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Two Decades of Semiconductor Research Trends in India: A Scientometric Study Based on the Web of Science

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Abstract

An attempt has been made in this study to identify the research trends on semiconductor scientific publications in India through the scientometric analysis using the Web of Science core collection database for a period of two decades from 2004 to 2023. A total of 17717 research outputs were collected during the research and properly tabulated using MS Excel spreadsheet and analyzed applying various tools and software such as VOSviewer and HistCite. The results show that the yearly growth rate is in the year 2022 with 1530 research publications and ranked first. It also shows that the doubling time (DT) has gradually decreased and the level of research relative growth rate (RGR) in semiconductors has significantly increased. The subject "Physics" ranked first with 54.29 percent of records as it is the fundamental discipline that reflects the importance of semiconductor research publications among the other research domains. The USA and South Korea are leading global contributors to Indian semiconductor research. Journal of Applied Physics and Journal of Alloys and Compounds are top journals in this field.

Keywords: Scientometric, Semiconductor Research, WOS, Visualization, Publication analysis, RGR, DT, India

1. Introduction

Semiconductors are widely well-known as silicon and the electronic components applying semiconductors are known as semiconductor devices, which include the IC, which is an integrated circuit of transistors. Semiconductor devices mounted inside many electronic appliances are important electronic components that support our everyday lives. As per the history, semiconductors were discovered back in the 19th century. In the 1940s, transistors were invented. Radios, which used vacuum tubes until then, were significantly downsized and became portable. Semiconductors play an important role in equipment control in a variety of fields, such as operating air conditioners at a comfortable room temperature, improving automobile safety, laser treatment in cutting-edge medical care, and many more.

The semiconductor industry has become a cornerstone of technological advancement, powering everything from consumer electronics to critical infrastructure. As the global demand for semiconductors continues to surge, the need for robust research and development (R&D) in this domain has never been more apparent. India, with its growing technical prowess, has increasingly contributed to semiconductor research, establishing itself as a notable player in this field. However, despite its growing presence, comprehensive analyses of India's contributions to semiconductor research remain scarce. With semiconductor technology being pivotal for the future of industries such as artificial intelligence, telecommunications, and energy, understanding the trajectory of Indian research is crucial for policymakers, researchers, and industry stakeholders. This article examined how India is positioning itself in the world of electronics and what opportunities and challenges lie ahead for its research efforts. For this study, researchers applied scientometric and visual mapping techniques to analyze research data to find out how Indian academia and industry are participating with semiconductors in these two experiments.

2. Review of Literature

A review of the literature is an essential tool to analyze the research gap in any field of knowledge and identify the previous ideas and thoughts. In this research, several bibliometric analyses are carried out in almost all fields, and few recent reviews have been taken. Anandraj and Aravind (2024) examined the recent trends and developments in mesentery research and retrieved data from the Web of Science core collection database for a period from 1989 to 2022. Their study indicated that journals were the most source medium for publication with 81.7% of papers that appeared in journals. It found that the most prolific journal was “The American Journal of Physiology-Heart and Circulatory Physics”. The authors measured various variables such as author productivity, geographic distribution, and international cooperation, and observed that the research offered invaluable insights into future directions of inquiry. Wang et al. (2024) carried out a study to observe the most recent developments in organic semiconductors, citing improvements in materials stability and higher device efficiency. From the analysis, they found that most of the scientific publications on organic semiconductors were multi-authors. It showed that a huge number of scientists were willing to publish their papers collaboratively. Yang et al. (2024) investigated the progress in organic semiconductors through publications and considered that it was not optimal just to transplant conventional silicon technology. Further, they noted the majority of the literature output was double-authored and jointly authored. Sharma and Singh (2024) tried to focus through their research work that the latest whole project, giving many pages to semiconductor products such as specialized low-voltage sensors and circuits.

Garcia et al. (2023) illustrated power electronics publications applying the bibliometric analysis and found the majority of publications were multi-authored and it showed the collaborative research trends were predominant. Nair and Reddy (2023) conducted a study using bibliometric techniques on semiconductor research in India to specify the increment of Indian incipient contributions and the focus area of this research theme. Zhang et al. (2022) discussed higher-power semiconductor materials and found a huge number of research documents were journal articles and the conference papers. The findings showed most of the researchers were interested in publishing their research papers in reputed journals and conferences. Abbas and Jayaprakash (2021) studied research publications published in various science and technology journals from 2011 to 2020 from India using the data collected from the WoS database. The study focused the various parameters such as the year-wise publications, annual distribution of publications, most prolific authors, articles, authors and organizations productivity, etc. The results revealed that a huge number of publications were published in 2019 (13.16%), followed by 2020 (12.98%), and 2018 (11.51%). It found that 88% of the research fund was received from the Government of India, and the remaining were from the Western world.

