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Research and impact of materials science publications in India: 1999-2008

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ABSTRACT

The study analyses the materials science publications in India for a period of ten years (1999-2008) based on the Scopus database. The objective of the study was to perform a scientometric analysis of all materials science research publications by Indian scientists. The parameters studied include growth of publications and citations, relative growth rate and doubling time, domain-wise distribution of publications and citations, activity index, Citation Index, national and international collaboration, highly productive institutions, highly productive authors, highly preferred journals and highly cited publications. A total of 14849 publications were published by the Indian scientists in materials science during 1999-2008 which received 94610 citations. The average number of publications per year was 1484.90. The average number of citations per publication was 6.37. The highest number of publications 1953 was published in 2007. The highest number of citations 12901 was received in 2003. There were 11961 (80.55%) national collaborative publications and 2190 (14.75%) international collaborative publications by the scientists from India with 59 countries. Indian Institute of Technology-Kharagpur topped the list with 1243 publications which received 7985 citations, followed by Indian Institute of Science-Bengaluru with 1052 publications and 8816 citations, and Bhabha Atomic Research Centre-Mumbai with 818 publications and 4252 citations.

Keywords: Publication productivity; Citations growth; Materials science; Indian highly cited publications; Indian highly cited authors.

INTRODUCTION

The development of mankind is defined in terms of advances in materials: the Stone Age, the Bronze Age, and the Iron Age. The advances in architecture and building were possible due to the invention of a new material such as concrete. The industrial revolution was mainly responsible in the advances and the use of materials in the development of industrial equipments. This has led to the rapid development of the railroads in the late nineteenth century and the buildings of the modern structure of the industrial world. In the last half a century, the growth of new materials has been highly explosive and its impact on our daily lives is visible significantly.

Materials science is an interdisciplinary field involving the properties of matter and its applications to various areas of science and engineering. This scientific field investigates the relationship between the structure of materials at atomic or molecular scales and their macroscopic properties. It incorporates elements of applied physics and chemistry. In recent years, materials science has become a major field of research as it is focused on

nanoscience and nanotechnology. Mankinds have just begun to see the impact of materials revolution. There is a lot of research conducted worldwide in materials science. Many Indian institutions and universities are also actively engaged in research in materials science. Indian Institute of Technology, Kharagpur; Indian Institute of Science, Bengaluru; Bhabha Atomic Research Centre, Mumbai; Indira Gandhi Centre for Atomic Research, Kalpakkam; and Indian Institute of Technology Madras, Chennai are the most active institutes carrying out research in materials science in India.

Scientometrics is a discipline which analyses scientific publications and citations appended to the papers to gain an understanding of the structure of science, growth of science at global level, performance of a country in a particular domain, performance of institutions, departments/divisions, and scientific eminence of an individual scientist. It also helps in knowing the information seeking behaviour of scientists and engineers by way of identifying where they publish and what they cite. Many scientometric studies have been presented in the literature to focus on the performance of science in various domains (Kademani et al. 2010; Mohan et al. 2010; Sagar, Kademani and Bhanumurthy 2010; Sagar et al. 2009a; Sagar et al. 2009b; Kademani et al. 2008; Prakasan et al. 2008; Kademani et al. 2007; Sagar, Kademani and Kumar 2007; Kademani et al. 2006a; Kademani et al. 2006b; Kademani et al. 2006c; Kumar et al. 2004).A few scientometric studies in materials science in India have been carried out. Kochhar et al. (1996) have analysed research output from Indian institutions in seven categories of materials, namely metals and alloys, aluminium, ceramics, composites, glass, polymers, and wood as per the database developed by Indian National Scientific Documentation Centre (INSDOC) through funding from Technology Information Forecasting & Assessment Council (TIFAC) during 1980-89. Mohan et al. (2003) studied the international collaborative papers of Indian scientists during 1995-99 as covered by *Materials Science Citation Index.*; Walke and Dhawan (2007) analysed the growth and publications size of the Indian publications in materials science during 1993-2001 based on *Science Citation Index–Expanded Version* (SCIE) of the Thomson-ISI. Recently Mohan et al. (2010) highlighted quantitatively the growth and development of Indian research in the field of nanoscience and nanotechnology in terms of publication output as reflected in *Science Citation Index* (SCI) during 1982-2008. This study attempts to highlight the research and development activity in the field of materials science in India as no studies have been conducted recently in this field.

OBJECTIVES, MATERIALS AND METHOD

The main objectives of the study are to: (a) present the growth of Materials Science literature published in India during 1999-2008 as per the *Scopus* database; and (b) conduct quantitative assessment by way of analysing various features of research output such as growth of publications and citations, relative growth rate and doubling time, domain-wise distribution of publications and citations, activity index, national and international collaboration, highly productive institutions, highly productive authors, channels of communication, impact factor-wise distribution of publications and highly cited publications.

Data was collected from the *Scopus* database (1999-2008). The *Scopus* database is chosen for the study as it is known for its comprehensiveness in its coverage of journals compared to other databases. By using suitable search strategy (INDIA in affiliation field and Materials Science in subject field), records pertaining to India in the Author affiliation field were downloaded for the years 1999-2008 on 25th November 2009. A total of 14849 publications published in journals and 94610 citations received to these publications were

considered for the present study. Further all the bibliographic details are transferred to an electronic spreadsheet. The data was analysed as per objectives of the study. *Journal Citation Report* (JCR) 2008 was used to collect information related to journal impact factor (IF). A 'citation index', defined as the number of citations divided by the number of years since publication during the period under study was obtained. The publications in journals without IF are largely due to non coverage of the majority of journals in *SCI-JCR*

RESULTS AND DISCUSSION

Country-wise Distribution of Publications in Materials Science

Figure 1 presents the top 20 countries that are actively pursuing research in the field of materials science. China topped the list with 66780 publications followed by United States with 42876 publications, Japan (37457 publications), Russian Federation (22549 publications), Germany (21382 publications), South Korea (15455 publications), France (15362 publications), India (14849 publications) and United Kingdom with 13820 publications. During this period India was ranked 8th among all the countries in the world producing research in this field.

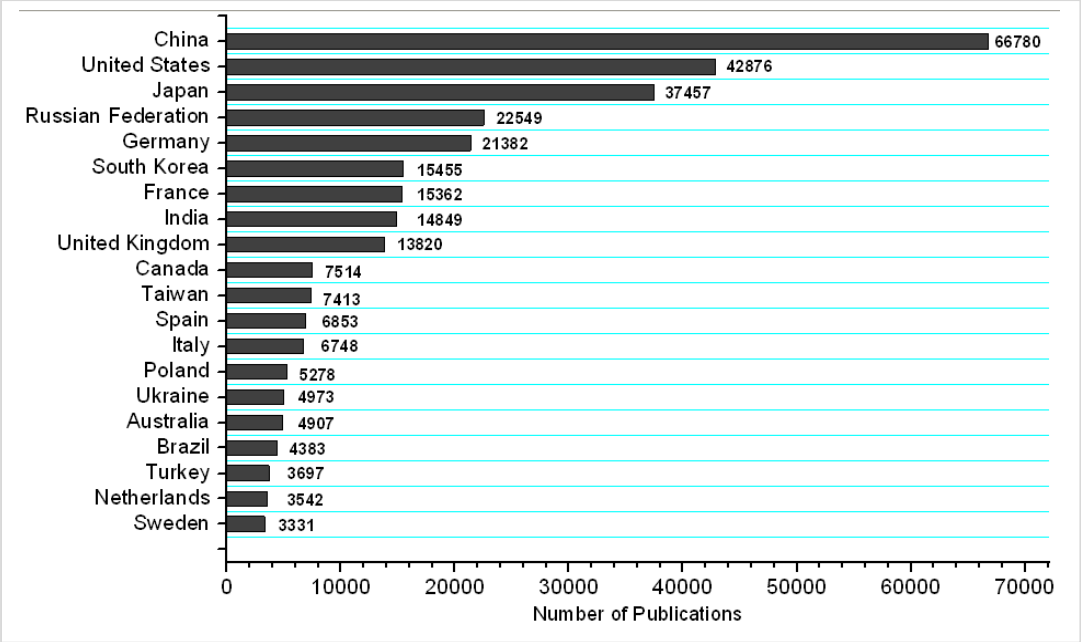

Figure 1: Top Twenty Highly Productive Countries in Materials Science Research in Terms of Publications during 1999-2008

