Bibliometric Analysis of Publications Related to Solid Oxide Fuel Cell (SOFC)

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The growing interest in renewable energies amid global energy challenges highlights the promising technology of solid oxide fuel cells (SOFCs) due to their efficiency, low pollutant emissions, and flexibility in using renewable sources. This study conducts a bibliometric analysis, identifying over 18,000 documents distributed across 1,800 journals worldwide. Between 2014 and 2024, there has been a significant increase in academic output on the topic, recently surpassing 141 publications annually. However, Brazil still shows a relatively modest presence in this research area. The study underscores the increasing potential of SOFCs and points to research and development opportunities that remain to be explored.

Keywords: Renewable Energies. Solid Oxide Fuel Cell (SOFC). Energy Efficiency. Pollutant Emissions. Technological Development.

This study conducts a bibliometric analysis of publications related to solid oxide fuel cells (SOFCs). Bibliometric analysis is a valuable tool for quantitatively and statistically assessing the landscape of a research field, identifying publication patterns, and exploring interconnections between study areas [1].

Researchers widely use this approach to evaluate the development of a scientific domain or to map its multidimensional characteristics [1].

The Scopus database, recognized as the largest repository of abstracts and citations from peer-reviewed literature, is commonly employed in bibliometric analyses. It includes scientific journals, books, and conference proceedings and serves as a fundamental source for this study [2].

Fuel cells—devices that convert chemical energy into electrical energy—have attracted attention due to their high efficiency (60–80%) and low environmental impact compared to combustion engines [3]. These systems operate continuously using fuel and an oxidant, typically hydrogen and oxygen from the air, with nearly zero pollutant emissions, positioning them as a sustainable energy solution [4,5].

SOFCs, in particular, have gained interest due to their high efficiency, rapid reaction kinetics at elevated temperatures, and fuel flexibility. They allow the use of natural gas, biomethane, and ethanol—fuels that are widely available in Brazil. This makes the development of SOFCs strategically important for the country, both economically and environmentally [6].

Considering the relevance of this technology, the present study analyzes global and national (Brazilian) publications on SOFCs indexed in the Scopus database. It identifies key research outputs, highlights potential areas for future investigation, and outlines the main themes consolidated in recent years. The data were compiled and analyzed using the Bibliometrix R package, a statistical tool for bibliometric research (Table 1 and 2).

Results and Discussion

Annual Scientific Production

The study analyzed 18,150 documents published between 2014 and 2024, with Brazil contributing only 228 of these documents. Figure 1a illustrates the annual distribution of articles globally during this period, while Figure 1b highlights the Brazilian contribution. There is a clear global growth trend

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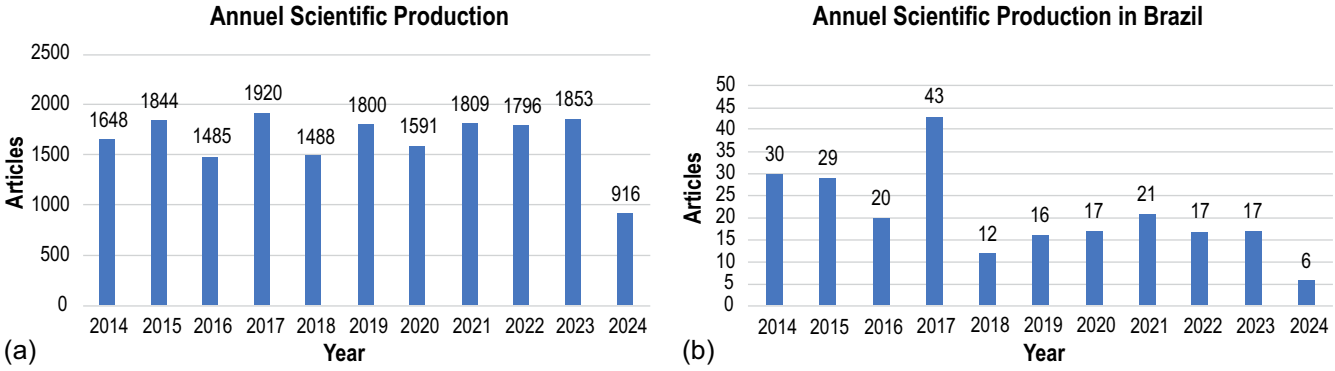
Table 1. Main information about the data generated by Bibliometrix.