Guan and Ma (2007) compared the scientific research papers in the semiconductor-related field in China and some major nations in Asia. This research was connected with the bibliometrics and the required data was collected from the SCI-Expanded database for a period between 1995 and 2004. The results showed that China was fast in semiconductor research, and was found the second most productive country in Asia as reflected by the publication analysis during the research. It also noted that similar to the scientists in Japan and South Korea, Chinese scientists were more inclined to work with larger groups.

3. Research Methodology

3.1. Data Collection and Tools Applied

The Web of Science indexing database is one of the popular and essential databases that is widely used by academicians all over the globe. Researchers chose the database for gathering raw data in the field of semiconductors. The data was downloaded in October 2024 for two decades (20 years) between 2004 and 2023. The search string “Semiconductor” in the address filed “India” has been chosen and the stipulated period was customized as “2004-2023”.After retrieving the raw data, it was found a total of 17, 717 records in the field of semiconductors from the Indian country. All these downloaded bibliographic records were transferred to the MS Excel spreadsheet application and it was analyzed by applying various software such as HistCite for analysis, and VOSviewer for mapping and visualization networks of data.

3.2. Research Process

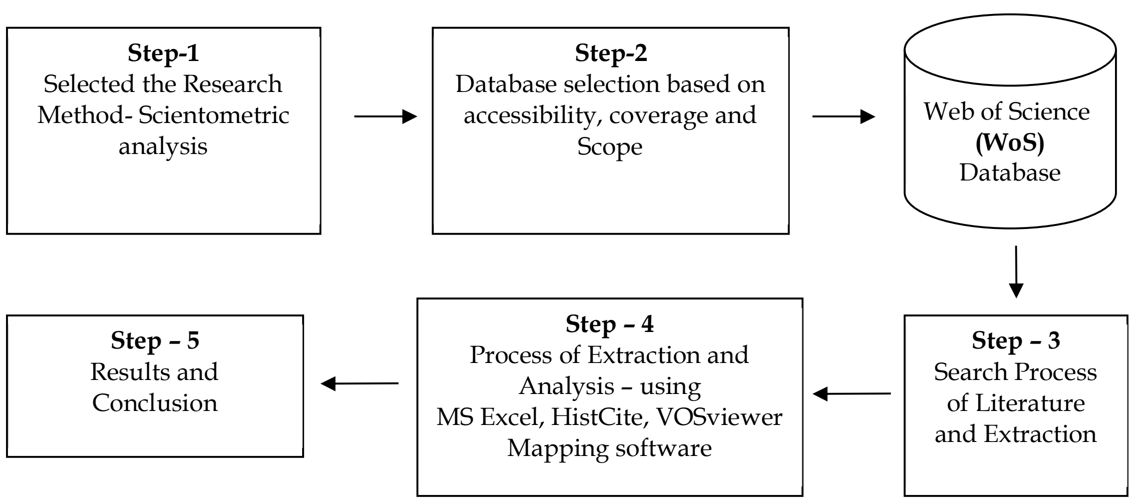

Figure 1: Layout of Research Process

4. Objectives of the Study

The main purpose of this research is to evaluate the semiconductor publications in India for a period between 2004 and 2023. The other objectives are:

1. To examine the growth trends of publication analysis on Semiconductor in India
2. To identify the Relative Growth Rate and Doubling Time on Indian Semiconductor literature
3. To examine the most prolific authors and productive Journals
4. To find out the top institutions in the field of Indian Semiconductor Research
5. To explore the discipline-wise contribution ofIndian semiconductor research
6. To analyzethe occurrence of the keywordsin Indian semiconductor research

5. Data Analysis and Discussion

5.1. Publication Analysis on Indian Semiconductor Research

Table 1 reveals a clear case of record growth year by year which can be traced in the contribution of research productivity on semiconductors. The number of records steadily increased from 2004 to 2006, with peaks of 298 in 2004 and 424 in 2006 followed by a slight decrease to a total of 417 records in 2007 reported during the year. The first stage shows the initial growth, though perhaps with a little variability. It found that the years from 2008 to 2012 showed a stronger uptrend, with huge records nearly doubling from 540 in 2008 to 671 in 2012. This period was defined by more consistent growth, especially from 2008 to 2012, and the period between 2013 and 2023 when the golden years of high and sustained growth were recorded. Overall the contributions show a rising trend, but with some fluctuations. However, it found that the yearly growth rate is in the year 2022 with 1530 research publications and ranked the first.