Year-wise Distribution of Indian Publications and Citations in Material Science Research

A total of 14849 publications were published during 1999-2008 which received 94610 citations. The highest numbers of publication (1953) were published in 2007 and these publications have received 5878 citations. The average number of publications published per year was 1484.90 and the average number of citations per paper was 6.37. Table 1 and Figure 2 depict the year-wise growth of publications and their citations. The declining trend in the number of publications in Indian materials science research was observed in 2004,

2005 and 2008. It was observed that the more number of publications in a particular year received the more number of citations, which indicates that quality and quantity of research always go hand in hand. The older publications tend to receive more citations than the publications published recently.

Table 1: Year-wise Distribution of Publications and Citations in Materials Science Research in India during 1999-2008

Year	TP	% of TP	TC	% of TC	ACP	TIF	AIF
1999	1190	8.01	11211	11.85	9.42	1338.98	1.13
2000	1249	8.41	11998	12.68	9.61	1401.25	1.12
2001	1262	8.50	11535	12.19	9.14	1548.01	1.23
2002	1282	8.63	11594	12.25	9.04	1550.44	1.21
2003	1515	10.20	12901	13.64	8.52	1915.9	1.26
2004	1508	10.16	11472	12.13	7.61	2008.44	1.33
2005	1472	9.91	8715	9.21	5.92	1937.18	1.32
2006	1660	11.18	6934	7.33	4.18	2094.24	1.26
2007	1953	13.15	5878	6.21	3.01	2621.62	1.34
2008	1758	11.84	2372	2.51	1.35	2275.56	1.29
Total	14849	100.00	94610	100.00	6.37	18691.62	1.26

(TP=Total Number of Collaborative Publications; TC=Total Number of Citations; ACP=Average Citations per Publication; TIF=Total Impact Factor; AIF=Average Impact Factor per Publication (*JCR-2008*))

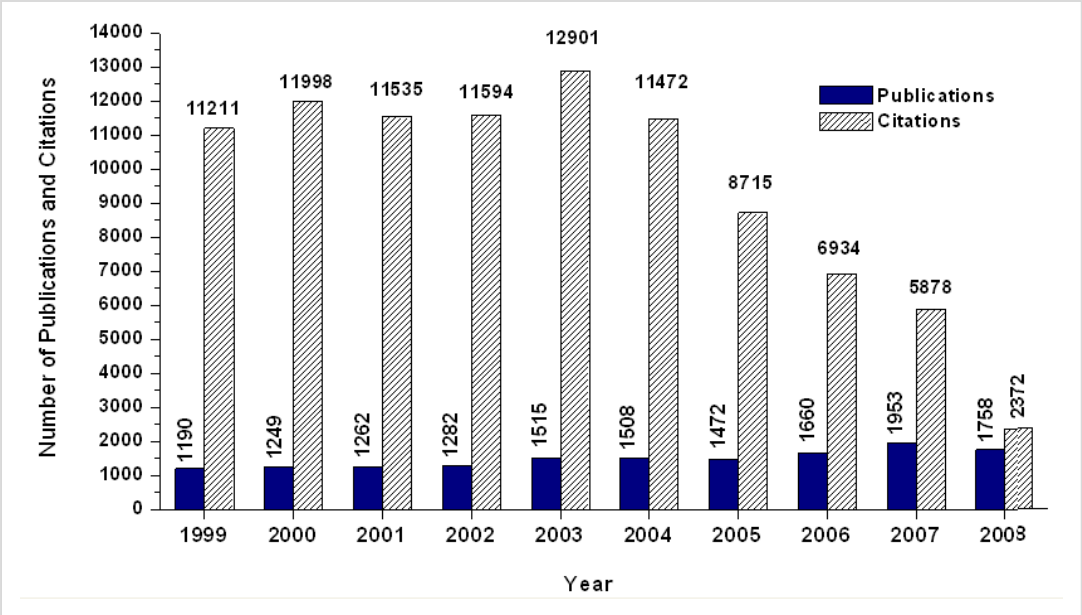

Figure 2: Year-wise Growth of Materials Science Related Publications Published by Indian Scientists and Citations Received to these Publications during 1999-2008

Relative Growth Rate (RGR) and Doubling Time (Dt) in Indian Materials Science Publications

Relative Growth Rate (RGR) is the increase in number of publications per unit of time. There exists a direct relation between the relative growth rate and the doubling time. The relative growth rate and doubling time of publications have been calculated using the formula followed by Krishnamoorthy, Ramakrishna and Devi (2009) and presented in Table 2. Figure 3 indicates the value of an average RGR of publications which decreased from 0.72 in 2000 to 0.13 in 2008. Simultaneously, the values of doubling time (Dt) of publications increased from 0.97 in 2000 to 5.50 in 2008 (Figure 4).

Table 2: Year-wise RGR and Dt for Research Output in Materials Science

Year	TP	CP	Log_e P1	Log_e P2	R (P)	Mean R (P)	Dt	Mean Dt
1999	1190	1190		7.08	-		-	
2000	1249	2439	7.08	7.80	0.72		0.97	
2001	1262	3701	7.80	8.22	0.42	0.34	1.66	1.51
2002	1282	4983	8.22	8.51	0.30		2.33	
2003	1515	6498	8.51	8.78	0.27		2.61	
2004	1508	8006	8.78	8.99	0.21		3.32	
2005	1472	9478	8.99	9.16	0.17		4.11	
2006	1660	11138	9.16	9.32	0.16	0.17	4.29	4.30
2007	1953	13091	9.32	9.48	0.16		4.29	
2008	1758	14849	9.48	9.61	0.13		5.50	

(TP=Total number of Publications, CP=Cumulative number of Publications;
R (P)=Relative Growth Rate of publications; Dt=Doubling time)

