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A bibliometric study of semiconductor literature, 1978-1997

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Semiconductor is the key element for information industry.The present study investigated the growth of semiconductor literature based on the database of INSPEC. Well-established bibliometric techniques, such as Bradford-Zipf's plot and Lotka's law have been employed to further explore the characteristics of semiconductor literature. Quantitative results on the literature growth, form of publication, research treatment, publishing country and language, author productivity and affiliate are reported. Moreover, from the Bradford-Zipf's plot, 25 core journals in semiconductor were identified and analyzed.

Introduction

Semiconductor is the key element for information industry. Research and development of semiconductor has grown very rapidly in recent decades and become increasingly important for the economic growth of a developing or developed country. As a reflection, the semiconductor literature has also grown rapidly, though diversified as well. This study investigates the characteristics of semiconductor literature and its implication during 1978 to 1997 by bibliometric techniques. A bibliometric technique is a simple statistical method of bibliography counting to evaluate and quantify the growth of a subject.

In this paper, database of Information Service for the Physics and Engineering, INSPEC,[1] which is produced by the Institution of Electrical Engineers (IEE), was used to retrieve data from 1978 to 1997 through OVID for this study. Although, other databases such as Applied Science and Technology ABS, Compendex, EngIndex/FS, can also be employed, INSPEC was selected because it is recognized as the leading English-language supplier of services providing access to the published information in the fields of computers and control, physics, electrical and electronics engineering.

The INSPEC database currently contains records for over six million scientific and technical papers through 60 countries. Generally, each record in the INSPEC database

0138–9130/2000/US $ 15.00

contains an English-language title and descriptive abstract, together with full bibliographic information. The bibliographic information include the journal or other publication title, the authors' name and affiliation, document type, treatment code, the language of the original document, etc. Document types indexed included books and monographs, conferences, symposia, meetings, journal articles, reports, theses and dissertations. The treatment codes indicate the particular aspects of a subject which are treated in the document or specify the approach taken in a document. It includes applications, bibliographic, economic aspects/market survey, experimental, general review, new developments, practical, product review and theoretical, etc.

In this study, the search command **semiconductor?. de.** was used to retrieve "semiconductor" or "semiconductors" which appear in the descriptor field of the INSPEC database. The descriptor field utilizes controlled vocabulary from the INSPEC Thesaurus. As indicated by *Lancaster*,[2] a controlled vocabulary would control the synonym, nearly synonyms, homographs and related terms; therefore, the search **semiconductor?.de** would retrieve items with semiconductor as its synonyms, nearly synonyms, homographs and related terms, such as condensed matter. The INSPEC tends to include broad descriptive terms, such as "semiconductor" or "semiconductors" in its indexing, and hence the strategy used in this study would be expected to retrieve most of the papers on semiconductors. Each relevant record was then downloaded to floppy disc. Care has been exercised to examine the data collected to assure their identity. Subsequently, the data were analyzed by Visual FoxPro and Excel. By application of bibliometric techniques, especially Bradford's law and Lotka's law, the results of this study were interpreted.

The objectives of this study are: (1) to explore the growth of semiconductor literature published; (2) to determine a nucleus of primary journals that contain a substantial portion of journal literature on semiconductor; (3) to find the productivity distribution of authors and their institutions on this subject; (4) to identify major contributing countries that publish semiconductor articles most; (5) to find the dispersion of kinds of language and document types of the literature on semiconductor.

The growth of semiconductor literature published

As indicated by *Hawkins*,[3] the semiconductor research and development began in the late 1940's. He also surveyed the semiconductor journals by analyzing bibliographic data of semiconductor from 1970 through April 1975 that were available on the DIALOG system.