Table 1. Publication Analysis on Indian Semiconductor Research

S.No	Year	Output	%	Rank
1	2023	1495	8.44	2
2	2022	1530	8.64	1
3	2021	1488	8.40	3
4	2020	1287	7.26	4
5	2019	1285	7.25	5
6	2018	1241	7.01	6
7	2017	1110	6.27	7
8	2016	1043	5.89	8
9	2015	908	5.13	9
10	2014	898	5.06	10
11	2013	783	4.43	11
12	2012	671	3.78	13
13	2011	673	3.79	12
14	2010	643	3.63	15

15	2009	660	3.72	14
16	2008	540	3.04	16
17	2007	417	2.35	18
18	2006	424	2.39	17
19	2005	323	1.83	19
20	2004	298	1.69	20
Total		17717	100	

5. 2. Relative Growth and Doubling Time on Indian Semiconductor Research

It can be seen from Table 2 that the literature output and the level of growth rate have been evaluated. The Relative Growth Rate (RGR) falls between 0.65 in the year 2004 and 2.47 in the year 2023 and the average growth rate is 1.834. The doubling time was measured and found 1.06 in the year 2004 and 0.28 in the year 2023 and the average doubling time was 0.42. It shows that the doubling time has gradually decreased and the level of research relative growth rate in semiconductors has significantly increased during the study.

Table 2. Growth Pattern of Semiconductor Research in India

Year	Records	Cumulative Records	Log1e	Log2e	RGR	DT
2004	298	298	5.70	5.70	-	-
2005	323	621	5.78	6.43	0.65	1.06
2006	424	1045	6.05	6.95	0.90	0.77
2007	417	1462	6.03	7.29	1.25	0.55
2008	540	2002	6.29	7.60	1.31	0.53
2009	660	2662	6.49	7.89	1.39	0.50
2010	643	3305	6.47	8.10	1.64	0.42
2011	673	3978	6.51	8.29	1.78	0.39
2012	671	4649	6.51	8.44	1.94	0.36
2013	783	5432	6.66	8.60	1.94	0.36
2014	898	6330	6.80	8.75	1.95	0.35
2015	908	7238	6.81	8.89	2.08	0.33
2016	1043	8281	6.95	9.02	2.07	0.33
2017	1110	9391	7.01	9.15	2.14	0.32
2018	1241	10632	7.12	9.27	2.15	0.32
2019	1285	11917	7.16	9.39	2.23	0.31
2020	1287	13204	7.16	9.49	2.33	0.30
2021	1488	14692	7.31	9.60	2.29	0.30
2022	1530	16222	7.33	9.69	2.36	0.29
2023	1495	17717	7.31	9.78	2.47	0.28

5.3. Major Research Areas

It analyzed the major research areas involved in semiconductor research in India during the research period. The results clearly show a strong emphasis on a few critical areas in Indian semiconductor research. It found that “Physics” ranked first with 54.29 percent of records as it is the fundamental discipline which reflects the importance of semiconductor research publications among the other research domains, followed by “Materials Science” related scientific records with 45.21%, highlighting the material properties and phenomena essential for semiconductor technologies and ranked the second. The third productive research output is from “Chemistry”and has also a significant contribution (28.86%) to this research, which makes clear the importance of chemical processes and properties in semiconductor development.

Further, below 20% of all major records are obtained concerning other scientific areas such as Science and Technology, and 17.67% of records represent the lowest contribution from Engineering and other research areas such as Optics (5.91%), Nuclear Science Technology (5.44%), Instruments Instrumentation and Metallurgy Metallurgical Engineering both (3.98%), and Computer Science with only 3.2% of records among them. The analysis shows that the data patterns indicate an overall emphasis on physics, Materials science, and chemistry as top priority research domains, alongside a range of other disciplines that have elements in common with those.