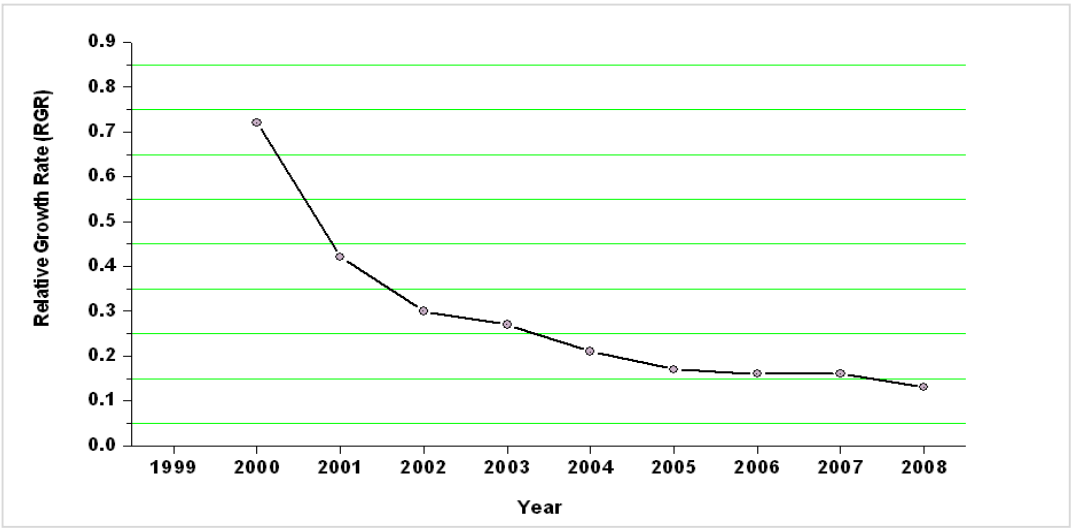

Figure 3: Relative Growth Rate for Research Output in Materials Science in India

Figure 4: Doubling Time for Research Output in Materials Science in India

Distribution of Publications and Citations in Materials Science Sub-domains

Table 3 gives the domain-wise distribution of the publications and citations. Materials-multidisciplinary discipline accounts for the largest share (13505, 90.95%) of publications in the total country output in materials science which received highest number of citations (88147, 93.17%) followed by ceramics with 819 (5.52%) publications and 5190 (5.49%) citations, materials characterization with 334 (2.25%) publications and 697 (0.74) citations and materials composites with 132 (0.89%) publications and 289 (0.31%) citations.

Table 3: Distribution of Publications and Citations in Materials Science Sub-domains

Sub-domains	TP	% of	TC	% of TC	TIF
Ceramics	819	5.52	5190	5.49	975.55
Coatings & Films	59	0.40	287	0.30	36.07
Composites	132	0.89	289	0.31	81.17
Materials Characterization	334	2.25	697	0.74	140.21
Materials-Multidisciplinary	13505	90.95	88147	93.17	17458.62
Total	14849	100.00	94610	100.00	18691.62

(TP=Total Number of Publications; TC=Total Number of Citations; TIF=Total Impact Factor)

Activity Index in Materials Science Sub-domains

The Activity Index (AI) characterizes the relative research efforts of a country in a given subject. On analysing the growth and decline in publication productivity using normalized AI (Karki, Garg, and Sharma 2000), it was observed that the highest AI in various materials science sub-domains were: ceramics (123.47) in 2007, coatings & films (149.12) in 2002, composites (221.65) in 2000, materials characterization (153.57) in 2008 and materials-multidisciplinary (103.68) in 2004 as presented in Figure 5.

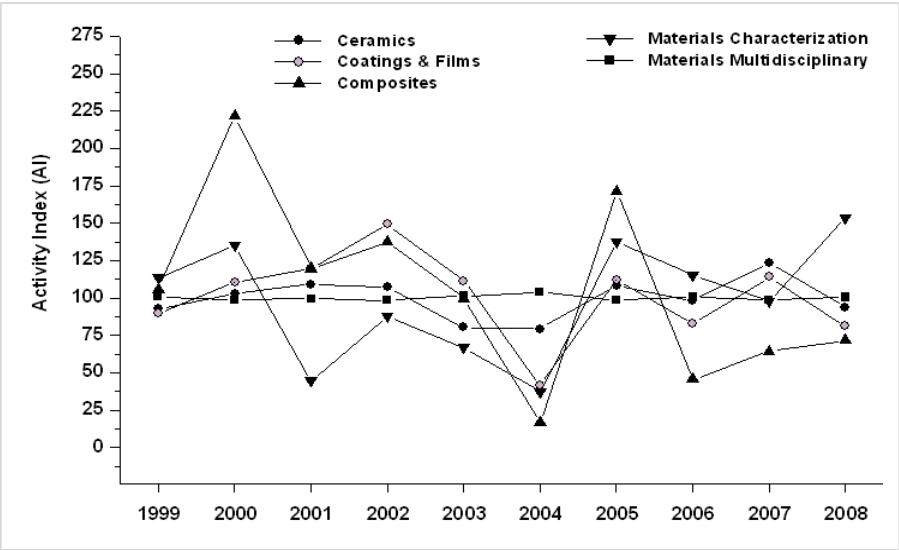

Figure 5: Activity Index (AI) in Materials Science Sub-domains during 1999-2008

Nature of Collaboration

Collaboration Pattern and Citations

Research is becoming more and more collaborative in recent years when compared to earlier years as most countries are giving a lot of impetus to research and development activities. The major impact of collaboration on scholarly research is the increase in productivity associated with multiple authorship (Beaver 1978, 1979a, 1979b). Publications of materials science have been divided into four categories according to number of authors (Figure 6). They are: single-authored with 698 (4.70%) publications which received 3784 (4.00%) citations, two-authored with 3896 (26.24%) publications which received 24966 (26.39%) citations, multi-authored publications (three to four authors) with 7452 (50.19%) publications which received 47074 (49.76%) citations, and mega-authored publications (five or more authors) with 2803 (18.88%) publications which received 18786 (19.86%) citations. It is observed that the papers have as many as 16 authors in the byline (Table 4) which indicates the intensive collaborative research in this field.

Domain-wise Collaboration

The collaboration trend in various domains with respect to national and international collaborative publications is given in Table 5 and Table 6. The materials-multidisciplinary sub-domain witnessed the highest number (10880) of collaborative publications published with Indian scientists, followed by ceramics with 667 publications, and materials characterization with 265 publications. A similar trend was also observed in the international collaborative publications.

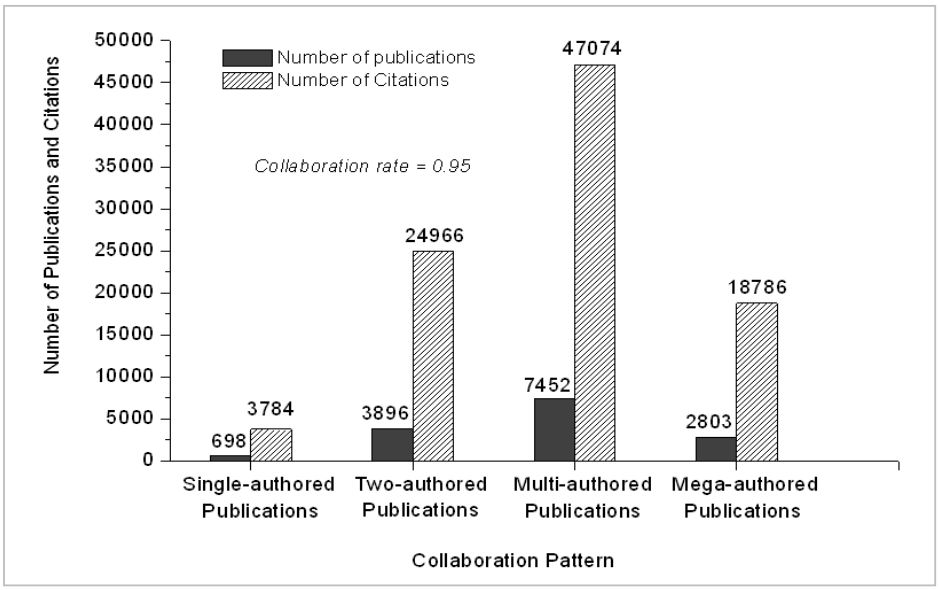

Figure 6: Collaboration Pattern in Materials Science Research in India during 1999-2008

