Synsint Research Group

Available online at www.synsint.com

Synthesis and Sintering

ISSN 2564-0186 (Print), ISSN 2564-0194 (Online)

Research article

Global research trends in spark plasma sintering: A bibliometric analysis of Scopus-indexed publications

Mohammad Hossein Norouzi [a], Samira Savani [b], Mohammad Alipour [c,*]

[a] *Department of Industrial Engineering, Università degli Studi di Padova, Via Marzolo 9, 35131 Padova (PD), Italy*
[b] *Otto Schott Institute of Materials Research, Friedrich Schiller University Jena, Löbdergraben 32, 07743 Jena, Germany*
[c] *Department of Chemical and Biological Engineering, College of Engineering, Koç University, Rumelifeneri Yolu, 34450 Sarıyer, Istanbul, Türkiye*

ABSTRACT

Spark plasma sintering (SPS) has become one of the most influential powder consolidation technologies for advanced materials. Its capability to rapidly densify ceramics, metals, composites, and functional materials while preserving fine microstructures has significantly expanded its applications across materials science and engineering. This study presents a comprehensive bibliometric analysis of 21,714 publications, updated as of June 27, 2026, indexed in the Scopus database using the keyword spark plasma sintering. Publication characteristics were analyzed with respect to annual production, subject areas, document types, languages, journals, authors, countries, affiliations, funding agencies, and open-access status. The results demonstrate remarkable growth in SPS research over the past two decades, particularly after 2010, reflecting increasing industrial and academic interest in rapid sintering technologies. Materials science remains the dominant discipline, followed by engineering, physics, and chemistry. China has emerged as the global leader in SPS research, accounting for more than one-third of all publications, supported by extensive governmental funding and strong institutional infrastructure. Japanese institutions continue to play a pioneering role, while European countries maintain substantial contributions through collaborative research networks. Ceramics International, Journal of Alloys and Compounds, and Journal of the European Ceramic Society constitute the principal publication venues. The bibliometric indicators provide valuable insights into the evolution, global distribution, and future directions of SPS research.

KEYWORDS

Spark plasma sintering
Bibliometric analysis
Scientometrics
Materials science
Powder metallurgy
Advanced ceramics

OPEN ACCESS

1. Introduction

Spark plasma sintering has emerged as one of the most transformative powder consolidation technologies developed during the past several decades. Unlike conventional pressureless sintering or hot pressing, SPS employs simultaneous application of uniaxial pressure and pulsed direct electric current, enabling extremely rapid heating rates, short processing times, and comparatively low sintering temperatures [1–5]. A schematic configuration of this consolidation setup is illustrated in Fig. 1. These unique characteristics have made SPS an attractive processing route for advanced ceramics, refractory compounds, hard materials, metals, intermetallics, composites, nanostructured materials, thermoelectric materials, and functional materials [6–9].

The increasing demand for materials possessing superior mechanical strength, thermal stability, electrical conductivity, and multifunctional performance has substantially accelerated research activities related to SPS [10, 11]. The technology has become particularly important in the fabrication of ultra-high-temperature ceramics, high-entropy materials,

* Corresponding author. *E-mail address:* malipour14@ku.edu.tr (M. Alipour)
Received 12 March 2026; Received in revised form 19 September 2026; Accepted 19 September 2026.

https://doi.org/10.53063/synsint.2026.63334

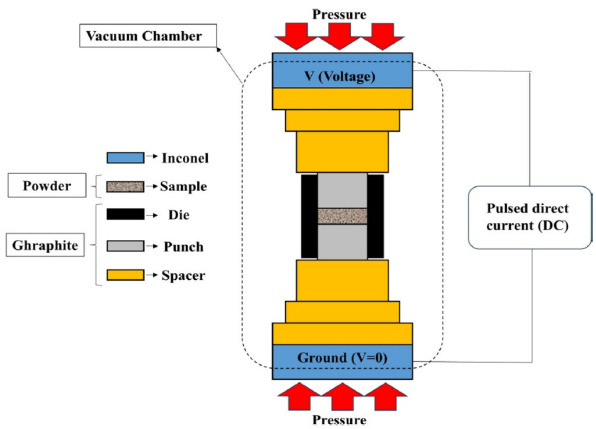

Fig. 1. Schematic of the SPS setup. Reused under a CC BY 4.0 license from Ref. [5].

transparent ceramics, biomaterials, magnetic materials, battery components, and nuclear materials. Consequently, the volume of scientific publications has expanded dramatically over the past two decades [12, 13].

