 | Matai, I.,Kaur, G.,Seyedsalehi, A.,McClinton, A.,Laurencin, C.T. (2020) | Progress in 3D bioprinting technology for tissue/organ regenerative engineering |

Source: Scopus, 2026

Table 1 presents the most impactful literatures in the field of advanced materials, showcasing the influential works with the highest citation counts. The articles listed are central to key research areas, including 3D printing, nanomaterials, tissue engineering, and energy storage, and reflect the diverse applications and innovations driving the field forward. For example, Ligon et al. (2017) with 3375 citations on "Polymers for 3D Printing and Customized Additive Manufacturing" stands out as a landmark study that has influenced the design and application of advanced polymers in additive manufacturing technologies. Similarly, the work by Lustig et al. (2017) on "Metal-organic frameworks" has provided crucial insights into luminescent and photonic materials, contributing significantly to the development of novel sensors. Other key papers, such as those by Jin et al. (2018) on two-dimensional nanomaterials for electrocatalysis and Song et al. (2018) on processing bulk natural wood into high-performance structural material, reflect the growing interdisciplinary nature of advanced materials research, addressing both environmental and technological challenges. These impactful works, through their high citation counts, highlight the major advances in material science, providing a foundation for future innovations in diverse fields such as energy, healthcare, and sustainable materials development.