Table 4: Publications Productivity and Citations of Materials Science Research in India as per Author(s) in By-line

Author (s) in By-line	TP	% of TP	TC	% of TC	TIF	% of TIF
1	698	4.70	3784	4.00	730.20	3.91
2	3896	26.24	24966	26.39	4825.59	25.82
3	4444	29.93	27392	28.95	5304.88	28.38
4	3008	20.26	19682	20.80	3811.21	20.39
5	1598	10.76	10260	10.84	2166.96	11.59
6	701	4.72	4667	4.93	1043.44	5.58
7	321	2.16	2336	2.47	499.32	2.67
8	104	0.70	850	0.90	173.29	0.93
9	44	0.30	347	0.37	72.28	0.39
10	14	0.09	57	0.06	22.54	0.12
11	8	0.05	155	0.16	24.52	0.13
12	8	0.05	91	0.10	11.18	0.06
13	2	0.01	8	0.01	2.32	0.01
14	1	0.01	8	0.01	0.93	0.00
16	2	0.01	7	0.01	2.97	0.02
Total	14849	100.00	94610	100.00	18691.63	100.00

(TP=Total Number of Publications; TC=Total Number of Citations; TIF=Total Impact Factor)

Table 5: National Collaboration in Materials Science Sub-domains

Sub-domains	National Collaboration						
	TCP	% of TCP	TC	% of TC	ACP	TIF	AIF
Ceramics	667	4.49	4065	4.30	6.09	781.08	1.17
Coatings & Films	47	0.32	221	0.23	4.70	28.44	0.61
Composites	102	0.69	255	0.27	2.50	61.49	0.60
Materials Characterization	265	1.78	503	0.53	1.90	110.36	0.42
Materials-Multidisciplinary	10880	73.27	67305	71.14	6.19	13361.1	1.23
Total	11961	80.5509	72349	76.4708	6.05	14342.4	1.20

(TCP=Total Number of Collaborative Publications; TC=Total Number of Citations; ACP=Average Citations per Publication; TIF=Total Impact Factor; AIF=Average Impact Factor per Publication)

Table 6: International Collaboration in Materials Science Sub-domains

Sub-domains	International Collaboration						
	TCP	% of TCP	TC	% of TC	ACP	TIF	AIF
Ceramics	123	0.83	1005	1.06	8.17	164.59	1.34
Coatings & Films	4	0.03	8	0.01	2.00	2.07	0.52
Composites	22	0.15	31	0.03	1.41	16.75	0.76
Materials Characterization	37	0.25	55	0.06	1.49	20.41	0.55
Materials-Multidisciplinary	2004	13.50	17378	18.37	8.67	3415.18	1.70
Total	2190	14.75	18477	19.53	8.44	3619.00	1.65

(TCP=Total Number of Collaborative Publications; TC=Total Number of Citations; ACP=Average Citations per Publication; TIF=Total Impact Factor; AIF=Average Impact Factor per Publication)

International Collaboration

In recent years, more countries have realised the importance of collaborative research to tackle many scientific problems resulting in many international collaborations. There were 2190 international collaborative publications with 59 countries. Table 7 provides the international collaboration pattern with Indian institutions in materials science with regards to publications, citations and impact. Indian institutions has the highest number of collaborative publications with countries such as the United States (Figure 7a), Germany (Figure 7b), Japan (Figure 7c), and South Korea (Figure 7d).

Table 7: International Collaboration with India in Materials Science Publications during 1999-2008

Collaboration Rank	Country	TCP	TC	ACP	Citation Index	TIF
1	United States	499	6117	12.26	611.70	958.64
2	Germany	329	2914	8.86	291.40	537.15
3	Japan	239	2000	8.37	200.00	429.54
4	South Korea	187	1247	6.67	138.56	293.36
5	United Kingdom	143	947	6.62	94.70	232.74
6	France	121	1020	8.43	102.00	233.72
7	Taiwan	73	392	5.37	43.56	122.25
8	Australia	59	433	7.34	48.11	66.18
9	Singapore	50	396	7.92	39.60	56.35
10	Canada	43	260	6.05	26.00	45.57
11	Italy	41	247	6.02	24.70	65.47
12	Netherlands	36	271	7.53	30.11	73.95
13	Sweden	35	220	6.29	24.44	65.34
14	China	33	206	6.24	25.75	41.03
15	Belgium	31	458	14.77	57.25	43.00
16	Portugal	30	92	3.07	15.33	35.42
17	Brazil	29	187	6.45	20.78	50.28
18	Russian Federation	24	92	3.83	10.22	27.85
19	Malaysia	20	109	5.45	12.11	20.73
20	Israel	15	148	9.87	18.50	31.75
21	Mexico	14	69	4.93	17.25	20.49
22	Poland	12	31	2.58	5.17	10.97
22	Spain	12	283	23.58	40.43	21.23
22	Switzerland	12	129	10.75	18.43	18.97
23	Austria	11	52	4.73	7.43	12.51
24	Finland	10	50	5.00	12.50	12.98
25	South Africa	9	14	1.56	3.50	9.09
26	Bangladesh	7	26	3.71	5.20	7.10
26	Iran	7	40	5.71	10.00	8.33
27	Bulgaria	6	71	11.83	23.67	8.87
28	Chile	5	11	2.20	5.50	9.78
28	Nigeria	5	91	18.20	18.20	5.90
28	Puerto Rico	5	21	4.20	7.00	6.13
29	Egypt	4	14	3.50	3.50	5.34
29	Hong Kong	4	46	11.50	11.50	3.78
29	Ireland	4	13	3.25	6.50	4.45
30	Czech Republic	3	25	8.33	12.50	9.53
30	Hungary	3	11	3.67	3.67	3.33
30	Norway	3	45	15.00	22.50	2.91
30	Slovakia	3	13	4.33	4.33	3.84
30	Slovenia	3	22	7.33	7.33	5.17
30	Thailand	3	13	4.33	6.50	7.56
30	Turkey	3	7	2.33	2.33	3.95
31	Denmark	2	13	6.50	6.50	5.42
31	Iraq	2	1	0.50	0.50	1.22
31	Nepal	2	22	11.00	11.00	1.92
31	New Zealand	2	12	6.00	6.00	1.20
31	Ukraine	2	9	4.50	4.50	2.91
31	Uzbekistan	2	22	11.00	11.00	3.12
32	Algeria	1	18	18.00	18.00	1.14

Collaboration Rank	Country	TCP	TC	ACP	Citation Index	TIF
32	Bhutan	1	3	3.00	3.00	1.63
32	Ethiopia	1	2	2.00	2.00	0.82
32	Greece	1	9	9.00	9.00	0.84
32	Indonesia	1	2	2.00	2.00	3.62
32	Oman	1	0	0.00	0.00	0.00
32	Romania	1	0	0.00	0.00	0.66
32	Tunisia	1	0	0.00	0.00	0.00
32	United Arab Emirates	1	0	0.00	0.00	0.00
32	Yugoslavia	1	7	7.00	7.00	1.87
Total (59 Countries)		2207	18973	8.59673765	1897.3	3658.90