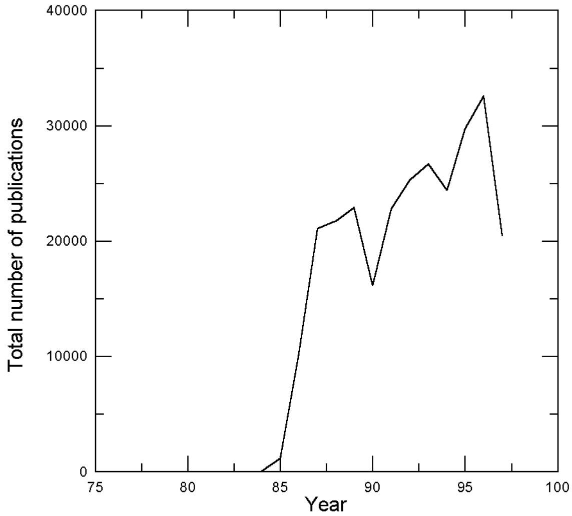

Fig. 1. Annual production of the semiconductor literature

Table 1
Annual production of the semiconductor literature

Document type Year	Journal	Conf. paper	Conf. procd.	Book chapter	Book	Report	Disser-tation	Report micro-fiche	Total	Cumulate
1978	0					3			3	3
1980	0					1			1	4
1983	2					0			2	6
1984	52					0			52	58
1985	521	613	9	30	3	1	3	2	1182	1240
1986	6787	3321	74	69	14	14	9	2	10290	11530
1987	14109	6673	131	114	16	18	7	2	21070	32600
1988	14946	6574	122	69	27	21	11	2	21772	54372
1989	16571	6137	139	62	20	14	7		22950	77322
1990	10740	5250	109	11	19	18	3		16150	93472
1991	15116	7425	164	52	18	15	5		22795	116267
1992	17282	7841	159	3	13	21	10		25329	141596
1993	18259	8247	149	30	5	8	0		26698	168294
1994	17928	6352	127	1	6	0	1		24415	192709
1995	17889	11668	179	1	19	20	4		29780	222489
1996	19517	12846	185	30	13	18	2		32611	255100
1997	14514	5860	95	0	3	2	0		20474	275574
Total	184233	88807	1642	472	176	174	62	8	275574	

In fact, the INSPEC begins its collection in 1978. Therefore, in this study, the INSPEC contains 275,574 items on semiconductor from 1978 to 1997. Table 1 shows the distribution of document type and the number of literature published each year. The table clearly indicates that before 1984, INSPEC contains only 6 items on semiconductor literature. This shows that the collections in INSPEC may not be comprehensive for the beginning stage of its collection. The year 1984 was the year of significant publication in semiconductor based on the INSPEC. It contains 52 items for that year. It was increased to 1182 items for the next year and sharply increased to 10290 items in 1986. The number reached a maximum in 1989, at which 22950 articles were published. There was a decrease in literature production in 1990. The literature published was steadily increased from 1991 to 1996, except the year of 1994. In 1996, the articles produced was as high as 32611 and is the maximum value during the study period and then the publications dropped to 20474 in 1997. Figure 1 illustrates the annual production of semiconductor literature. The figure clearly demonstrates the decrease in 1990, 1994 and 1997. This may be attributed to the recession in semiconductor production having taken place in the previous year.

The growth of semiconductor literature based on the INSPEC is shown in Fig. 2. Again, the paper selection of semiconductor literature in the INSPEC starts growing in 1984. After the year 1986, the literature grows approximately linearly with a growth rate of about 23000 items per year. The study of *Tabab*[4] also illustrates an approximately linear growth for the superconductivity literature in journal articles from year 1977 to 1986.

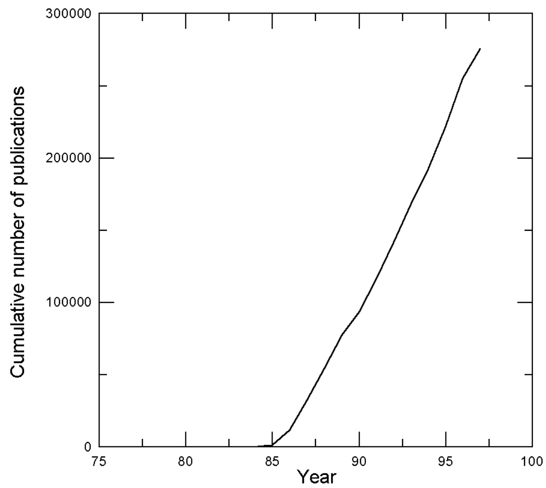

Fig. 2. Cumulative growth of the semiconductor literature

Some characteristics of semiconductor literature

Table 2 illustrates the distribution of document type in semiconductor literature. As in common in many fields, the single most prevalent form of publication is the journal article, which contributes 66.85% of the total literature. It is interesting to note that 32.82% of total literature are covered in conference/symposia documents. Proceedings of conferences are seemed to becoming more and more important specially for a newly growing subject. Such communication channel is more effective and speedier, though restricted only to participating scientists of the conferences, than publication of ideas in primary journals. Books, technical reports and theses make up the remaining 0.33%. Most of document type in semiconductor that collected in the INSPEC is in the form of journal articles or conference proceedings, constituting 99.7% of the total literature, indicating that semiconductor study extremely emphasizes timeliness and originality. On the other hand, this also reflects the collection policy of the INSPEC. The major source materials for the INSPEC database are scientific and technical journals and conferences publications published throughout the world in a wide range of languages. It covers 4100 journals and some 2000 published conference proceedings, as well as numerous books, reports and dissertations. Patents are not covered by the INSPEC after 1976.