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2014:2024
Sources (Journals, Books, etc)	1811
Documents	18150
Document Average Age	5,15
Average citations per doc	17,5
DOCUMENT CONTENTS	
Article	14057
Conference paper	3204
Review	705
Authors	22435
Documents by author	1,24
Authors per document	0,81
Co-Authors per Doc	5,23
International co-authorships %	26,15

Table 2. Main information about the data generated by Bibliometrix linked to Brazilian institutions or researchers.

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2014:2024
Sources (Journals, Books, etc)	89
Documents	228
Document Average Age	5.95
Average citations per doc	12.67
DOCUMENT CONTENTS	
Article	155
Conference paper	61
Review	10
Authors	230
Documents by author	1,01
Authors per document	0,99
Co-Authors per Doc	5,5
International co-authorships %	50,88

Figure 1. Number of articles per year between 2014 and 2024 worldwide (a) and in Brazil (b).



in research and publication in this area, indicating its contemporary relevance as a driving force for the field's development.

In the Brazilian context, the scarcity of studies dedicated to solid oxide fuel cells (SOFC) is notable, suggesting a nascent research area with vast potential for exploration.

Countries of Corresponding Authors

The data reveal an intriguing distribution of the countries of origin of the corresponding authors of the analyzed documents. Figure 2 provides a comprehensive view of this distribution, highlighting the twenty most prominent countries contributing to the examined research. Notably, China leads unequivocally, followed by South Korea and the United States. Brazil, on the other hand, ranks 21st, with 106 documents.

Most Relevant Sources

Figure 3 highlights the 20 most relevant sources when analyzing the documents. Notably, the International Journal of Hydrogen Energy leads with 1,784 published documents, followed closely by ECS Transactions, with 1,356 articles in the field. In the Brazilian context, as shown in Figure 4, ECS Transactions and the International Journal of Hydrogen Energy lead with 22 publications each, followed by Ceramics International with 19 publications. These data indicate a trend of journals addressing the SOFC topic more frequently, providing valuable insights for selecting journals for future investigations.

Observing the growth of the primary publication sources on Solid Oxide Fuel Cells (SOFC) from 2014 to 2024, both globally and in Brazil, clear trends stand out. Globally, the International Journal of Hydrogen Energy and ECS Transactions lead with consistent growth, followed by the Journal of Power Sources, Ceramics International, and the Journal of the Electrochemical Society. In Brazil, ECS Transactions and the International Journal of Hydrogen Energy remain significant, with notable growth in Ceramics International. Additionally, Materials Science Forum and Revista Materia show gradual increases, reflecting the country's growing interest and expansion of SOFC research.

Most Relevant Affiliations

The leading global institutions involved in SOFC research and publication are highlighted in Figures 5 and 6. In Figure 6, Kyushu University leads globally with 570 articles, followed by Huazhong University of Science and Technology with 474. In the Brazilian context, shown in Figure 7, the Materials Science and Engineering Postgraduate Program stands out with 21 articles, followed by the Federal University of Rio de Janeiro and the University of São Paulo with 12 articles. These figures demonstrate the strong engagement of universities and research centers in the study and development of this topic.

Figure 2. Distribution of the corresponding authors' countries of origin.