(TCP=Total Number of Collaborative Publications; TC=Total Number of Citations; TIF=Total Impact Factor)

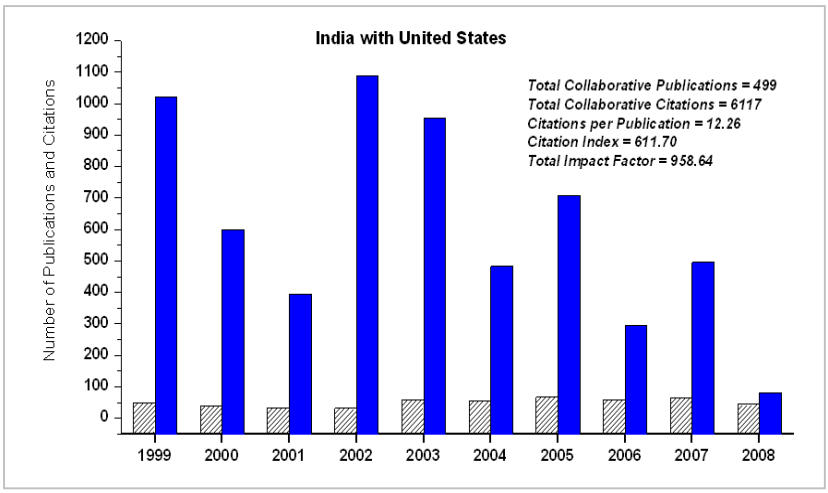

Figure 7a: Year-wise Collaboration Trend of Publications and Citations with United States

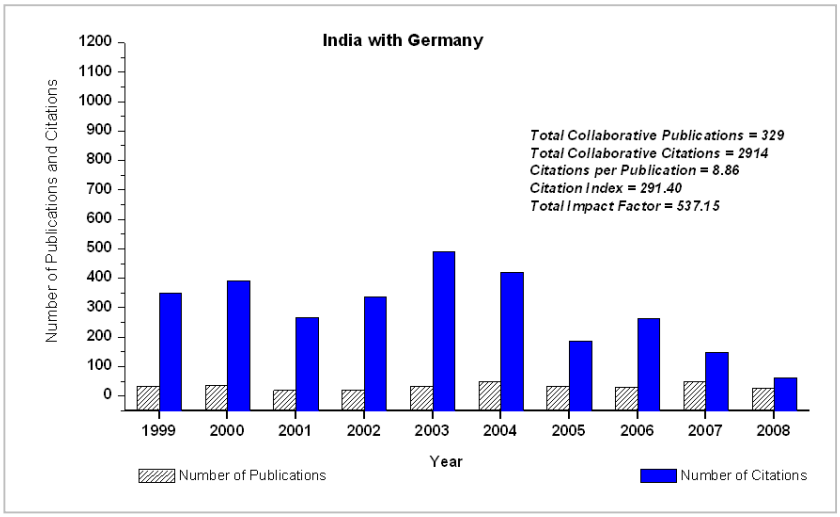

Figure 7b: Year-wise Collaboration Trend of Publications and Citations with Germany

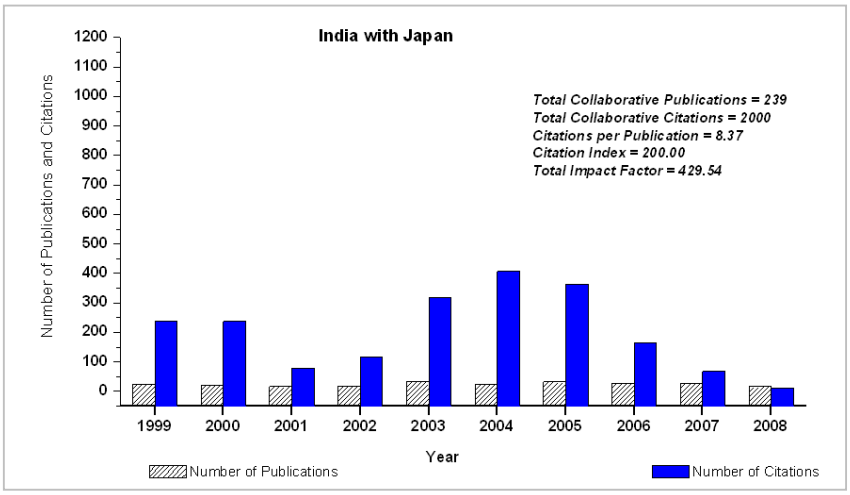

Figure 7c: Year-wise Collaboration Trend of Publications and Citations with Japan

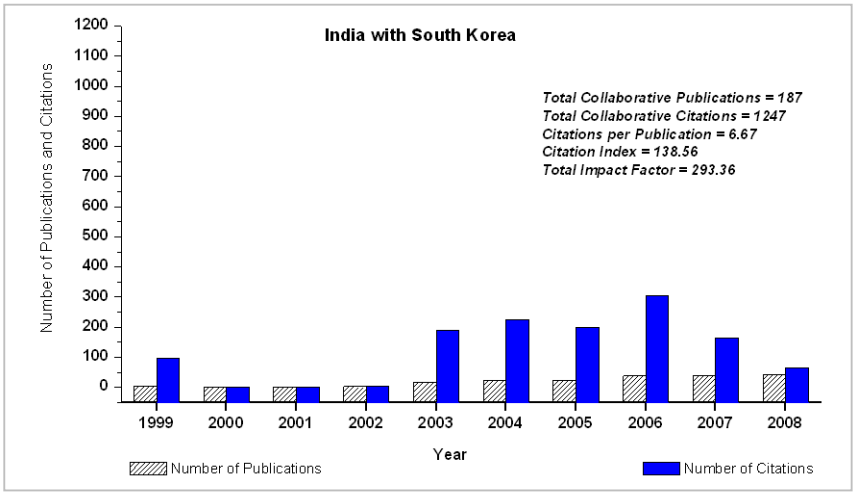

Figure 7d: Year-wise Collaboration Trend of Publications and Citations with South Korea

Highly Productive Indian Institutions in Materials Science

Table 8 provides the list of highly productive Indian institutions based on number of publications and citations in materials science. Indian Institute of Technology-Kharagpur topped the list with 1243 publications, which received 7985 citations, followed by Indian Institute of Science-Bengaluru (with 1052 publications and 8816 citations), Bhabha Atomic Research Centre-Mumbai (with 818 publications and 4252 citations), Indira Gandhi Centre for Atomic Research-Kalpakkam (with 641 publications and 3146 citations) and Indian Institute of Technology Madras-Chennai (with 629 publications and 3206 citations).