Table 2
Distribution of document types literature in semiconductor

Document type	No. of articles	%	Cum.%
Journal	184233	66.85	66.85
Conference	90449	32.82	99.67
Book(including book chapter)	648	0.24	99.91
Technical report	182	0.07	99.98
Thesis	62	0.02	100.00
Total	275574	100.00	100.00

It is also of interest to explore the particular aspects of a subject, which are treated in the document in semiconductor. Table 3 exhibits the statistics. Since an individual article may take one or more approaches, the total number of approaches employed (320389) significantly greater than the total items of literature (275574). Table 3 clearly demonstrates that the experimental approach is employed most by the researchers in semiconductor subject. It accounts for about one half (49.87%). This is of no surprise.

Most of new technologies rely on experiments. The theoretical/mathematical and the practical are the second and the third most used approaches in semiconductor literature. They account for 17.3% and 17.1%, respectively. The articles with applications (7.2%) or general/review (6.0%) also have significant contributions on semiconductor literature. *Jain* and *Garg*[5] also found a similar distribution for world literature in laser research, on the average, the experimental approach of 41.6%, theoretical approach of 14.74% and 39.66% for application. The application part is much higher for laser literature.

Table 3
Statistics of approach applied in semiconductor literature

Approach	No. of articles	%	Cum.%
Experimental	159785	49.87	49.87
Theoretical/mathematical	55448	17.31	67.18
Practical	54760	17.09	84.27
Applications	22971	7.17	91.44
General or review	19197	5.99	97.43
New development	5702	1.78	99.21
Bibliography/literature survey	1884	0.59	99.80
Product review	411	0.13	99.93
Economic/commercial	231	0.07	100.00
Total	320389		100.00

There are 65 countries publish semiconductor literature. Table 4 provides country distribution of semiconductor literature. As expected and possibly the INSPEC is a British-based database, the USA is the predominant country that publishes literature in semiconductor. About 47% of the semiconductor literature were published in the USA. The rapid growth of semiconductor products in the USA and its impact on national economic policy clearly justify predominance of American contributions in semiconductor literature. The UK (12.2%) and the Netherlands (11.7%) contributes the second and third followed by Japan, Russia (previous USSR) and Switzerland each contributing more than 5% of the total literature. Germany, Singapore and China also have significant contribution on the publication of semiconductor literature. The involvement of scientists of so many countries in semiconductor research clearly suggests that semiconductor has been able to draw the attention of the whole world.

Table 4
Country distribution

Countries	Percent	Cum. %
USA	47.06	47.06
UK	12.15	59.21
Netherlands	11.74	70.95
Japan	6.01	76.96
USSR	5.60	82.56
Switzerland	5.05	87.61
Germany	3.44	91.05
Singapore	1.87	92.92
China	1.28	94.20
France	1.21	95.41
Others	4.59	100.00

Another interesting observation is the growing number of languages in which semiconductor literature is being communicated. Consistent with the countries of publication, English is the predominant language of articles on semiconductor. As shown in Table 5 English language articles constitute 95.93% of the total. There are only 4.07% non-English-language articles. Essentially, English is the only language for semiconductor literature. This may be due to the fact that the USA and the UK are the predominant countries of publication and the INSPEC is a British-based database. Moreover, English is the official language for most international conferences.

Table 5
Language distribution

Languages	Percent	Cum.%
English	95.93	95.93
Japanese	1.17	97.10
Chinese	1.00	98.10
Russian	0.45	98.55
Korean	0.45	99.00
German	0.34	99.34
French	0.32	99.66
Others	0.34	100.00

Bradford law and journal literature

As discussed previously, the journal article is the single most prevalent form of publication. In total, there are 1877 journals published 184233 semiconductor articles. Among them 438 journals publish only one article. The Bradford's law[6] has been widely employed to study journal literature distribution. Figure 3 illustrates the Bradford-Zipf plot – the cumulative number of papers for each journal against the logarithm of its ranks – for journal literature of semiconductor. Clearly, the figure demonstrates approximately the S-shape as the typical Bradford-Zipf plot,[7] though the initial rise is somewhat faster than the typical one. The approximately linear portion appears after the journal rank of about 25. The top 25 journals may be considered as the core journals in semiconductor literature. Table 6 provides the ranking list of journals and number of articles published by these journals. In order to avoid making the ranking table too long, 1000 articles were taken as the cut off number. Thus, Table 6 lists 37 titles which have at least published 1000 articles on semiconductor. Comparing Table 6 and Fig. 3 clearly indicates that the discontinuity of slope in the curve suggests that there is sharp drop in the number of articles contributed by the next journal. For example, the ranked 25 journal contributes 1885 articles which is significantly larger than the next ranked journal (1603).