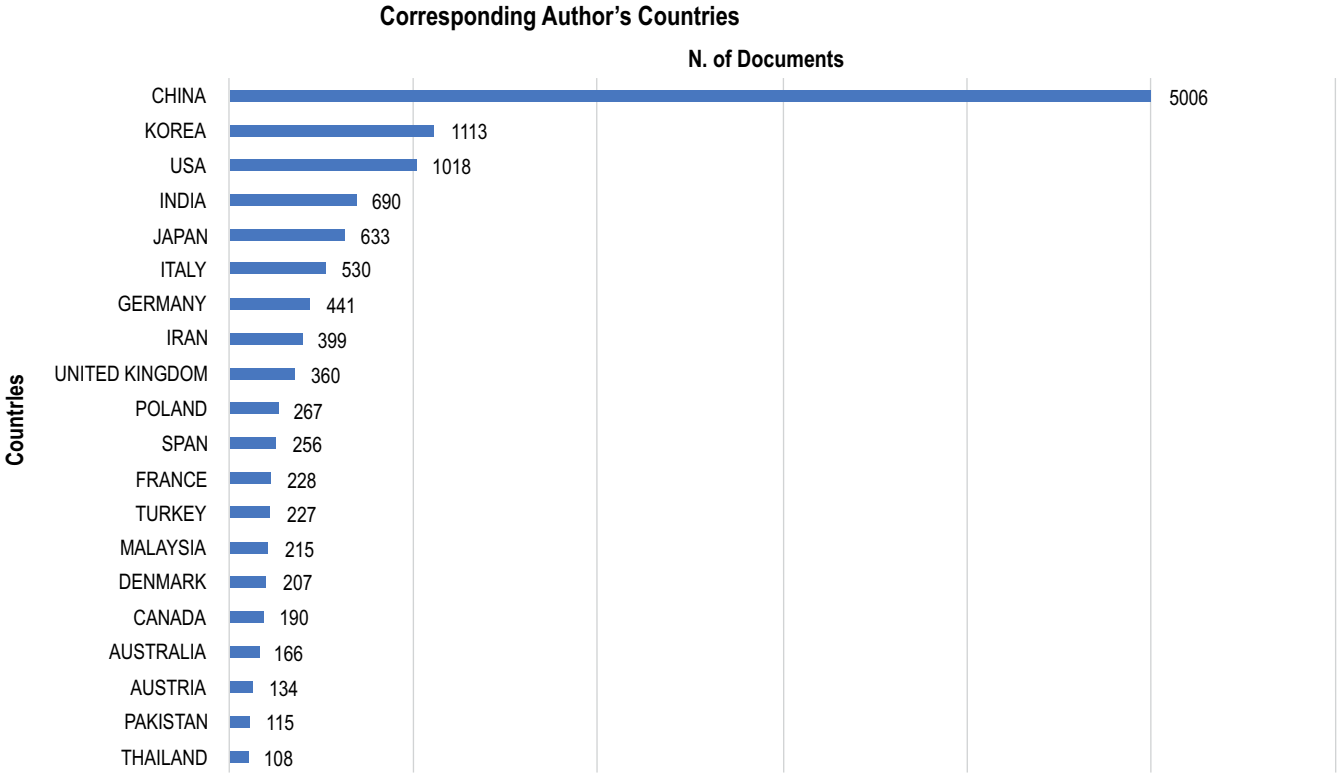


Figure 3. Most relevant sources with their respective number of publications in the SOFC field.