Table 3. Major Research Areas of Indian Semiconductor Research

S. No	Research Areas	Record Count	Percentage
1	Physics	83	54.29
2	Materials Science	71	45.21
3	Chemistry	44	28.86
4	Science and Technology	28	18.30
5	Engineering	27	17.67
6	Optics	10	5.91
7	Nuclear Science Technology	8	5.44
8	Instruments Instrumentation	6	3.98
9	Metallurgy Metallurgical Engineering	6	3.98
10	Computer Science	4	3.24

5.4. Affiliated Institutions

Institution-wise contribution is one of the variables to analyze in Semiconductor research in India. This analysis reflects the involvement and interest in publishing scientific publications among research groups in the field of semiconductors. It examined that a total of 545 affiliated institutions are significantly contributed in this research. Out of 545 institutions, researchers have taken only the top-ranked institutions. The results reveal that among the top institutes the Indian Institute of Technology (IIT), Kharagpur contributes 1705 research publications with 40459 global citations, and the average citation per paper is 23.73 and total link strength of 1348. This is followed by the Indian Institute of Science (IISc) with 896 contributions, 26389 global citations, and the average citation per paper is 29.45 and a total link strength of 897. Bhabha Atomic Research Center contributes 504 publications, with 11487 citations, and a total link strength of 628.Other notable institutions such as the National Institute of Technology (655 papers, 12967 citations, with 554 total link strength) and Jadavpur University (461 records, 6894 citations, and 458 total link strength). It also noted the least number of publications produced by Homi Bhabha National Institute with 195 and the total citations are 1782. Fig 2 shows the VOSviewer visualization displays a co-authorship network of institutions, where 545 institutions have met the threshold of 13,456, indicating substantial research activity.

Table 4. Affiliated Research Institutions

S.No	Institutions	Records	Citations	CPP	Total Link Strength
1	Indian Institute of Technology	1705	40459	23.73	1348
2	Indian Institute of Science	896	26389	29.45	897
3	Bhabha Atomic Research Center	504	11487	22.79	628
4	National Institute of Technology	655	12967	19.79	554
5	King Saud University	198	5109	25.80	537
6	Jadavpur University	461	6894	14.95	458
7	CSIR	296	8794	29.71	412
8	King Khalid University	108	1549	14.34	358
9	Anna University	339	7759	22.88	377
10	Homi Bhabha National Institute	195	1782	9.14	295