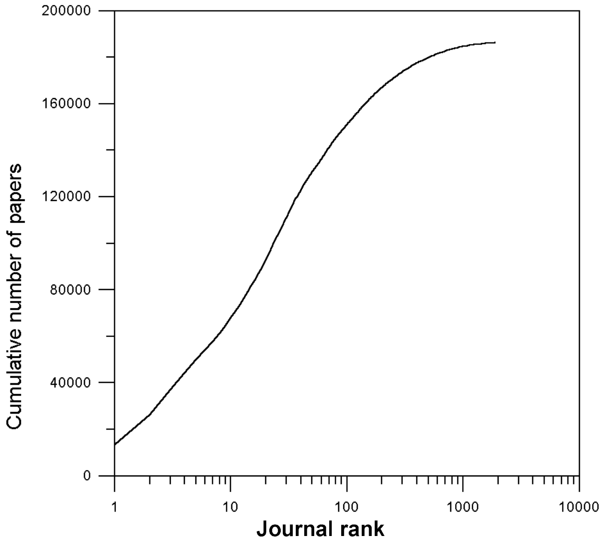

Fig. 3. The Bradford-Zipf plot of semiconductor journal literature

Table 6
Journals publishing more than 1000 articles

Rank	Journal	No. of articles	Cum. No.	Cum. %
1	*Applied Physics Letters*	13403	13403	7.19
2	*Physical Review B. Condensed Matter*	12771	26174	14.04
3	*Journal of Applied Physics*	10905	37079	19.89
4	*Proceedings of SPIE*	7194	44273	23.75
5	*Journal of Crystal Growth*	5756	50029	26.84
6	*Electronics Letters*	4113	54142	29.05
7	*Japanese Journal of Applied Physics. Part 1*	3654	57796	31.0
8	*IEEE. Transactions on Electron Devices*	3383	61179	32.82
9	*Surface Science*	3351	64530	34.62
10	*Journal of Vacuum Science and Technology. B. Micro-Electronics Processing and Phenomena*	3294	67824	36.39
11	*Semiconductor Science and Technology*	3047	70871	38.02
12	*Solid State Communications*	2949	73820	39.60
13	*Solid State Electronics*	2697	76517	41.05
14	*Soviet Physics. Semiconductors*	2618	79135	42.45
15	*Thin Solid Films*	2484	81619	43.79
16	*Japanese Journal of Applied Physics. Part 2. Letters*	2438	84057	45.09
17	*Journal of the Electrochemical Society*	2266	86323	46.31
18	*Physical Review Letters*	2252	88575	47.52
19	*Applications of Surface Science*	2225	90800	48.71
20	*Nuclear Instruments and Methods in Physics Research. B. Beam Interactions with Materials and Atoms*	2194	92994	49.89
21	*Physica Status Solidi. A. Applied Research*	2168	95162	51.05
22	*Journal of Vacuum Science and Technology. A. Vacuum, Surfaces, and Films*	2139	97301	52.20
23	*Journal of Non-Crystalline Solids*	2092	99393	53.32
24	*Physica Status Solidi. B. Basic Research*	1949	101342	54.37
25	*Photonics Technology Letters*	1885	103227	55.38
26	*IEEE Journal of Quantum Electronics*	1603	104830	56.24
27	*Materials Science and Engineering. B. Solid State Materials for Advanced Technology*	1568	106398	57.08
28	*Journal of Physics. Condensed Matter*	1548	107946	57.91
29	*IEEE. Electron Device Letters*	1513	109459	58.72
30	*Material Science Forum*	1509	110968	59.53
31	*Journal of Electronic Materials*	1486	112454	60.33
32	*Superlattices and Microstructures*	1416	113870	61.09
33	*Nuclear Instruments and Methods in Physics Research*	1389	115259	61.83
34	*Semiconductors*	1369	116628	62.57
35	*Soviet Physics. Solid State [English Translation]*	1202	117830	63.21
36	*Physica B. Europhysics Journal. Low Temperature and Solid State Physics*	1192	119022	63.85
37	*Acta Physica Polonica. Series A*	1074	120096	64.43