The rapid growth of any research field naturally raises important questions regarding its scientific evolution. Which countries dominate SPS research? Which journals have become the preferred publication platforms? Which institutions and researchers have played leading roles? How has the disciplinary distribution changed over time? Which funding agencies have driven technological development? Answers to these questions provide valuable perspectives for researchers, funding organizations, journal editors, and policymakers.

Bibliometric analysis has become an indispensable approach for quantitatively evaluating scientific productivity and identifying emerging research trends [14]. By examining publication outputs, citation databases, institutional contributions, and collaboration patterns, bibliometric studies reveal the structural evolution of research domains while identifying influential contributors and future research opportunities.

Although numerous review papers have summarized the processing mechanisms, densification behavior, and material applications of SPS, relatively few studies have investigated the global evolution of SPS research from a scientometric perspective using comprehensive publication metadata.

The present study addresses this gap through a large-scale bibliometric analysis of 21,714 Scopus-indexed publications retrieved using the search term "spark plasma sintering." Multiple bibliometric indicators were examined, including annual publication trends, subject classifications, document types, publication languages, journal distribution, leading authors, contributing countries, institutional affiliations, funding sponsors, and open-access dissemination. The analysis provides an integrated overview of the global development of SPS research over more than four decades and identifies the principal scientific drivers responsible for its remarkable expansion.

The results contribute to a deeper understanding of how SPS has evolved from a specialized powder metallurgy technique into a multidisciplinary manufacturing platform influencing numerous areas of materials science and engineering.

2. Methodology

The bibliometric dataset was retrieved from the Scopus database [15] using the search keyword "spark plasma sintering" within the document search interface. The search returned 21,714 publications, updated as of June 27, 2026, representing one of the largest available datasets devoted exclusively to SPS research.

The bibliographic metadata provided by Scopus were analyzed according to several indicators:

- Annual publication output
- Subject area
- Language
- Open-access status
- Document type
- Source title
- Author productivity
- Country contribution
- Institutional affiliation
- Funding sponsor

The analysis was descriptive in nature and aimed to identify long-term publication patterns rather than citation impact. The retrieved statistics were interpreted to reveal the scientific maturity, internationalization, and interdisciplinary expansion of SPS research.

3. Results and discussion

3.1. Evolution of scientific output

The annual publication profile clearly illustrates the remarkable evolution of SPS research over the past four decades. Only one publication appeared in 1980, while virtually no publications were recorded during much of the 1980s and early 1990s. This observation confirms that SPS remained an emerging laboratory-scale technology during its early developmental stage. The chronological distribution and annual growth trend of these global publications are illustrated in Fig. 2.

The first noticeable increase occurred after 2000, when publication numbers exceeded sixty papers annually. Between 2000 and 2010, scientific production increased nearly tenfold, reaching 588 publications in 2010. This period coincides with widespread commercialization of SPS equipment and growing interest in nanostructured materials.

An even more pronounced expansion occurred during the following decade. Annual publications consistently exceeded one thousand after 2016 and remained above 1,300 papers every year thereafter. The highest output was observed in 2025 with 1,607 publications, while 2026 had already produced 888 publications despite representing an incomplete year.

This sustained increase demonstrates that SPS has progressed beyond a developing technology into a mature research field with continuous innovation. Unlike many emerging technologies that experience temporary publication surges followed by stagnation, SPS has maintained long-term growth, reflecting its expanding industrial relevance and broad applicability across multiple material systems.