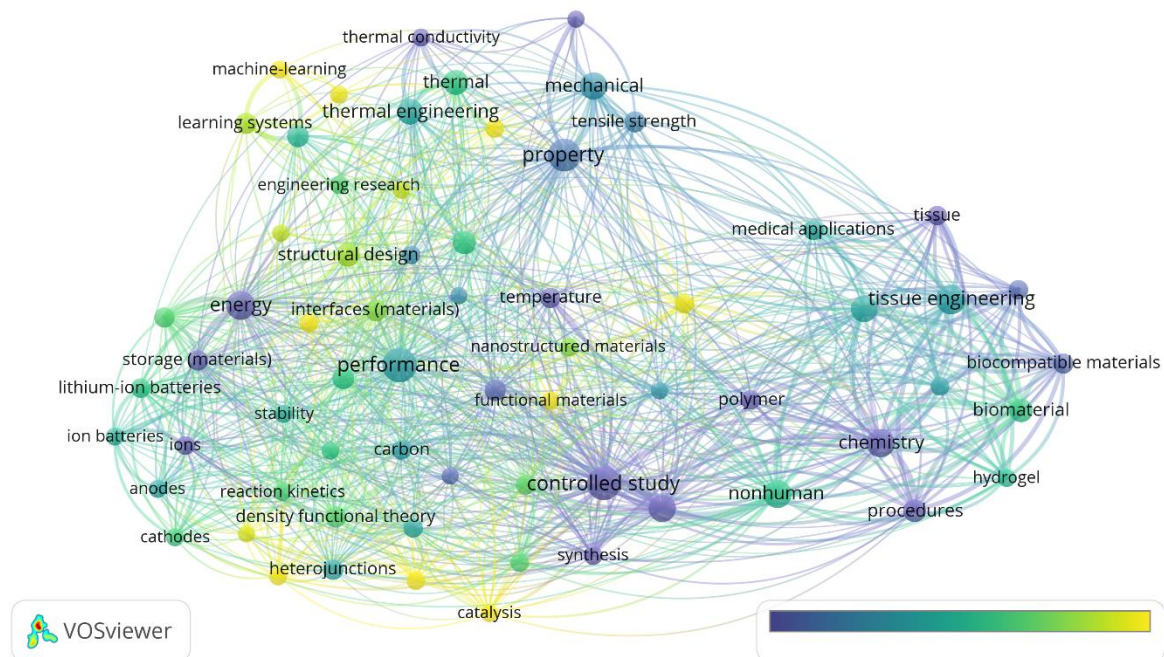


Figure 4. Overlay Visualization

Source: Data Analysis

Figure 4 presents an overlay visualization of the co-occurrence network in advanced materials research, with the colors representing the timeline of publication activity, from early research (in yellow) to more recent studies (in purple). The visualization clearly highlights the evolving focus areas in the field. For instance, terms like *thermal engineering*, *machine learning*, and *performance* are colored in green and blue, indicating their prominence in recent years, especially in the context of advancements in energy materials, structural design, and nanomaterials. The increasing prominence of terms such as *tissue engineering*, *biomaterials*, and *biocompatible materials* in the purple region reflects the growing trend toward biomedical applications of advanced materials. Additionally, the clustering of energy-related terms like *lithium-ion batteries* and *carbon* in green and blue emphasizes the increasing emphasis on energy storage and sustainable materials in contemporary research. The overlay visualization offers a dynamic view of how research interests in advanced materials have shifted over time, showing a shift toward more interdisciplinary studies, where topics such as performance, material properties, and energy are becoming increasingly intertwined with biomedical applications and computational techniques. This visualization illustrates not only the thematic evolution in advanced materials research but also the growing integration of various research fields, signaling future opportunities for innovation.