Hawkins also observed the presence of a discontinuity of slope in the Bradford-Zipf plot,[8] when he investigated the journal literature in online information retrieval. He suggested that this phenomenon might be due to the dispersion of the literature on the subject of online information retrieval. This may also be true for semiconductor literature. It may be seen that only the first 20 journals cover 50% of literature and the first 3 journals together cover about 20% of the literature. That means while 50% of literature is concentrated only in the first 20 journals, remaining 50% is scattered within 1857 journals. This, again, shows tremendous scattering of semiconductor literature. The final droop portion begins roughly at a journal rank of 120. The presence of the final droop portion indicates that the literature in the semiconductor literature has been widely spread to many different journals. This is consistent with the fact that 438 journals publish only one semiconductor article. The scattering of information pose a great problem in the retrieval of relevant information.

Core journals

To look more deeply into the nature of the 25 core journals Table 7 was generated. In this table, the top twenty-five journals are ranked in descending order. The table also lists initial publication date, frequency of publication and subject field, taken from *Journal Citation Reports on CD-ROM* (1997, Science Edition) and *Ulrich's on Disc*, 1998.

Journal age

The most productive journals are in general older than less productive ones. An old journal is usually well established and known worldwide. With longer publishing history, such journals tend to publish more articles than newer journals. Table 7 indicates that the oldest journal, *Journal of Electrochemical Society* is 98 years old and *Journal of Applied Physics* is about 70 years old. *IEEE Transactions on Electron Devices*, *Nuclear Instruments and Methods in Physics Research B. Beam Interactions with Materials and Atoms* and *Physical Review Letters* come next and published in 1952,1957 and 1958, respectively. More than half of the core journals (15 out of 25) begins their publication in 1960s. *Physica Status Solidi. A. Applied Research*, a German journal, and *Physical Review B. Condensed Matter*, published their first issue in 1970. The remaining three journals, published in 1980s, are oriented in particular specific subject field. They are *Semiconductor Science and Technology, IEEE Photonics Technology Letters*, and *Applications of Surface Science*.

Publication frequency

In general, the more frequently a journal is published, the more productive it is likely to be. For example, fifteen top productive journals are published weekly or biweekly, whereas the remaining ten are likely to be monthly or bimonthly journals. Table 7 shows that nine of the twenty-five core journals (including one journal published seventy-eight times and one journal published sixty-eight times a year) are published weekly. Most of them are journal of letters or communication type, such as *Applied Physics Letters, Solid State Communications, Physical Review Letters*. The purpose of this preliminary communication is to establish priority for an invention and to disseminate nascent information on current research in the scientific community.[9] It is, therefore, not surprising that these letters journals published a lot of semiconductor papers. Two journals with the shortest interval of publication are *Surface Science* (78 issues/year) and *Applications of Surface Science* (68 issues/year).

Table 7
Publication date, publication frequency and subject field of 25 core journals

Title	*Publication date	**Publication frequency (issues/yr)	**Subject
Applied Physics Letters	1962	52	Physics,applied
Physical Review B. Condensed Matter	1970	***48** 36	Condensed matter, physics
Journal of Applied Physics	1931	24	Physics,applied
Proceedings of SPIE	1964	Unknown	Optics
Journal of Crystal Growth	1967	***48** 24	Crystallography
Electronics Letters	1965	25	Engineering, electrical/electronic
Japanese Journal of Applied Physics. Part 1	1962	12	Physics, applied
IEEE. Transactions on Electron Devices	1952	12	Physics, applied Electrical/electronic
Surface Science	1964	***78** 28	Chemistry, physical

(Table 7. cont)