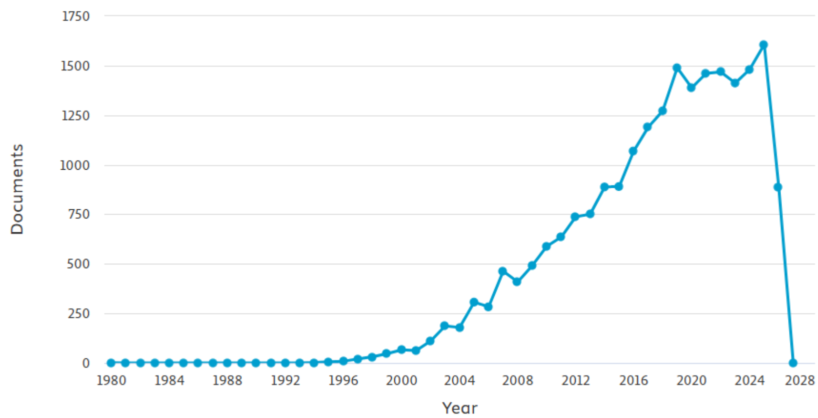

Fig. 2. Chronological distribution and annual growth trend of global publications.

The publication trajectory resembles a classical technology adoption curve, which includes a latency stage (1980–1999), a rapid expansion stage (2000–2015), and a mature growth stage (2016 onward).

3.2. Distribution across subject areas

Materials Science overwhelmingly dominates SPS research with 18,938 publications, representing the technological foundation of the field. This finding is expected because SPS was originally developed for powder metallurgy and ceramic processing. Engineering occupies the second position with 10,809 publications, emphasizing the importance of process optimization, equipment design, manufacturing technologies, and industrial implementation.

Physics and Astronomy contribute 8,082 publications, reflecting extensive investigations into electrical current effects, plasma generation mechanisms, diffusion kinetics, and thermal transport during SPS. Chemistry and Chemical Engineering each contribute approximately 2,500 publications, indicating increasing interest in reaction synthesis, catalytic materials, functional ceramics, and chemically assisted densification. Energy-related applications account for 898 publications, demonstrating the growing role of SPS in thermoelectric materials, fuel cells, hydrogen storage systems, battery electrodes, and nuclear energy components.

Smaller but steadily increasing contributions originate from medicine, environmental science, computer science, and biology. Although these disciplines represent relatively small fractions of the literature, they indicate continuing interdisciplinary diversification.

The subject distribution demonstrates that SPS has evolved from a specialized ceramic processing technique into a broadly applicable manufacturing technology serving numerous scientific disciplines.

3.3. Language distribution

English overwhelmingly dominates SPS publications, with 20,161 documents, accounting for more than 92% of the database. This dominance reflects the international nature of scientific communication and facilitates global dissemination of SPS research.

Chinese is the second most common publication language with 1,275 documents, reflecting China's leading position in global SPS research. Japanese ranks third with 328 publications, highlighting Japan's historical leadership in SPS technology development. Other languages including Korean, Russian, Spanish, Italian, German, Turkish, Persian, French, and Polish collectively contribute only a small percentage of publications.

The strong predominance of English indicates that SPS research has become highly internationalized, enabling efficient dissemination and collaboration across geographical boundaries.

3.4. Open-access publications

Among the retrieved publications, 6,478 are available through open-access publishing models. Green Open Access is identified for 3,431 publications, while Gold Open Access accounts for 3,214 publications. Hybrid Gold and Bronze Open Access are identified for 1,559 and 721 publications, respectively. Because these open-access categories are not mutually exclusive, their individual counts may overlap and should not be summed to obtain the total number of open-access publications. The substantial availability of open-access literature indicates broad dissemination of SPS-related research and facilitates access for both academic researchers and industrial practitioners.

3.5. Document types

Research articles dominate SPS literature with 18,374 publications, representing approximately 85% of the database. Conference papers account for 2,640 publications, indicating active participation within international scientific conferences. Review articles total 348 publications, suggesting that the field has matured sufficiently to support comprehensive knowledge synthesis. The relatively small numbers of book chapters, letters, editorials, and conference reviews further emphasize that original experimental research constitutes the primary driver of SPS development. The dominance of full-length research articles reflects continuous innovation in processing methods, material systems, and engineering applications. The distribution of these publication types is illustrated in Fig. 3 as a donut chart.