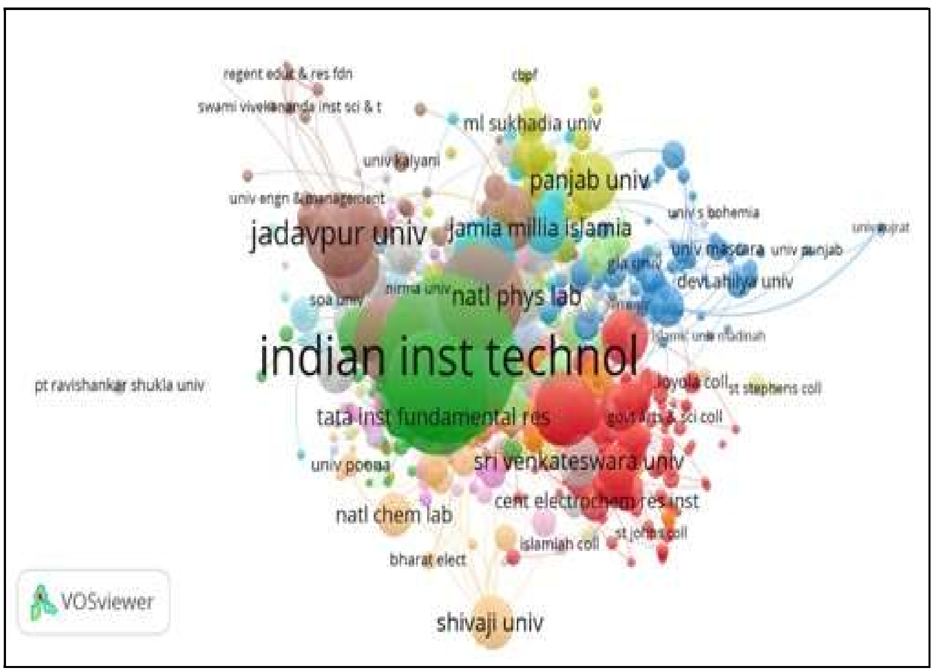

Figure 2. Affiliated Institutions of network visualization

5.5. Authorship Pattern and Collaborative Index

Table 5 illustrates the analysis of authorship patterns and collaborative index in semiconductor research in India. The analysis shows a total of 30, 120 authors participated and produced their research papers on semiconductors in India from various countries. Out of 30120 productive authors, the single-authors are very least amount of 407 while multi-authored papers are more. Based on Table 3 the number of joined authors is 3563 and for three authors the number is somewhat higher (3,966) and for four authors it is still significant (3,247). The results show that there is a strong trend towards large collaboration the largest number of records published by more than five authors. The analysis of the authorship pattern reveals that the majority of papers are published collaboratively.

Table 5. Authorship Pattern

S.No	Authorship Pattern	No. of Authors	CI
1	Single Author	407	98.65%
2	Double Author	3563	
3	Three Authors	3966	
4	Four Authors	3247	
5	Five Authors	2242	
6	More Than Five Authors	16695	
Total		**30120**	

Authorshipand co-authorship in the field of semiconductor research in India was found to be highly collaborative. The leading contributor is Kumar, A. with 95 documents and 2154 citations giving it a total link strength of 86, and followed by V. Rajagopal Reddy has contributed 76 documents with 1463 citations and link strength (S) of 47. Also Kumar, Sandeep and Choudhary, R.N.P., both of them with 66 documents having over 1300 citations. Ray, Partha Pratim, and Ghosh, Hirendra N. have authored another 64 articles apiece as well with these papers receiving citations of 1335 and 1487.

Figure 3 represents the VOSviewer visualization illustrates a co-authorship network, with “Kumar, Sandeep”, “Ghosh, Hirendra N.”, and “Ray, Partha Pratim” as central figures, reflecting their significant role in collaboration due to their larger nodes. Different colored clusters represent tightly connected groups of researchers.

Table 6. Most Productive Authors

S.No	Authors	Affiliations	TR*	TP*	h-index
1	Kumar, A	Gurukul Kangri Vishwa vidyalaya	445	2.45	5
2	Kumar, S	DAV University, Jalandhar	292	1.61	19
3	Ghosh, S	Vikram University	226	1.25	10
4	Singh, S	National Institute of Technology, Patna	219	1.21	18
5	Kumar, P	Graphic Era University	212	1.17	15
6	Kumar, R	Garg PG Degree College	201	1.11	5
7	Kumar, M	Mahatma Jyotiba Phule Rohil khand University	164	0.91	5
8	Das, S	National Institute of Technology, Meghalaya	161	0.88	9
9	Kumar, V	Indian Institute of Technology, Dhanbad	153	0.84	13
10	Singh, A	Thapar Institute of Engineering & Technology	142	0.77	6