Title	*Publication date	**Publication frequency (issues/yr)	**Subject
Journal of Vacuum Science and Technology B. Micro-Electronics Processing and Phenomena	1964	6	Electrical/electronic engineering
Semiconductor Science and Technology	1986	12	Physics, condensed matter Electrical/electronic, engineering
Solid State Communications	1963	48	Physics, condensed matter
Solid-State Electronics	1960	*12 24	Physics, applied Engineering, electrical/ electronic
Soviet Physics. Semiconductors	1967	12	Physics, condensed matter
Thin Solid Films	1968	*46 20	Physics, applied Material science
Japanese Journal of Applied Physics. Part 2. Letters	1962	24	Physics, applied
Journal. Electrochemical Society	1902	12	Electrochemistry Material science Coating & Films
Physical Review Letters	1958	52	Physics
Applications of Surface Science	1978	*68 16	Physics, applied Condensed matter
Nuclear Instruments and Methods in Physics Research.B. Beam Interactions with Materials and Atoms	1957	*52 22	Nuclear science/technology
Physica Status Solidi. A. Applied Research	1970	12	Physics, condensed matter
Journal of Vacuum Science and Technology. A. Vacuum, Surfaces, and Films	1964	6	Material science Coating & films
Journal of Non-Crystalline Solids	1969	*54 21	Material science, ceramics
Physica Status Solidi. B. Basic Research	1961	12	Physics, condensed matter
IEEE Photonics Technology Letters	1989	12	Optics Physics, applied

* Data from Ulrich.
** Data from JCR.

Subject field

The subject field of a journal is also related to the productivity. Although the core semiconductor literature is concentrated in a small number of journals, they are quite diversified in their subject coverage. As indicated in Table 7, most of the core journals deal with general physics, applied physics, electrical/electronic engineering and material science. The top three journals, *Applied Physics Letter, Physical Review B. Condensed Matter* and *Journal of Applied Physics* are publications of the American Institute of Physics and each published more than ten thousands semiconductor papers. This suggests the major role played the American Institute of Physics on semiconductor research. Moreover, this also suggests that researches on semiconductor is very much physics oriented. These journals contain literature on various physic disciplines, and have been chosen for the announcement of many major physics discoveries, including semiconductor. It is, therefore, not surprising that these three physics journals are the top most productive journals. In fact, these three journals are among the five productive journals in physics for literature published in 1986.[10] In addition, the fourth productive journal, *Proceedings of the Society of Photo-optical Instrumentation Engineers, International Society for Optical Engineering*, can also be considered as in physics subject. Two journals published in Japan are applied physics oriented.

Journals in specific electrical/electronic and material science subject areas also published abundant semiconductor literature. These subject areas include surface science, crystallography, solid state, etc. It is interesting to note that among the speciality journals in the field of semiconductor, only three have found their place within the core. *Soviet Physics. Semiconductors* (rank 14), a translation journal, almost exclusively devoted to semiconductors would be expected to be included in the list. The other two journals that specially emphasize semiconductor literature are *Semiconductor Science and Technology* (rank 11) and *Semiconductor* (rank 34). Although semiconductor seems to be a physics subject, it is not uncommon that the subject has some connections with chemistry. *Journal of the Electrochemical Society* (rank 17) is an excellent example showing the relation between semiconductor and chemistry.

Author productivity and Lotka's law

Table 8 shows a total of 125990 authors, including senior personal authors and co-authors, contribute to the publications of 275574 articles in semiconductor. In average, 2.19 papers was published by each author. The vast majority (62958 authors (49.97%)) contributed only one article. It is unlike the Lotka's law[11] that about 60% authors contribute only one paper. More than 8% of authors contributed more than 10 articles. The largest number of articles by one author is 564. The second and third largest are also as high as 386 and 238, respectively. This shows the extremely large number of publication contributed by a single author in semiconductor literature. Table 9 lists 104 most productive authors, who published more than 100 articles, and their number of publications. A detail examination of the top three authors indicates that their first publication in semiconductor (according to the INSPEC) appeared in 1985 or 1986 and they remained active in 1997.

Table 8
Productivity of authors

No. or articles	No. of authors	%	Cum. %
1	62958	49.97	49.97
2	20117	15.97	65.94
3	10403	8.25	74.19
4	6607	5.24	79.43
5	4581	3.64	83.07
6	3389	2.69	85.76
7	2531	2.01	87.77
8	2020	1.60	89.37
9	1656	1.31	90.68
10	1433	1.14	91.82
>10	10295	8.17	99.99
Total	125990	99.99	99.99

In this study a procedure which conforms closely to Lotka's original formulation in the test of conformity of the author data. Lotka's law[11] was used to measure the productivity of authors. The general form of Lotka's law can be expressed as $y=c/x^n$, where y=percentage of authors, x=number of articles published by an author, c=constant and $-n$=slope of the log-log plot.

The data of author productivity and two fitted curves are shown in Fig. 4. The fitted curve of dash line is based on all data. However, it overestimates very significantly the percentage of low productive authors. In fact, the percentage for the author of single publication would be larger than 100, which is unrealistic.