3.6. Leading publication sources

The distribution of publications across journals demonstrates a strong concentration within high-impact materials science journals. Ceramics International leads with 1,476 publications, followed by Journal of

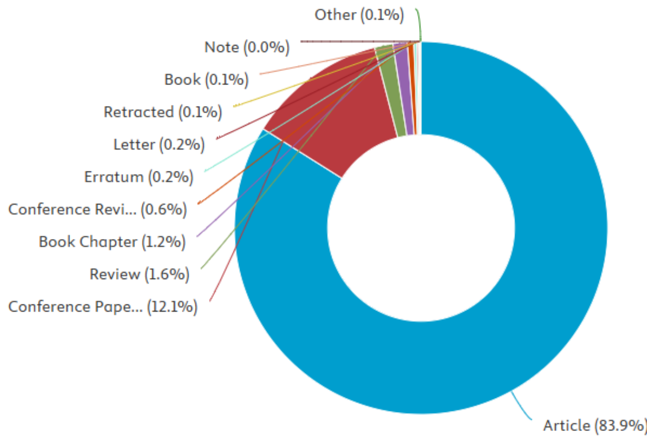

Fig. 3. Donut chart showing the distribution of publication types.

Alloys and Compounds (1,238), Journal of the European Ceramic Society (899), Materials Science and Engineering A (634), and Journal of the American Ceramic Society (558). The annual publication trends of these top 5 core journals are illustrated in Fig. 4. These journals collectively publish a substantial proportion of SPS literature because they specialize in advanced ceramics, powder metallurgy, and structural materials. The concentration of publications within a relatively limited number of journals indicates the establishment of dedicated publication platforms serving the SPS research community.

3.7. Most productive authors

Several researchers have made exceptionally large contributions to SPS research. P.A. Olubambi leads with 166 publications, followed by M.J. Reece (145), Y. Sakka (132), T. Goto (130), C. Estournès (125), T. Yanagida (120), J.F. Li (118), K. Kondoh (114), Z. Shen (114), W. Jiang (110), M.S. Boldin (108), M. Yue (108), S. Grasso (105), T. Kato (104), M. Shahedi Asl (104), and Q. Shen (100). The document counts of these most prolific authors are displayed in Fig. 5. The presence of researchers from Asia, Europe, and Africa demonstrates the global nature of SPS research. Many of these scientists have contributed not only through experimental investigations but also through the development of theoretical models, novel processing routes, and industrial applications.

3.8. Country contributions

The geographic distribution of scientific production across these top 10 leading countries is illustrated in Fig. 6. China overwhelmingly dominates global SPS research with 8,633 publications, accounting for approximately 40% of all retrieved documents. Japan follows with 3,008 publications, reflecting its pioneering role in the invention and commercialization of SPS. The United States contributes 1,969 publications, followed by India (1,345), Russia (1,256), France (1,233), South Korea (1,189), Germany (922), Iran (721), and Spain (621).

China's remarkable leadership can be attributed to sustained governmental investment, extensive laboratory infrastructure, strong university networks, and strategic prioritization of advanced manufacturing technologies. Japan maintains scientific leadership through long-term expertise in powder metallurgy and ceramic engineering. European countries collectively contribute a highly influential body of research, particularly in ceramic processing and functional materials.

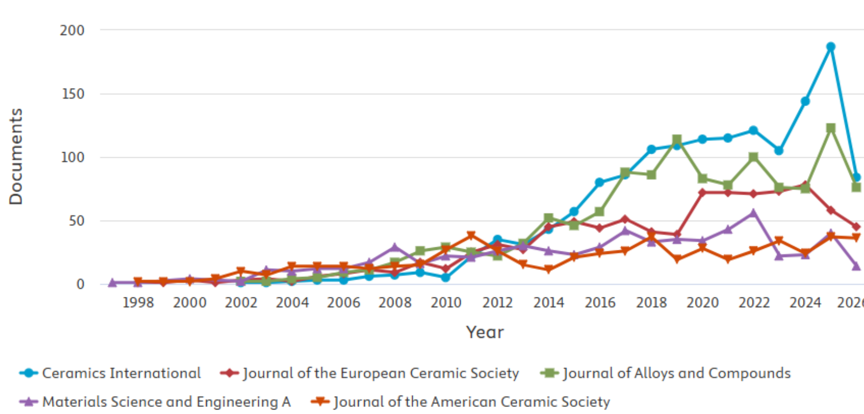

Fig. 4. Annual publication trends of the top 5 core journals in the field of spark plasma sintering.