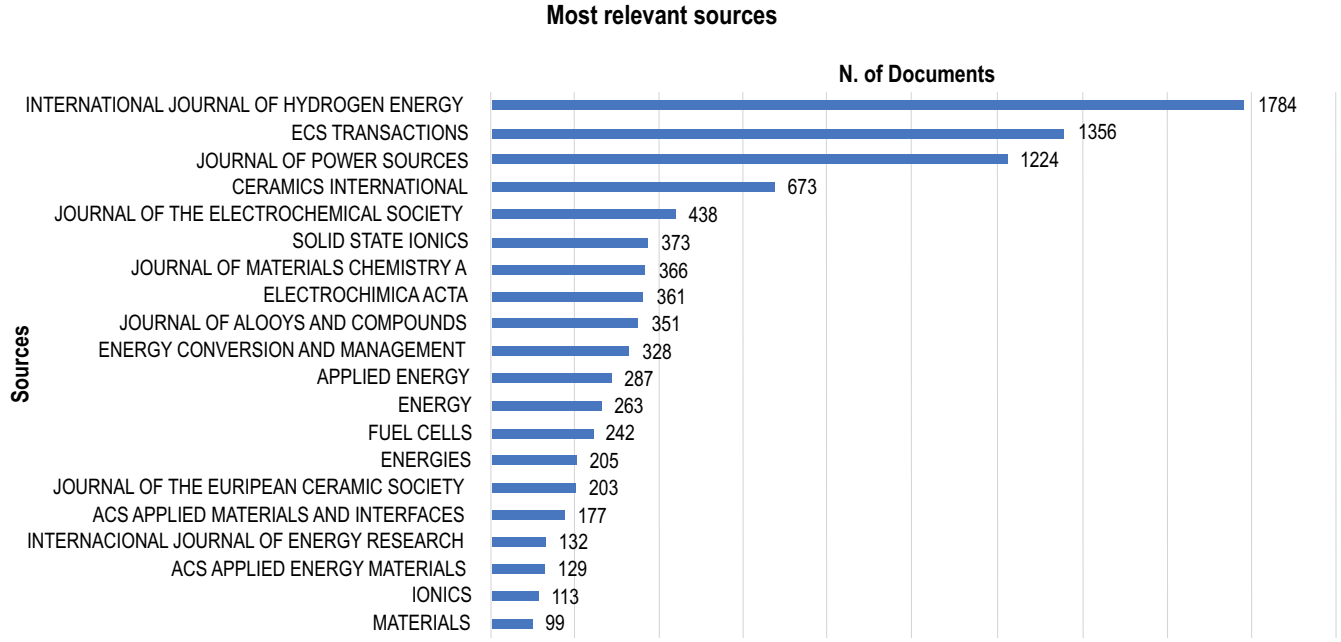


Figure 4. Most relevant sources with their respective number of Brazilian publications in the SOFC field.

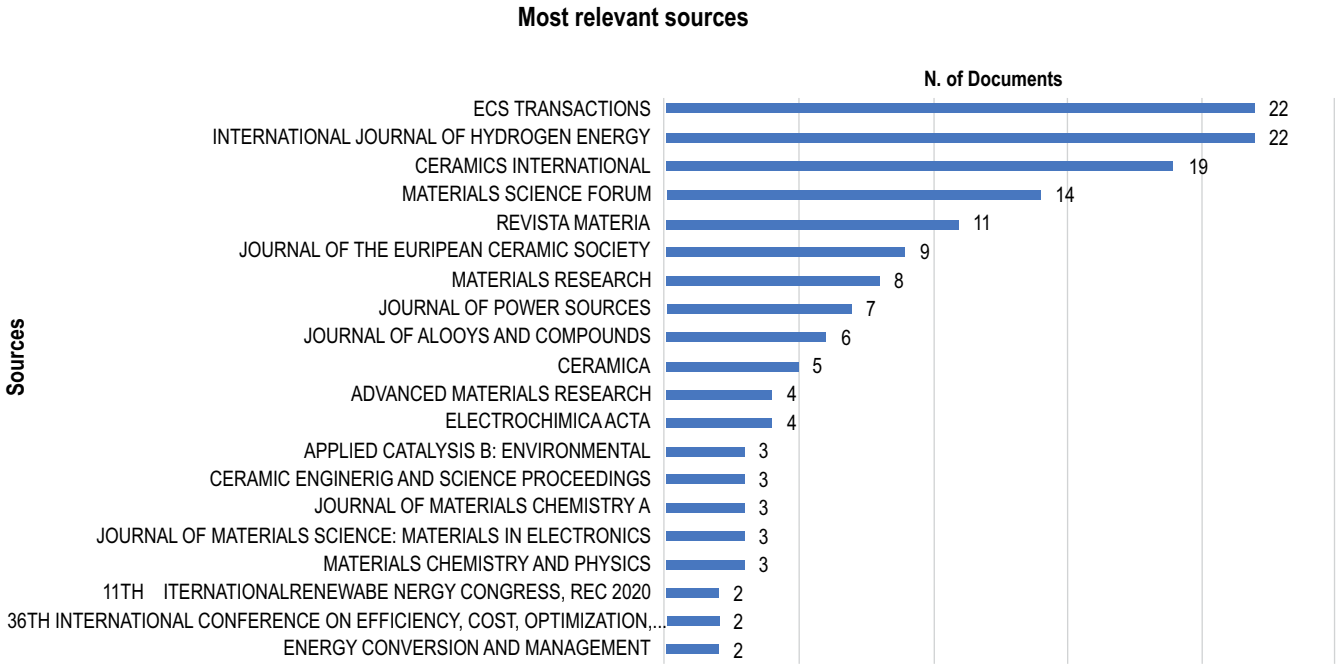


Figure 5. Most relevant institutions and their respective number of produced articles.