The data of high publication numbers are quite scattering and may not be representative. If those data of publication number greater than 50 are omitted, the least square fit results in the solid-line curve. Indeed, it has been suggested in the literature that data of high productivity authors should be omitted to have good fitting.[12]

Table 9
Authors publishing more than 100 articles

Rank	Author	No. of articles	Rank	Author	No. of articles
1	Cardona M.	564	53	Cristoloveanu S.	124
2	Abernathy C.R.	386	54	Ando S.	124
3	Cho A.Y.	238	55	Harbison J.P.	124
4	Bhat R.	219	56	Capasso F.	123
5	Abstreiter G.	217	57	Kurz H.	123
6	Coldren L.A.	210	58	Abe T.	122
7	Chu S.N.G.	206	59	Aoki M.	120
8	Morkoc H.	187	60	Kobayashi M.	120
9	Caneau C.	179	61	Bowers J.	119
10	Cunningham J.E.	177	62	Arai S.	118
11	Landwehr G.	172	63	Chang T.Y.	118
12	Monemar B.	172	64	Chand N.	117
13	Henini M.	169	65	Adachi S.	116
14	Kohler K.	168	66	Chen L.J.	116
15	Aoyagi Y.	167	67	Harris J.J.	116
16	Bhattacharya P.K.	167	68	Inoue K.	116
17	Claeys C.	167	69	Borghesi S.	115
18	Melloch M.R	167	70	Bour D.P.	115
19	Cingolani R.	165	71	Joyce B.A.	115
20	Jones G.A.C.	164	72	Cibert J.	113
21	Coleman J.J.	163	73	Cheng K.Y.	112
22	Bohm C.	159	74	Beaumont S.P.	111
23	Hobson W.S.	159	75	Luth H.	111
24	Kobayashi T.	158	76	Arakawa T.	110
25	Ahmed H.	156	77	Morante J.R.	110
26	Adesida I.	156	78	Campbell J.C.	109
27	Kwong D.L.	154	79	Allen S.J.	109
28	Merz J.L.	154	80	Asahara Y.	109
29	Akasaki I.	152	81	Beton P.H.	109
30	Banerjee S.K.	150	82	Hemment P.L.F.	109
31	Bimberg D.B.	149	83	Kobayashi N.	109
32	Miura N.	149	84	Brandt O.	108
33	Ito T.	144	85	Hasegawa H.	108
34	Iga K.	140	86	Cavenett B.C.	107
35	Logan R.A.	140	87	Chaudhuri S.	107
36	Lucovsky G.	140	88	Chow D.H.	107
37	Kobayashi K.	139	89	Haller E.E.	107
38	Chen Y.	138	90	Amano H.	105
39	Koch S.W.	137	91	Hirose M.	105
40	Bauer G.W.E.	136	92	Horikoshi Y.	105
41	Chen J.	135	93	Benyattou T.	104
42	Chen Y.K.	134	94	Kim T.W.	104
43	Chang C.Y.	132	95	Konagai M.	104
44	Bimbault L.	132	96	Bhattacharya P.H.	103
45	Bowers J.E.	131	97	Buchanan M.	103
46	Christou A.	130	98	Chen W.	103
47	Harris J.S.Jr.	129	99	Choyke W.J.	103
48	Chemla D.S.	128	100	Akimoto K.	103
49	Koren U.	127	101	Meyer B.K.	103
50	Hill G.	126	102	Bauer G.E.W.	102
51	Chen W.M.	125	103	Boker G.R.	102
52	Koyama F.	125	104	Canali C.	101

The solid-line fitted curve results in n=–2.03 and c=94.4. Although the solid-line curve does show good fitting for medium productive data, it still overestimates the data of single or two publications. Clearly, the author productivity distribution does not fit the original Lotka's law.