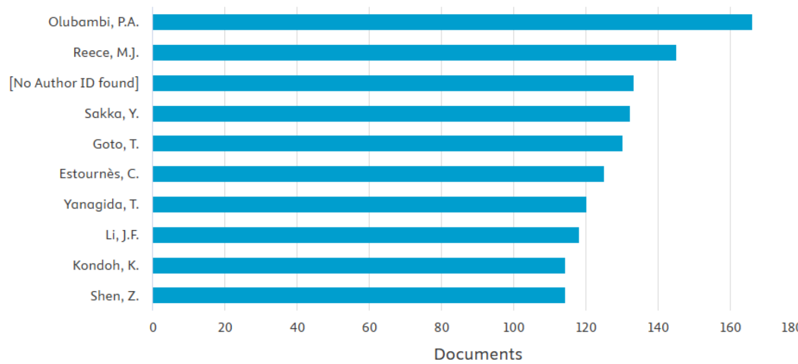

Fig. 5. Document counts of the most prolific authors in spark plasma sintering research.

3.9. Leading institutions

Chinese institutions dominate institutional productivity. The Ministry of Education of China appears in 971 publications, followed by the Chinese Academy of Sciences (944), Wuhan University of Technology (700), CNRS (668), University of Science and Technology Beijing (547), State Key Laboratory of Advanced Technology for Materials Synthesis and Processing (538), Tohoku University (516), Tsinghua University (505), National Institute for Materials Science (486), and Harbin Institute of Technology (413). These institutions collectively represent global centers of excellence in powder metallurgy, advanced ceramics, and functional materials research. The document volumes and productivity of these top 10 global research organizations are detailed in Fig. 7.

3.10. Funding landscape

Funding analysis reveals strong governmental support for SPS research. The contribution of these top 10 global funding sponsors to spark plasma sintering research is detailed in Fig. 8. The National Natural Science Foundation of China funded 4,157 publications, substantially exceeding all other funding agencies. Additional major contributors include the National Key Research and Development Program of China (692), Japan Society for the Promotion of Science (604), Fundamental Research Funds for the Central Universities (580), Russian Science Foundation (378), U.S. National Science Foundation (322), National Research Foundation of Korea (311), U.S. Department of Energy (280), Ministry of Education and Science of the Russian Federation (274), and China Postdoctoral Science Foundation (260). The dominance of Chinese funding agencies strongly correlates with China's leading publication output, demonstrating the effectiveness of sustained governmental investment in advanced manufacturing research.

4. Future research directions

The publication trends indicate that SPS research has entered a mature yet continuously expanding phase. Future developments are expected to emphasize artificial intelligence-assisted process optimization, digital manufacturing, additive manufacturing integration, high-entropy materials, ultra-high-temperature ceramics, multifunctional composites, battery materials, hydrogen technologies, biomedical implants, and sustainable manufacturing.

Increasing interdisciplinary collaboration among materials scientists, mechanical engineers, chemists, physicists, and computational scientists is expected to further broaden the application spectrum of SPS. The growing adoption of machine learning, digital twins, and real-time process monitoring is also likely to transform SPS into a more intelligent manufacturing technology.

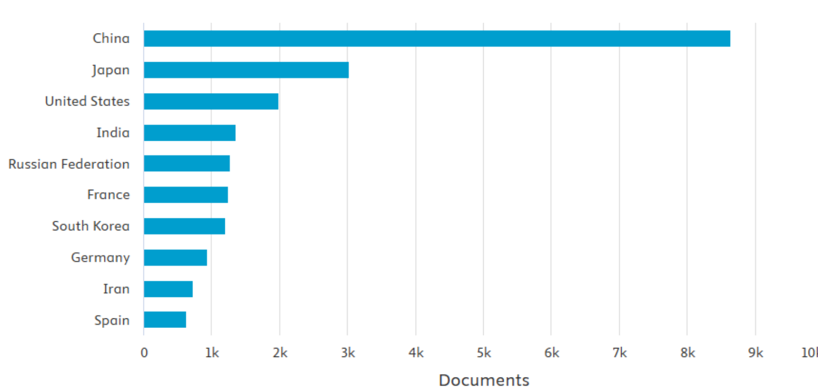

Fig. 6. Geographic distribution of scientific production by the top 10 leading countries.