Table 8: Highly Productive Institutes in India based on Publications in Materials Science

No.	Institutions	TP	TC	ACP	CI	TIF	AIF
1	Indian Institute of Technology-Kharagpur	1243	7985	6.42	798.50	1364.10	1.10
2	Indian Institute of Science-Bengaluru	1052	8816	8.38	881.60	1672.00	1.59
3	Bhabha Atomic Research Centre-Mumbai	818	4252	5.20	425.20	1130.20	1.38
4	Indira Gandhi Centre for Atomic Research-Kalpakkam	641	3146	4.91	314.60	733.31	1.14
5	Indian Institute of Technology Madras-Chennai	629	3206	5.10	320.60	738.70	1.17
6	Indian Institute of Technology-Kanpur	593	3148	5.31	314.80	682.05	1.15
7	Indian Institute of Technology-Delhi	517	2801	5.42	280.10	604.55	1.17
8	Indian Institute of Technology Bombay-Mumbai	456	2302	5.05	230.20	501.15	1.10
9	Defence Metallurgical Research Laboratory-Hyderabad	436	2249	5.16	224.90	491.02	1.13
10	Anna University-Chennai	395	2276	5.76	227.60	493.78	1.25
11	Banaras Hindu University-Varanasi	351	1453	4.14	145.30	364.10	1.04
12	Central Glass and Ceramic Research Institute-Kolkata	331	2375	7.18	237.50	407.40	1.23
13	Indian Association for the Cultivation of Science-Kolkata	296	2440	8.24	244.00	539.71	1.82
14	Regional Research Laboratory (CSIR)-Trivandrum	295	2548	8.64	254.80	489.18	1.66
15	Mahatma Gandhi University-Kottayam	249	1705	6.85	170.50	294.97	1.18
16	Shivaji University-Kolhapur	247	2535	10.26	253.50	361.44	1.46
17	Indian Institute of Technology-Roorkee	246	1050	4.27	105.00	240.08	0.98
18	Central Electrochemical and Research Institute-Karaikudi	203	1085	5.34	108.50	253.67	1.25
19	National Physical Laboratory (CSIR)-New Delhi	194	971	5.01	97.10	267.90	1.38
20	Vikram Sarabhai Space Centre-Thiruvananthapuram	171	1010	5.91	101.00	178.14	1.04
21	Central Leather Research Institute-Chennai	152	921	6.06	92.10	203.85	1.34
22	Alagappa University-Karaikudi	151	919	6.09	91.90	202.63	1.34
23	Jadavpur University-Kolkata	151	673	4.46	67.30	143.01	0.95
24	Indian Institute of Chemical Technology-Hyderabad	149	1166	7.83	116.60	217.81	1.46
25	Osmania University-Hyderabad	148	821	5.55	82.10	176.70	1.19
26	University of Delhi- Delhi	141	663	4.70	66.30	170.52	1.21
27	Mumbai University-Mumbai	136	762	5.60	76.20	127.46	0.94
28	Jawaharlal Nehru Centre for Adv. Sci. Res.-Bengaluru	128	2198	17.17	219.80	287.38	2.25
29	Sri Venkateswara University-Tirupati	123	745	6.06	74.50	179.01	1.46
30	Sardar Patel University-Vallabh Vidyanagar	113	449	3.97	44.90	118.25	1.05
31	Regional Research Laboratory (CSIR)-Bhopal	112	522	4.66	52.20	94.45	0.84
32	Regional Research Laboratory (CSIR)-Bhubaneswar	112	598	5.34	59.80	108.66	0.97
33	Cochin University of Science and Technology-Cochin	111	319	2.87	31.90	143.68	1.29
34	National Aerospace Laboratories (CSIR)-Bengaluru	110	686	6.24	68.60	104.60	0.95
35	University of Calcutta-Kolkata	108	740	6.85	74.00	118.44	1.10
36	Karnatak University-Dharwad	107	920	8.60	92.00	107.09	1.00

(TP=Total number of Publications; TC= Total number of Citations; ACP=Average Citations per Publication; CI= Citation Index; TIF=Total Impact Factor; AIF=Average Impact Factor per Publication)

Author Productivity

Table 9 provides the list of most productive and highly cited authors who have contributed in at least 30 publications in materials science during 1999-2008. The most prolific authors having more than 100 papers were: Thomas, S. with 144 publications, Bhowmick, A. K. with 129 publications, Raj, B. with 123 publications, and Tyagi, A. K. with 106 publications. The highly cited authors receiving more than 1000 citations were Rao, C. N. R. with 1643 citations, Bhowmick, A. K. with 1267 citations, and Thomas, S. with 1136 citations.

Table 9: Most Productive Authors in Materials Science during 1999-2008

Authors	Institutions	TP	TC	Citation Index	TIF
Thomas, S.	Mahatma Gandhi University, Kottayam, Kerala	144	1136	113.60	165.47
Bhowmick, A. K.	Indian Institute of Technology, Kharagpur	129	1267	126.70	134.64
Raj, B.	Indira Gandhi Centre for Atomic Research, Kalpakkam	123	662	66.20	141.02
Tyagi, A. K.	Bhabha Atomic Research Centre, Mumbai	106	682	68.20	150.23
Aminabhavi, T. M.	Karnatak University, Dharwad	95	852	85.20	96.00
Choudhary, R. N. P.	Indian Institute of Technology, Kharagpur	93	452	45.20	109.52
Balasubramaniam, R.	Indian Institute of Technology, Kanpur	86	561	56.10	110.12
Ravi, V.	National Chemical Laboratory, Pune	85	524	58.22	122.90
Mannan, S. L.	Indira Gandhi Centre for Atomic Research, Kalpakkam	83	336	33.60	60.34
Siddaramaiah	S. J. College of Engineering, Mysore	78	270	27.00	67.80
Chattopadhyay, K.	Indian Institute of Science, Bengaluru	73	578	57.80	120.32
Das, C. K.	Indian Institute of Technology, Kharagpur	72	254	28.22	76.19
Banerjee, S.	Bhabha Atomic Research Centre, Mumbai	70	493	49.30	119.21
Basu, B.	Indian Institute of Technology, Kanpur	69	573	81.86	111.32
Dey, G. K.	Bhabha Atomic Research Centre, Mumbai	66	354	35.40	101.11
Kishore	Indian Institute of Science, Bengaluru	62	410	41.00	72.09
Ninan, K. N.	Vikram Sarabhai Space Centre, Thiruvananthapuram	61	444	44.40	73.46
Jayakumar, T.	Indira Gandhi Centre for Atomic Research, Kalpakkam	61	295	29.50	68.89
Ravinder, D.	Osmania University, Hyderabad	59	337	37.44	86.28
Pramanik, P.	Indian Institute of Technology, Kharagpur	58	460	51.11	75.44
Rao, C. N. R.	Jawaharlal Nehru Center for Adv. Sci. Res, Bengaluru	57	1643	164.30	153.41
Prakash, S.	Indian Institute of Technology, Roorkee	57	166	20.75	48.15
Manna, I.	Indian Institute of Technology, Kharagpur	55	424	42.40	83.22
Bhanu Sankara Rao, K.	Indira Gandhi Centre for Atomic Research, Kalpakkam	55	202	20.20	40.15
Venugopal, V.	Bhabha Atomic Research Centre, Mumbai	53	139	13.90	81.28
Brar, A. S.	Indian Institute of Technology Delhi, New Delhi	51	240	30.00	87.96
Maiti, H. S.	Central Glass and Ceramic Research Institute, Kolkata	50	424	42.40	76.95
Pai, B. C.	Regional Research Laboratory (CSIR), Thiruvananthapuram	50	245	30.63	46.76

(TP=Total number of publications; TC=Total number of citations; Citation Index=Number of Citations divided by number of years since publications up to 2008; TIF=Total Impact Factor)

Preference of Journals for Publication by the Scientists

The distribution of 'Materials Science' publications were spread over 247 journals across the world. The leading journals preferred by the scientists were: *Journal of Applied Polymer Science* with 1637 publications which received 10574 citations, *Materials Letters* (with 900 publications and 5948 citations), *Bulletin of Materials Science* (with 848 publications and 3788 citations), *Materials Science and Engineering-A* (with 713 publications and 4848 citations), *Materials Chemistry and Physics* (with 662 publications

and 6434 citations) and *Journal of Alloys and Compounds* (with 537 publications and 2572 citations). Table 10 lists the highly preferred journals by the scientists in the field.