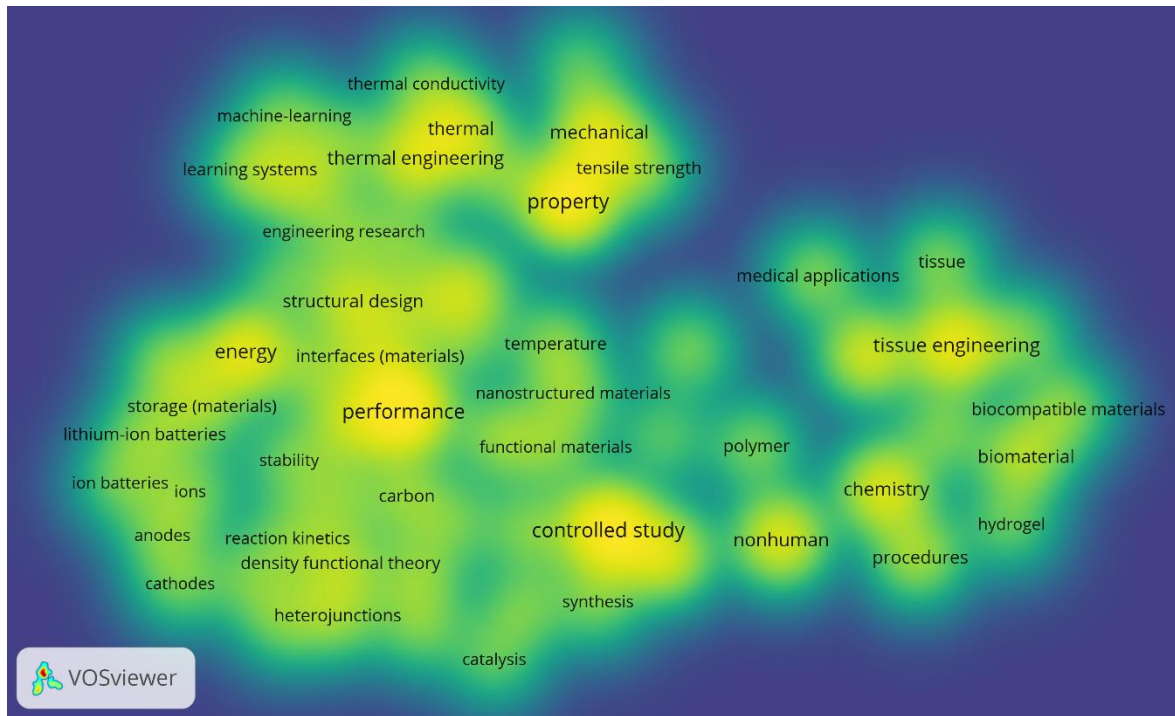


Figure 5. Density Visualization

Source: Data Analysis

Figure 5 shows a density visualization that highlights the concentration of research themes in advanced materials. The areas in bright yellow and green represent the most concentrated research topics, while the darker blue regions indicate less activity or focus. The clusters in yellow-green, such as *thermal engineering*, *property*, and *performance*, reflect key areas of intense research, which are central to the understanding of material behaviors in engineering applications. Topics like *energy*, *storage materials*, and *lithium-ion batteries* show strong concentrations in the lower-left region, emphasizing the growing interest in sustainable energy solutions and energy storage technologies. Similarly, the *tissue engineering* cluster on the right side reveals the increasing focus on biomedical applications, including the development of *biomaterials* and *hydrogels*. The clustering of terms such as *nanostructured materials* and *functional materials* further underscores the interdisciplinary approach to advanced materials, where different material types are optimized for specific functional applications. This visualization effectively illustrates the thematic hotspots in advanced materials research, providing a visual summary of the areas receiving the most scholarly attention and pointing to future areas of exploration.

Discussion

The bibliometric analysis of advanced materials research reveals several key trends and developments that highlight the dynamic nature of the field. One of the most notable findings is the increasing interdisciplinary collaboration within materials science. As demonstrated in the co-authorship and country network visualizations, countries such as China, the United States, and India are at the forefront of research efforts, and these collaborations are essential for driving innovations in various domains, including energy storage, biomedical materials, and nanotechnology. The interconnectedness among research hubs, particularly between engineering, chemistry, and biology, illustrates how the boundaries of material science are continuously expanding to address global challenges such as sustainability, health, and energy efficiency.

The strong emphasis on sustainable materials, particularly in energy storage technologies, is a significant outcome of this analysis. The high citation counts of works like those by [7] on 3D printing and [8] on metal-organic frameworks reflect the growing recognition of the need for energy-

efficient solutions. Lithium-ion batteries, a key component in renewable energy systems, continue to dominate the research landscape, but the increasing focus on alternative energy storage materials such as sodium-ion and potassium-ion batteries indicates the field's responsiveness to challenges like resource scarcity and environmental impact. The growing body of research on the *performance* and *stability* of these materials highlights the importance of ensuring that new materials can meet the rigorous demands of modern applications while being economically viable and sustainable.

In addition to energy-related research, the increasing role of advanced materials in biomedical applications is noteworthy. The emphasis on *tissue engineering* and *biomaterials*, as observed in the keyword co-occurrence and density visualizations, highlights the significant progress in the integration of materials science with medicine. The development of *biocompatible materials*, such as hydrogels and polymers, has the potential to revolutionize tissue regeneration and prosthetics. This growing field not only benefits from advancements in material design but also from innovations in fabrication techniques, such as 3D bioprinting, that enable the creation of more complex, patient-specific implants. These findings reflect a shift towards more personalized medicine, where advanced materials can be tailored to the specific needs of individuals [9], [10].

Finally, the increasing application of computational techniques in material design is a promising avenue for the future. The integration of *machine learning* and *density functional theory* in materials research, particularly in the fields of energy storage and nanomaterials, underscores the growing importance of data-driven approaches. These technologies enable the prediction of material properties and the optimization of materials for specific applications, significantly accelerating the development process. As the field progresses, it is likely that computational methods will become even more integrated with experimental research, allowing for faster discovery of novel materials with enhanced performance and sustainability. The continuing evolution of these interdisciplinary and computational techniques will drive the next generation of innovations in advanced materials, particularly in fields where performance and sustainability are of paramount importance.

CONCLUSION

This bibliometric analysis of advanced materials in engineering underscores the dynamic and rapidly evolving nature of the field. The study highlights the increasing integration of sustainability and energy efficiency in material design, particularly in the development of alternative energy storage systems. The strong emphasis on biomedical applications, such as tissue engineering and biocompatible materials, reflects the growing role of materials science in addressing health challenges. Additionally, the findings indicate a shift toward more interdisciplinary research, where collaboration between different fields, such as engineering, chemistry, and biology, plays a crucial role in driving innovation. The application of computational tools, such as machine learning and density functional theory, is expected to play an increasingly prominent role in accelerating material discovery and optimization. The findings from this review provide a comprehensive understanding of the current state of research and offer valuable guidance for future investigations aimed at addressing pressing global issues in energy, sustainability, and healthcare. As the field continues to evolve, continued interdisciplinary collaboration and computational innovation will be key to advancing the development of next-generation materials.

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