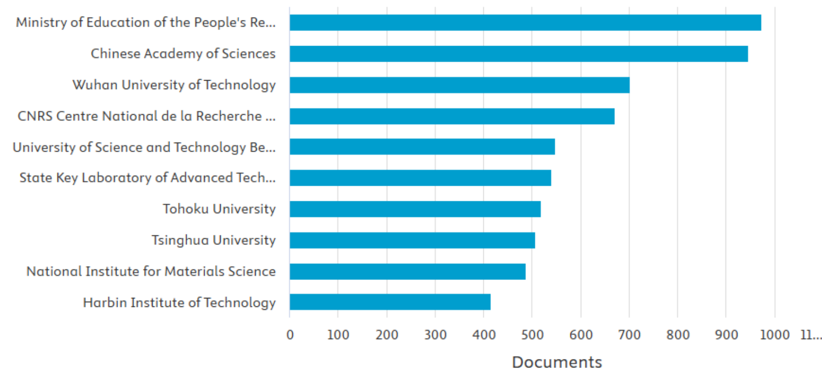

Fig. 7. Top 10 global research organizations by document volume in the spark plasma sintering domain.

5. Conclusions

The bibliometric analysis of 21,714 Scopus-indexed publications demonstrates the extraordinary growth and global expansion of spark plasma sintering research over the past four decades. The field has evolved from a niche powder consolidation technique into one of the most active research areas in advanced materials processing. Materials Science remains the dominant discipline, while Engineering, Physics, Chemistry, and Energy have become major complementary fields. China has established clear global leadership through strong governmental funding and extensive institutional support, whereas Japan continues to maintain a prominent scientific position owing to its pioneering contributions. The concentration of publications in specialized materials journals, together with the predominance of original research articles, reflects the technological maturity and sustained innovation of SPS research. The continuous increase in annual publications, expanding interdisciplinary applications, and growing open-access dissemination collectively indicate that SPS will remain a strategically important manufacturing technology for next-generation structural and functional materials.

CRediT authorship contribution statement

Mohammad Hossein Norouzi: Writing – original draft, Methodology.
Samira Savani: Writing – original draft, Resources.
Mohammad Alipour: Writing – review & editing, Conceptualization.

Data availability

The data underlying this article will be shared on reasonable request to the corresponding author.
During the peer-review and revision process, and in consultation with the handling editor, this article was updated to incorporate the latest available Scopus data as of 27 June 2026.

Declaration of competing interest

The authors declare no competing interests.

Funding and acknowledgment

This research received no external funding.

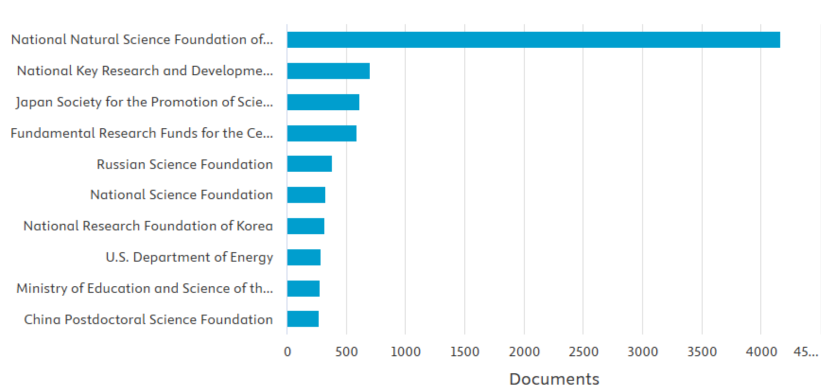

Fig. 8. Top 10 global funding sponsors supporting scientific research in spark plasma sintering.

Declaration of AI-assisted technologies in the writing process

During the preparation of this manuscript, the authors used ChatGPT to improve the manuscript's organization, grammatical accuracy, and overall readability. All AI-assisted revisions were carefully reviewed, verified, and, where necessary, modified by the authors. The authors take full responsibility for the content of the manuscript, including the accuracy of the data, the validity of the analyses, and the conclusions presented.