Table 10: Preference of journals for publication in Materials Science with Publications ≥50

No.	Journals	TP	% of TP	TC	ACP	TIF	AIF
1.	Journal of Applied Polymer Science	1637	11.02	10574	6.46	1650.10	1.01
2.	Materials Letters	900	6.06	5948	6.61	1462.50	1.63
3.	Bulletin of Materials Science	848	5.71	3788	4.47	511.34	0.60
4.	Materials Science and Engineering-A	713	4.80	4848	6.80	32.69	0.05
5.	Materials Chemistry and Physics	662	4.46	6434	9.72	1238.60	1.87
6.	Journal of Alloys and Compounds	537	3.62	2572	4.79	781.34	1.46
7.	Journal of Materials Processing Technology	400	2.69	2305	5.76	326.40	0.82
8.	Materials Research Bulletin	390	2.63	2879	7.38	0.00	0.00
9.	Transactions of the Indian Institute of Metals	304	2.05	223	0.73	27.06	0.09
10.	Journal of Materials Science	289	1.95	2113	7.31	11.70	0.04
11.	Journal of Reinforced Plastics and Composites	267	1.80	812	3.04	111.34	0.42
12.	Journal of Polymer Materials	240	1.62	474	1.98	89.52	0.37
13.	Journal of Non-Crystalline Solids	232	1.56	1371	5.91	306.01	1.32
14.	Journal of the American Ceramic Society	231	1.56	1599	6.92	413.95	1.79
15.	Scripta Materialia	220	1.48	1692	7.69	545.82	2.48
16.	Journal of Materials Science Letters	218	1.47	799	3.67	312.41	1.43
17.	Journal of Nuclear Materials	214	1.44	1048	4.90	351.60	1.64
18.	Ceramics International	205	1.38	1543	7.53	278.80	1.36
19.	Materials Science and Technology	203	1.37	740	3.65	0.00	0.00
20.	Metallurgical and Materials Transactions-A	203	1.37	941	4.64	259.43	1.28
21.	Polymer International	198	1.33	1580	7.98	308.29	1.56
22.	Journal of Polymer Science-A	192	1.29	1664	8.67	677.57	3.53
23.	Chemistry of Materials	178	1.20	4993	28.05	869.17	4.88
24.	Journal of Materials Research	178	1.20	1419	7.97	341.05	1.92
25.	Journal of Macromolecular Science-Pure and Applied Chemistry	161	1.08	700	4.35	122.20	0.76
26.	Synthetic Metals	152	1.02	1748	11.50	271.78	1.79
27.	ISIJ International	140	0.94	537	3.84	103.46	0.74
28.	Acta Materialia	132	0.89	2003	15.17	478.37	3.62
29.	Journal of Materials Engineering and Performance	130	0.88	294	2.26	38.74	0.30
30.	Optical Materials	127	0.86	921	7.25	192.91	1.52
31.	Macromolecules	117	0.79	2261	19.32	516.09	4.41
32.	Ironmaking and Steelmaking	100	0.67	264	2.64	43.80	0.44
33.	Journal of the European Ceramic Society	100	0.67	931	9.31	156.20	1.56
34.	Canadian Journal of Chemical Engineering	99	0.67	324	3.27	45.84	0.46
35.	Corrosion Science	99	0.67	975	9.85	33.36	0.34
36.	Smart Materials and Structures	96	0.65	595	6.20	0.00	0.00
37.	Journal of Polymer Science-B	93	0.63	1030	11.08	141.73	1.52
38.	Materials Characterization	87	0.59	433	4.98	81.08	0.93
39.	Metallurgical and Materials Transactions-B	87	0.59	332	3.82	54.03	0.62
40.	Science and Technology of Welding and Joining	86	0.58	339	3.94	88.58	1.03
41.	Chemical Engineering Research and Design	81	0.55	397	4.90	67.80	0.84
42.	Solid State Sciences	79	0.53	557	7.05	134.14	1.70
43.	Journal of Macromolecular Science-A	78	0.53	96	1.23	59.20	0.76
44.	Polymer Composites	77	0.52	357	4.64	81.47	1.06

No.	Journals	TP	% of TP	TC	ACP	TIF	AIF
45.	Polymers for Advanced Technologies	75	0.51	313	4.17	112.80	1.50
46.	Anti-Corrosion Methods and Materials	68	0.46	242	3.56	24.55	0.36
47.	Carbon	67	0.45	992	14.81	285.42	4.26
48.	Designed Monomers and Polymers	64	0.43	159	2.48	46.85	0.73
49.	Polymers and Polymer Composites	64	0.43	134	2.09	26.88	0.42
50.	Zeitschrift fuer Metallkunde	62	0.42	206	3.32	53.13	0.86
51.	Measurement Science and Technology	60	0.40	275	4.58	77.82	1.30
52.	Iranian Polymer Journal	56	0.38	157	2.80	32.09	0.57
53.	Journal of Polymer Research	56	0.38	167	2.98	47.15	0.84
54.	Journal of Testing and Evaluation	56	0.38	83	1.48	12.94	0.23
55.	Polymer-Plastics Technology and Engineering	56	0.38	267	4.77	19.15	0.34
56.	Rubber Chemistry and Technology	55	0.37	360	6.55	46.37	0.84
57.	Advanced Materials	54	0.36	2175	40.28	0.53	0.01
58.	Intermetallics	54	0.36	452	8.37	119.83	2.22
59.	Journal of the Institution of Engineers (India)-MM	50	0.34	34	0.68	0.00	0.00

(TP=Total number of publications; TC=Total number of citations; TIF=Total Impact Factor; ACP=Average citations per publication; AIF=Average Impact Factor per publications)

Impact Factor-wise Distribution of Publications and Citations

Table 11 gives the impact factor-wise distribution of publications and citations. A total of 93.24 percent (13845) of the publications were published in the journals with IF ranging from 0.001 to 21.00 and received 92.22 percent (87245) citations, and 6.76 percent (1004) publications published in journals which are not covered by *JCR* 2008 and received 7.78 percent (7365) citations. A significantly large number of publications (54.04 percent, 8024) appeared in journals having IF 1.00 to <2.00, followed by 31.64 percent (4698) publications appeared in journal having IF 0.01 to <1.00, and 2.58 percent (383) of publications appeared in journals having IF 3.00 to <4.00. Table 12 provides the distribution of publications in terms of authorships.

Table 11: Distribution of Publications and Citations as per Impact Factor during 1999-2008

Impact Factor (*JCR* 2008)	Total no. of Journals	Number of Publications	% of Publications	Number of Citations	% of Citations
0.01 to < 1.00	98	4698	31.64	23524	24.86
1.00 to < 2.00	49	8024	54.04	45201	47.78
2.00 to < 3.00	2	274	1.85	2144	2.27
3.00 to < 4.00	5	383	2.58	4641	4.91
4.00 to < 5.00	5	367	2.47	8480	8.96
5.00 to < 21.00	6	99	0.67	3255	3.44
Not available	86	1004	6.76	7365	7.78
Total	251	14849	100.00	94610	100.00

Highly Cited Publications

Table 12 lists the highly cited materials science publications during 1999-2008. Murphy and Jana's paper entitled "Controlling the aspect ratio of inorganic nanorods and nanowires" which appeared in *Advanced Materials, 2002, Vol. 14 (1)* received the highest number (511) of citations followed by Rao et al.'s "Inorganic nanowires" published in *Progress in Solid State Chemistry, 2003, Vol. 31* with 364 citations, and Gangopadhyay's "Conducting polymer nanocomposites: A brief overview" in *Chemistry of Materials, 2000, Vol. 12 (3)* with 345 citations.