**TR=Total Record count, TP= Total Percentage*

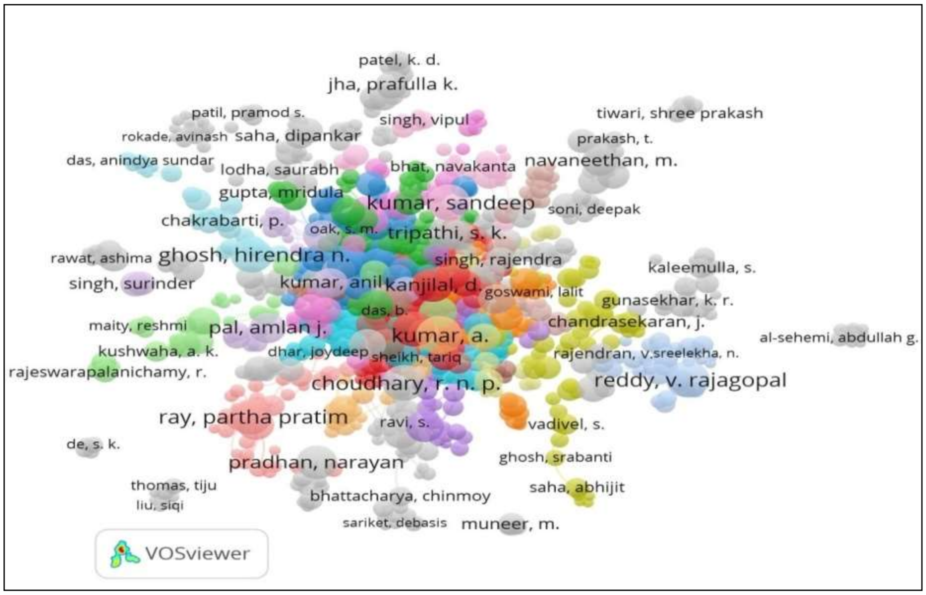

Figure 3. Network Visualization of Authors' Contributions

5.6. Most Prolific Journals

Table 7 represents the journal-wise contribution in the field of semiconductors in India. A total of 356 journals involved in this study. Out of 356 journals, it has been chosen only the top-ranked ten journals for the present analysis. This semiconductor research in India has been analyzed in terms of the journal's name, its total records, publisher, h-index, impact factor, and name of the location where the journal was published. The results reveal that “The Journal of Applied Physics” is the top-rankedwith 510 articles and an h-index of 351, it is published by the American Institute of Physics in the United States and it has an impact factor of 3.2. The next prolific journal is “Journal of Alloys and Compounds” with 427 records published by Elsevier B.V. in the Netherlands it’s an h-index of 215 which also sounds good and the impact factor is high i.e. 6.2 and it has ranked second. The third productive journal is “The Journal of Physical Chemistry” published bythe American Chemical Society in the USA with an impact factor of 3.3 and it publishes 375 records with a high h-index of 338, and the impact factor is 3.3.

Further, the Journal of Materials Science: Materials in Electronics has 369 records, published by Springer in NY, USA, and it has an h-index of 97 and an impact factor of 2.8. The analysis indicates that these journals are instrumental in the progress of the semiconductor research happening in India and that is a testimony to their massive output and impact on the Indian semiconductor research landscape.

Table 7. Journals preference for the communication by the researchers

Rank	Journal Title	TR*	Publisher	Country	h-index	Impact Factor
1	Journal of Applied Physics	510	American Institute of Physics	USA	351	3.2
2	Journal of Alloys and Compounds	427	Elsevier B V	Netherlands	215	6.2
3	Journal of Physical Chemistry	375	American Chemical Society	USA	338	3.3
4	Journal of Materials Science:	369	Springer, NY	USA	97	2.8

	Materials in Electronics					
5	Physical Review B	294	American Chemical Society	USA	497	3.7
6	Materials Chemistry and Physics	295	Elsevier B V	Netherlands	177	4.3
7	Physica B Condensed Matter	286	Elsevier B V	Netherlands	130	2.9
8	Materials Letters	278	Elsevier B V	Netherlands	172	2.7
9	IEEE Transactions on Electron Devices	259	IEEE Transactions on Electron Devices	USA	205	3.2
10	Applied Surface Science	254	Elsevier B V	Netherlands	235	6.3

**TR= Total Records*

5.7. Most Productive Countries

Table 8 shows that the top 10 countries contributed in the research of semiconductors connected with India. A total number of 108 countries produced publications and analysed accordingly. In terms of contributions for the sample provided, India leads by a large amount of 17, 717 records with 100 percent. The dominance of the publications from the "United States" is evident from their 27, 349 citations and the average citation per paper is 30.42 and ranked the first. The next productive country is "South Korea" with 774 (4.28%) and the total global citations are 19778 and the average citation per paper is 25.55. The third rank is occupied by "Saudi Arabia" with 478 (2.67%) and the global citations are 13617, and the average citation per paper is 28.49. It found countries like China, Germany, and England, Taiwan and Australia show contributions ranging below 400 records, with notable citations and average citation per paper, suggesting the need for active engagement in this research field. The results reflect a broad international interest in Indian semiconductor-related research, with contributions varying in scale but significant in academic impacts.

Table 8. Most Productive Countries

S.No	Country	Records	Percentage	Citations	ACPP
1	India	17717	100	394914	22.29
2	USA	899	5.94	27349	30.42
3	South Korea	774	4.28	19778	25.55
4	Saudi Arabia	478	2.67	13617	28.49
5	Japan	446	2.56	13289	29.79
6	China	389	2.12	11354	29.18
7	Germany	354	2.01	12034	33.99
8	England	294	1.99	10452	35.55
9	Taiwan	251	1.42	6571	26.18
10	Australia	201	1.02	6517	32.42

The VOSviewer visualization highlights in Figure 4 that there is a strong global collaboration, with 108 countries meeting the 77 thresholds, indicating extensive international research exchange. India is the central node in the green cluster, reflecting its prominent role in global partnerships with major collaborating countries.