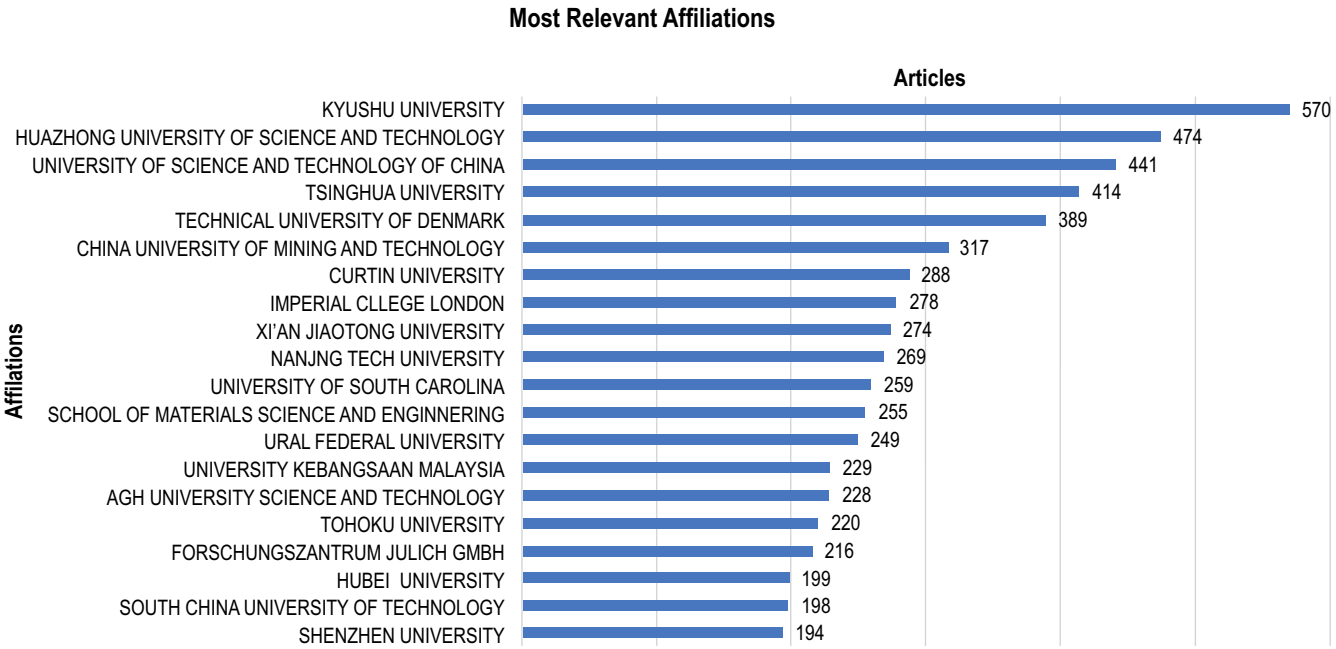
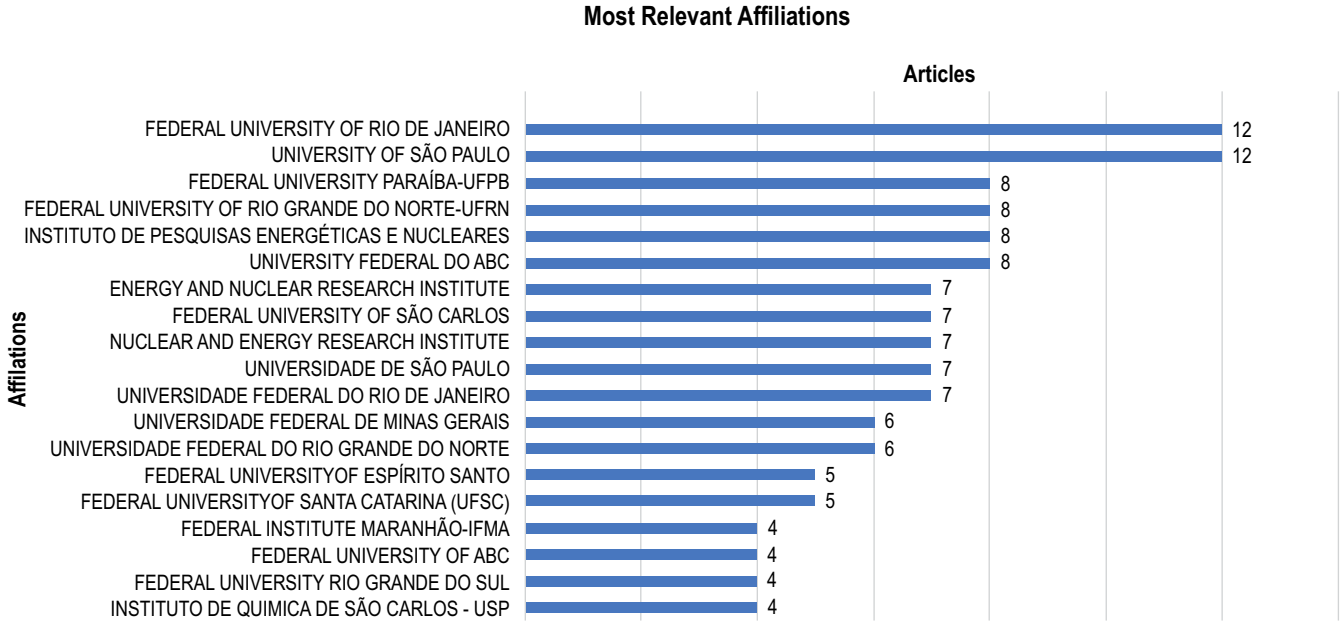