References

[1] Y. Le Godec, S. Le Floch, Recent Developments of High-Pressure Spark Plasma Sintering: An Overview of Current Applications, Challenges and Future Directions, Materials (Basel). 16 (2023) 997. https://doi.org/10.3390/ma16030997.

[2] M. Tokita, Progress of Spark Plasma Sintering (SPS) Method, Systems, Ceramics Applications and Industrialization, Ceramics. 4 (2021) 160–198. https://doi.org/10.3390/ceramics4020014.

[3] X.Y. Li, Z.H. Zhang, X.W. Cheng, G.J. Huo, S.Z. Zhang, Q. Song, The Development and Application of Spark Plasma Sintering Technique in Advanced Metal Structure Materials: A Review, Powder Metall. Met. Ceram. 60 (2021) 410–438. https://doi.org/10.1007/s11106-021-00254-w.

[4] O. Guillon, J. Gonzalez-Julian, B. Dargatz, T. Kessel, G. Schierning, et al., Field-Assisted Sintering Technology/Spark Plasma Sintering: Mechanisms, Materials, and Technology Developments, Adv. Eng. Mater. 16 (2014) 830–849. https://doi.org/10.1002/adem.201300409.

[5] M. Sakkaki, V. Pouyafar, R. Meshkabadi, M. Shahedi Asl, Fabrication, application, and phase formation rules in high-entropy alloys, J. Mater. Sci. 61 (2026) 19161–19209. https://doi.org/10.1007/s10853-026-12906-6.

[6] A. Nisar, C. Zhang, B. Boesl, A. Agarwal, Unconventional Materials Processing Using Spark Plasma Sintering, Ceramics. 4 (2021) 20–39. https://doi.org/10.3390/ceramics4010003.

[7] W.R. Matizamhuka, Spark plasma sintering (SPS) - an advanced sintering technique for structural nanocomposite materials, J. South. African Inst. Min. Metall. 116 (2016) 1171–1180. https://doi.org/10.17159/2411-9717/2016/v116n12a12.

[8] P.C. Verma, S.K. Tiwari, A. Saurabh, A. Manoj, Recent Advances in High-Entropy Ceramics: Synthesis Methods, Properties, and Emerging Applications, Ceramics. 7 (2024) 1365–1389. https://doi.org/10.3390/ceramics7040089.

[9] J.-P. Monchoux, A. Couret, L. Durand, T. Voisin, Z. Trzaska, M. Thomas, Elaboration of Metallic Materials by SPS: Processing, Microstructures, Properties, and Shaping, Metals (Basel). 11 (2021) 322. https://doi.org/10.3390/met11020322.

[10] N. Saheb, U. Hayat, S.F. Hassan, Recent Advances and Future Prospects in Spark Plasma Sintered Alumina Hybrid Nanocomposites, Nanomaterials. 9 (2019) 1607. https://doi.org/10.3390/nano9111607.

[11] J. Binner, M. Porter, B. Baker, J. Zou, V. Venkatachalam, et al., Selection, processing, properties and applications of ultra-high temperature ceramic matrix composites, UHTCMCs – a review, Int. Mater. Rev. 65 (2020) 389–444. https://doi.org/10.1080/09506608.2019.1652006.

[12] W. Xu, P. Lv, J. Li, J. Yang, L. Cao, J. Huang, Advances in Fabrication Technologies of Advanced Ceramics and High-Quality Development Trends in Catalytic Applications, Catalysts. 16 (2026) 79. https://doi.org/10.3390/catal16010079.

[13] S. Habibi Anganeh, V. Shahedifar, B. Tekyeh Marouf, Corrosion behavior and in-vitro bioactivity of Ti-based composites: Synergistic and competitive effects of ZrO2 and nHA ceramic reinforcements, Synth. Sinter. 6 (2026) 83–96. https://doi.org/10.53063/synsint.2026.62342.

[14] W. Hassan, A.E. Duarte, Bibliometric analysis: A few suggestions, Curr. Probl. Cardiol. 49 (2024) 102640. https://doi.org/10.1016/j.cpcardiol.2024.102640.

[15] Elsevier, Scopus, (2026). (accessed June 27, 2026).