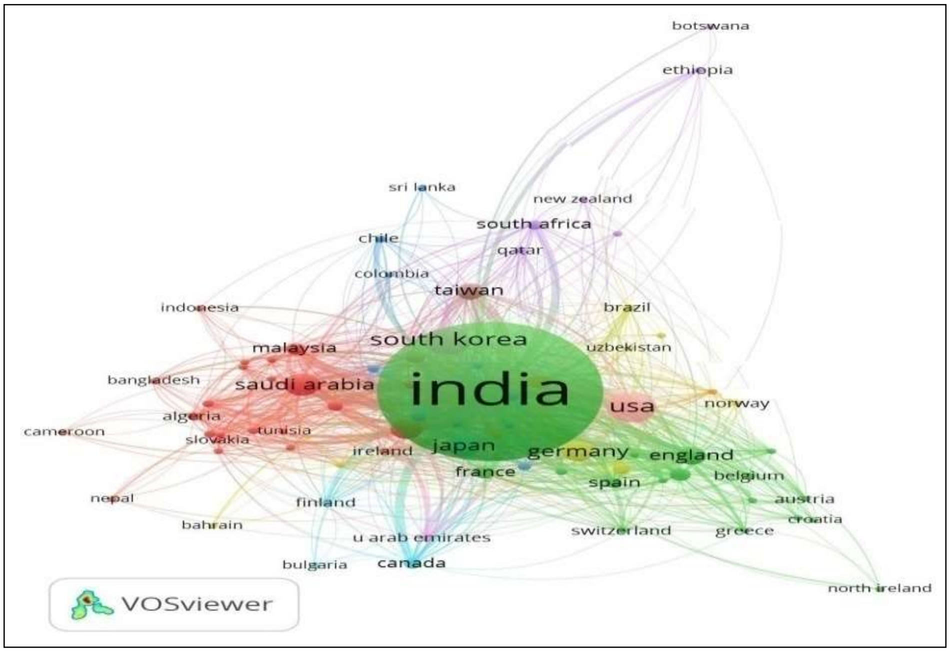

Figure 4. Network Visualization of Indian Semiconductor Research

5.8. Distribution of Keywords Occurrences

Table 9 depicts the analysis of keyword occurrences that show "Semiconductor" as the strongest term, occurring 2924 times with a log frequency of 3.466. It is further followed by the presence of "Nanoparticles" and "Semiconductors" with good frequencies and low log values. The other keywords of import include "Optical-properties" "Performance", and "Thin-films". These include "Photoluminescence", "Growth" and "Temperature", all of which suggest that the focus was on the material properties and how it propagated. The analysis results dataset highlights considering semiconductor materials and nano-particles as a key topic of this enormous effort to understand in detail each aspect of these specific features.

Table 9. Zips Law of Keyword of Occurrences

S. No	Keywords	Occurrence	Rank	Log F	Log R	Log C
1	Semiconductor	2924	1	3.466	0	3.466
2	Nanoparticles	1950	2	3.29	0.3	3.59
3	Semiconductors	1886	3	3.276	0.48	3.756
4	Optical-properties	1512	4	3.155	0.6	3.755
5	Performance	1509	5	3.153	0.7	3.853
6	Thin-films	1346	6	3.128	0.78	3.908
7	Photoluminescence	1205	7	3.081	0.85	3.931
8	Growth	1093	8	3.039	0.9	3.939
9	Temperature	875	9	2.943	0.95	3.893
10	Nanocrystals	873	10	2.94	1	3.94
11	Films	869	11	2.939	1.04	3.979
12	Quantum dots	784	12	2.894	1.08	3.974
13	Degradation	761	13	2.881	1.11	3.991

14	Nanostructures	744	14	2.771	1.15	3.921
15	Fabrication	691	15	2.839	1.18	4.019

Figure 5 shows the keyword network structure with clear clusters and relationships, reflecting subfields and relatedness within the research space. This wide variety and complexity were underlined when just 4,700 of the 41,559 keywords met the threshold. Key terms are larger nodes, which provide clues as to trends and potentially emerging areas for further research.