Figure 6. Most relevant Brazilian institutions and their respective number of produced articles.



Most Cited Articles in Word

Table 3 presents the 20 most cited articles globally between 2014 and 2024, including the total number of citations. Table 4 lists Brazil's 20 most-cited articles during the same period. The authors and their affiliations were attributed based on the first author of each article.

Conclusion

This study analyzed 18,150 documents from 1,811 international scientific journals and 228 publications authored by Brazilian researchers across 89 journals between 2014 and 2024, using data from the Scopus database and the Bibliometrix R package. The findings demonstrate that research on renewable energy sources—particularly hydrogen and solid oxide fuel cells (SOFCs)—has shown steady growth, with a clear trajectory for future expansion.

The main objective was to conduct a bibliometric analysis of publications focused on SOFCs. Despite the relatively limited volume of literature in certain regions, the analysis identified specific areas needing further investigation and with strong potential for technological development, thus signaling a promising field for future research.

The bibliometric mapping also revealed a notable scarcity of studies on SOFCs within the Brazilian context, underscoring the country's untapped potential for further exploration. The study identified global and national publication trends, major research institutions, and key contributing authors, offering a broad and informative overview of SOFC-related research in Brazil and internationally.

These insights guide future research efforts, providing researchers with a clearer understanding of the principal journals publishing in this field. Moreover, the results highlight underexplored research themes, which could foster the development of innovative solutions for climate change mitigation and environmental sustainability through hydrogen production from renewable sources.

Additionally, the analysis identified the International Journal of Hydrogen Energy and ECS Transactions as the leading journals in terms of publication volume. There has also been a recent increase in the number of Brazilian

authors contributing to this field. Brazil's primary research center is the Postgraduate Program in Materials Science and Engineering, followed by the Federal University of Rio de Janeiro (UFRJ) and the University of São Paulo (USP), indicating a growing—albeit still comparatively modest—presence in the global research landscape.

Acknowledgments

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Table 3. The most cited articles worldwide related to SOFC.