Table 12: Top Twenty Highly Cited Publications in Materials Science during 1999-2008

No	Bibliographic Details	Times Cited
1.	Murphy, C.J; Jana, N.R. Controlling the aspect ratio of inorganic nanorods and nanowires *Advanced Materials. 2002. Vol. 14 (1): pp. 80-82*	511
2.	Rao, C.N.R; Deepak, F.L; Gundiah, G; Govindaraj, A. Inorganic nanowires *Progress in Solid State Chemistry. 2003. Vol. 31: pp. 5-147*	364
3.	Gangopadhyay, R; De, A. Conducting polymer nanocomposites: A brief overview *Chemistry of Materials. 2000. Vol. 12 (3): pp. 608-622*	345
4.	Galgali, G; Ramesh, C; Lele, A. Rheological study on the kinetics of hybrid formation in polypropylene nanocomposites *Macromolecules. 2001. Vol. 34 (4): pp. 852-858*	288
5.	Rao, K.J; Vaidhyanathan, B; Ganguli, M; Ramakrishnan, P.A. Synthesis of inorganic solids using microwaves *Chemistry of Materials. 1999. Vol. 11 (4): pp. 882-895*	254
6.	Britto, P.J; Santhanam, K.S.V; Rubio, A; Alonso, J.A; Ajayan, P.M. Improved charge transfer at carbon nanotube electrodes *Advanced Materials. 1999. Vol. 11 (2): pp. 154-157*	248
7.	Mane, R.S; Lokhande, C.D. Chemical deposition method for metal chalcogenide thin films *Materials Chemistry and Physics. 2000. Vol. 65 (1): pp. 1-31*	209
8.	Adhikari, B; Majumdar, S. Polymers in sensor applications *Progress in Polymer Science. 2004. Vol. 29 (7): pp. 699-766*	203
9.	Biswas, M; Ray, S.S. Recent progress in synthesis and evaluation of polymer-montmorillonite nanocomposites *Advances in Polymer Science. 2001. Vol. 155: pp. 167-221*	195
10.	Schuh, C.A; Hufnagel, T.C; Ramamurty, U. Mechanical behavior of amorphous alloys *Acta Materialia. 2007. Vol. 55 (12): pp. 4067-4109*	195
11.	Somani, P.R; Radhakrishnan, S. Electrochromic materials and devices: Present and future *Materials Chemistry and Physics. 2003. Vol. 77 (1): pp. 117-133*	160
12.	Wang, S.X; Begg, B.D; Wang, L.M; Ewing, R.C; Weber, W.J; Govidan, Kutty, K.V. Radiation stability of gadolinium zirconate: A waste form for plutonium disposition *Journal of Materials Research. 1999. Vol. 14 (12): pp. 4470-4473*	158
13.	Therese, G.H.A; Kamath, P.V. Electrochemical synthesis of metal oxides and hydroxides *Chemistry of Materials. 2000. Vol. 12 (5): pp. 1195-1204*	158
14.	Patil, K.C; Aruna, S.T; Mimani, T. Combustion synthesis: An update *Current Opinion in Solid State and Materials Science. 2002. Vol. 6 (6): pp. 507-512*	154
15.	Nanda, J; Sapra, S; Sarma, D.D; Chandrasekharan, N; Hodes, G. Size-selected zinc sulfide nanocrystallites: Synthesis, structure, and optical studies *Chemistry of Materials. 2000. Vol. 12 (4): pp. 1018-1024*	153
16.	Govindaraj, A; Satishkumar, B.C; Nath, M; Rao, C.N.R. Metal nanowires and intercalated metal layers in single-walled carbon nanotube bundles *Chemistry of Materials. 2000. Vol. 12 (1): pp. 202-205*	151
17.	Liu, B.Y.H; Yoo, S.-H; Chae, S.-K; Sun, J.J; Christenson, K; Butterbaugh, J; Weygand, J.F; Narayanswami, N. Evaluating wafer inspection and cleaning with standard particles *Semiconductor International. 2000. Vol. 23 (6): pp. 145-146*	150

No	Bibliographic Details	Times Cited
18.	Nath M., Govindaraj A., Rao C.N.R. Simple synthesis of MoS2 and WS2 nanotubes. 2001. *Advanced Materials*. Vol. 13 (4): pp. 283-286	140
19.	Patil P.S. Versatility of chemical spray pyrolysis technique. 1999. *Materials Chemistry and Physics*. Vol. 59 (3): pp. 185-198	133
20.	Welsh D.M., Kumar A., Meijer E.W., Reynolds J.R. Enhanced contrast ratios and rapid switching in electrochromics based on poly(3,4-propylenedioxythiophene) derivatives. 1999. *Advanced Materials*. Vol. 11 (16): pp. 1379-1382	121

CONCLUSION

The present study analyses the materials science publications in India for the period 1999-2008 based on the *Scopus database.* A total of 14849 publications were published by the Indian Scientists in materials science during 1999-2008 which received 94610 citations. The average number of publications per year was 1484.90. The average number of citations per publication was 6.37. The highest number of publications 1953 was published in 2007 and the highest number of citations 12901 was received in 2003. The mean relative growth rate of publications in materials science decreased from 0.34 during 1999-2003 to 0.17 during 2004-2008. The doubling time of publications increased from 1.51 during 1999-2003 to 4.30 during 2004-2008 indicating the declining trend of publications in Indian materials science research.

Materials-multidisciplinary sciences sub-domain accounts for the largest share (13505, 90.95%) from the total output in the country in materials science and received the highest number of citations (88147, 93.17%) followed by ceramics, materials characterization and materials composites. The highest AI in various subject categories was: ceramics (123.47) in 2007, coatings & films (149.12) in 2002, composites (221.65) in 2000, materials characterization (153.57) in 2008 and materials-multidisciplinary (103.68) in 2004. There were 11961(80.55%) national collaborative publications and 2190 (14.75%) international collaborative publications by the Indian scientists with 59 countries. Indian institutions had more number of collaborative publications with the following countries: the United States, Germany, Japan, South Korea, France and United Kingdom.

Among the research institutions, Indian Institute of Technology-Kharagpur topped the list with 1243 publications (which received 7985 citations) followed by Indian Institute of Science-Bengaluru, Bhabha Atomic Research Centre-Mumbai, Indira Gandhi Centre for Atomic Research-Kalpakkam and Indian Institute of Technology Madras-Chennai. The leading journals preferred by the scientists were: *Journal of Applied Polymer Science* with 1637 publications, *Materials Letters* with 900 publications, *Bulletin of Materials Science* with 848 publications, and *Materials Science and Engineering-A* with 713 publications. A significantly large number of publications have been published in journals having impact factor 1.00 to <2.00.

Scientometric studies enable the science policy makers and administrators to understand and grasp the growth, development and impact of research and to know the countries, institutions and the individual scientists who are active in a particular field of research activity. These studies will also provide some insights into the dynamics of research activity and enable one to gauge the direction of research activity and take appropriate measures.

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