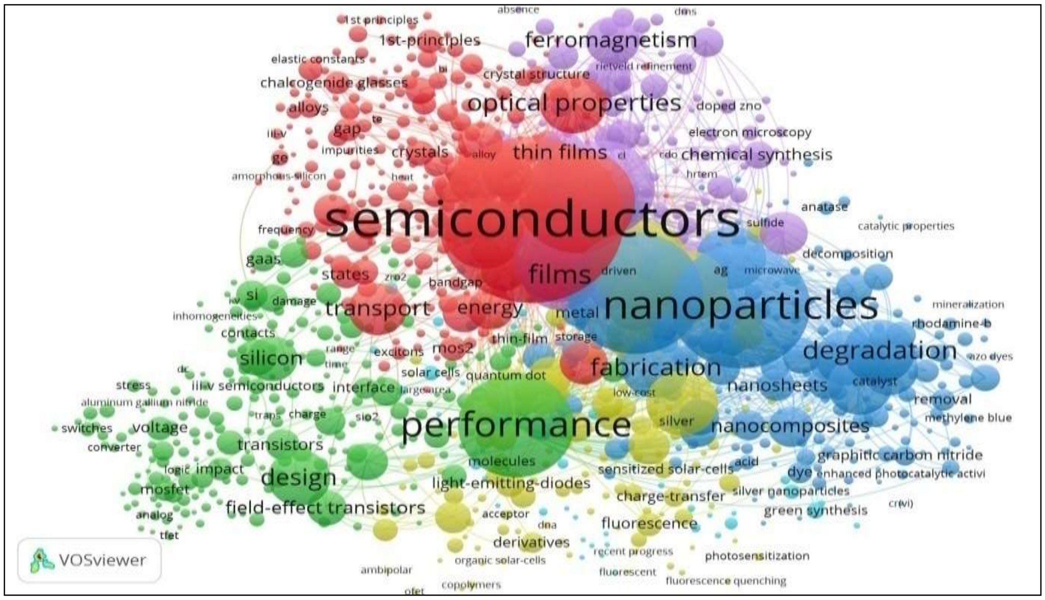

Figure 5. Network Visualization of Keyword of Occurrences

6. Findings and Suggestions

The following major findings are listed below as per the results.

- It found that the yearly growth rate is in the year 2022 with 1530 research publications and ranked the first.
- It shows that the doubling time (DT) has gradually decreased and the level of research relative growth rate (RGR) in semiconductors has significantly increased.
- It found that "Physics" ranked first with 54.29 percent of records as it is the fundamental discipline which reflects the importance of semiconductor research publications among the other research domains, followed by "Materials Science" related scientific records with 45.21%,
- Among the top institutes the Indian Institute of Technology (IIT), Kharagpur contributes 1705 research publications with 40, 459 global citations, and the average citation per paper is 23.73 and a total link strength of 1348.

- It found that the leading collaborative contributor is Kumar, A. with 95 documents and 2154 citations giving it a total link strength of 86, followed by V. Rajagopal Reddy has contributed 76 documents with 1463 citations and a link strength of 47.

- The results reveal that "The Journal of Applied Physics" is the top-ranked with 510 articles and an h-index of 351, it is published by the American Institute of Physics in the United States and it has an impact factor of 3.2. The next prolific journal is "Journal of Alloys and Compounds" with 427 records published by Elsevier B.V. in the Netherlands

- The dominance of the publications from the "United States" is evident from their 27, 349 citations and the average citation per paper is 30.42 and ranked first. The next productive country is "South Korea" with 774 (4.28%).

Future, this study should also explore other databases of literature like Scopus and Google Scholar to capture more evidence on this issue. Taking data from other databases and analyzing it would be interesting for researchers to take data and look at worldwide contributions to semiconductor research as a whole on a more global basis.

Conclusion

We can conclude that this paper studied the scientometric mapping and visualization analysis on semiconductor research in India from 2004 to 2023, which covers the growth trends, institutional contributions and research areas, authorship trends, collaborative patterns etc. This analysis provides an overview of the Indian semiconductor research landscape, benefiting from such work to the next layer of efforts explaining emerging trends and focus areas as well as identification of important research hubs in the country.

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