Authors	Affiliations	DOI	Total Citations
HOU Q et al.	Harbin Institute of Technology	10.1115/ES2020-1650	2020
MILCAREK RJ et al.	Arizona State University	10.1115/ES2020-1634	2020
LAVERNIA A et al.		NA	2020
RODRÍGUEZ JC et al.	National Energy Technology Laboratory	10.1115/POWER2020-16620	2019
GEMMEN RS et al.	National Energy Technology Laboratory	10.1149/09601.0025ecst	2019
JOHNSON RW et al.	Stanford University	10.1016/j.mattod.2014.04.026	1358
BUTTLER A et al.	TU München	10.1016/j.rser.2017.09.003	1303
SCHMIDT O et al.	Imperial College London	10.1016/j.ijhydene.2017.10.045	1229
MAHATO N et al.	Indian Institute of Technology Kanpur	10.1016/j.pmatsci.2015.01.001	1188
DUAN C et al.	Colorado School of Mines	10.1126/science.aab3987	1005
GAO Z et al.	Northwestern University	10.1039/c5ee03858h	728
DING D et al.	Georgia Institute of Technology	10.1039/c3ee42926a	711
LI M et al.	University of Sheffield	10.1038/nmat3782	708
SENGODAN S et al.	Ulsan National Institute of Science and Technology	10.1038/nmat4166	612
MEFFORD JT et al.	The University of Texas at Austin	10.1038/nmat4000	591
DUAN C et al.	Colorado School of Mines	10.1038/s41586-018-0082-6	515
GU W et al.	Southeast University	10.1016/j.ijepes.2013.06.028	515
GIDDEY S et al.	CSIRO Energy	10.1021/acssuschemeng.7b02219	492
DUAN C et al.	Colorado School of Mines	10.1038/s41560-019-0333-2	433
GRAVES C et al.	Technical University of Denmark	10.1038/nmat4165	419

Table 4. The most cited articles in Brazil related to SOFC.

Authors	Affiliations	DOI	Total Citations
DA SILVA FS et al.	São Paulo State University (Unesp)	10.1016/j.ijhydene.2017.08.105	297
GÓMEZ SY et al.	Federal University of Santa Catarina (UFSC)	10.1016/j.rser.2016.03.005	283
FERNANDES MD et al.	Federal University of Minas Gerais (UFMG)	10.1016/j.ijhydene.2018.07.004	96
DA SILVA AAA et al.	Military Institute of Engineering	10.1016/j.apcatb.2017.01.069	81
LO FARO M et al.	Institute for Advanced Energy Technologies "Nicola Giordano" (ITAE) of the Italian National Research Council (CNR)	10.1016/j.apcatb.2017.08.010	65
DA SILVA MJ et al.	Nuclear and Energy Research Institute (IPEN)	10.1016/j.jeurceramsoc.2015.10.005	65
STEIL MC et al.	Université Grenoble Alpes	10.1016/j.apenergy.2017.04.086	63
GUAITOLINI SVM et al.	Federal University of Espírito Santo (UFES)	10.1109/IREC.2018.8362573	55
RODRÍGUEZ-LÓPEZ S et al.	Ceramics and Glass Institute (CSIC)	10.1016/j.jeurceramsoc.2017.03.054	54
LIMA CGM et al.	Universidade Federal da Paraíba (UFPB)	10.1016/j.ceramint.2014.12.093	53
LOUREIRO FJA et al.	Universidade Federal do Rio Grande do Norte (UFRN)	10.1016/j.jeurceramsoc.2019.01.013	50
DA SILVA CA et al.	Federal University of Rio de Janeiro (UFRJ)	10.1016/j.ijhydene.2015.06.019	48
ALIOTTA C et al.	Università degli Studi di Palermo	10.1016/j.apcatb.2016.02.044	43
SARRUF BJM et al.	Federal University of Rio de Janeiro (UFRJ)	10.1016/j.ijhydene.2019.04.075	42
NOBRESA SD et al.	Nuclear and Energy Research Institute (IPEN)	10.1149/2.107403jes	36
SARRUF BJM et al.	Federal University of Rio de Janeiro (UFRJ)	10.1016/j.ijhydene.2018.01.192	34
AUGUSTO BL et al.	Federal Fluminense University (UFF)	10.1016/j.ijhydene.2014.05.088	34
LO FARO M et al.	Institute of Advanced Energy Technologies	10.1007/s10800-015-0849-5	33
TARRAGÓ DP et al.	Federal University of Rio Grande do Sul (UFRGS)	10.1016/j.powtec.2014.09.037	30
SANTOS JRD et al.	Universidade Federal da Paraíba (UFPB)	10.1016/j.electacta.2018.08.018	29

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