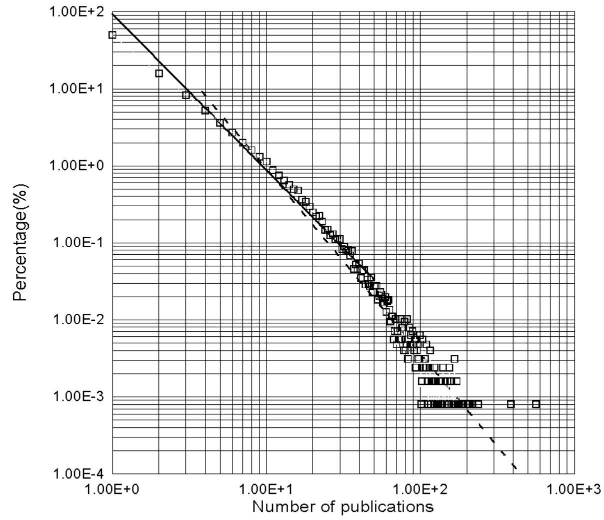

Fig. 4. Distribution of author productivity

Author's affiliation

It is also significant to explore the author's affiliation in semiconductor literature. The authors are affiliated with 23883 institutes except the affiliate of 7737 items among 275574 articles could not be identified from the INSPEC. Table10 lists the top 31 most productive institutes, which published more than one thousand articles. The AT&T Inc. in USA is the most productive institute for semiconductor literature. It contributes 4520 articles in total. The University of California, all campuses, USA and the NTT Corp., Japan rank the second and third, respectively. The ten most productive institutes in the publication of semiconductor literature published 29727 articles, accounting for 12.93% of all semiconductor literature. Among the top ten most productive institutes, four are private companies doing business related to semiconductor, four are major universities and two are research institutes. This shows that semiconductor researches are wide dispersed in research division of private companies, major universities and research institutes.

Table 10
Top most productive institutes in publication of semiconductor literature

Rank	Institute	No. of Articles	Comments
1	AT&T Inc., USA	4520	Company
2	UC (all campus), USA	4018	University
3	NTT Corp., Japan	3375	Company
4	A.F. Ioffe Phys. Tech. Inst.	3237	Research Inst.
5	IBM Corp., USA	3161	Company
6	CNRS, France	2560	Research Inst.
7	Tech. Univ., Berlin, Germany	2469	University
8	Tokyo Univ., Japan	2227	University
9	NEC Corp., Japan	2098	Company
10	Univ. Illinois, USA	2062	University
11	Hitachi Ltd., Japan	1771	Company
12	North Carolina State Univ., Raleigh, NC, USA	1737	University
13	MIT, Cambridge, MA, USA.	1733	University
14	Max-Planck-Inst. für Festkorperforschung, Germany	1699	Company
15	Sinica, Beijing, China	1668	Research Inst.
16	Standford Univ., CA, USA	1647	University
17	CNET, France	1627	Research Inst.
18	Osaka Univ., Japan	1455	University
19	Philips, Netherlands	1385	Company
20	Warsaw Tech. Univ., Poland	1348	University
21	Inst. Of Semiconductor Phys., USSR	1320	Research Inst.
22	Fujitsu Ltd., Kawasaki, Japan	1305	Company
23	Naval Research Lab., Washington, DC, USA	1218	Research Inst.
24	Tohoku Univ., Sendai, Japan.	1207	University
25	Sandia National Labs., Albuqueraue, NM, USA	1179	Research Inst.
26	Siemens AG, Germany	1146	Company
27	Tokyo Inst. Technol. Japan	1132	University
28	Toshiba Corp., Japan	1122	Company
29	Texas Univ., USA	1117	University
30	Cambridge Univ., UK	1063	University
31	Michigan Univ., MI, USA	1049	University

Summary and conclusions

This study explored the growth of semiconductor literature, based on the INSPEC database, and examined the various characteristics of the literature using well-established bibliometric techniques. The results are summarized as follows:

1. After the year 1986, the literature grows approximately linearly with a growth rate of about 23000 items per year.

2. The single most prevalent form of publication is the journal article, which contributes 66.85% of the total literature in semiconductor.
3. The researchers employ the experimental approach most (about one half) in semiconductor subject.
4. The USA is the predominant (about 50%) publishing country in semiconductor.
5. English is the most used language of articles on semiconductor. English articles constitute 95.93% of the total literature.
6. The journal literature in semiconductor conforms approximately the typical S-shape Bradford-Zifp's plot, though, the initial rise is somewhat faster than the typical one.
7. Twenty-five core journals may be identified from the Bradford-Zipf's plot. On the other hand, the journal literature in semiconductor is found to be widely spread to many different journals. About 50% of literature is concentrated in first 20 journals only, the remaining 50% is scattered within 1857 journals.
8. The analysis of the core journals indicates that (1) the most productive journals are in general older than less productive ones; (2) the more frequently a journal is published, the more productive it is likely to be; (3) most of the core journals deal with general physics, applied physics, electrical/electronic engineering and material science.
9. The vast majority (49.9%) of authors contributed only one article. It is unlike the Lotka's law that about 60% authors contribute only one paper. Moreover, the author productivity distribution does not fit the original Lotka's law.
10. More than 8% authors contribute more than ten articles. The largest number of papers by one author is 564.
11. The analysis of author affiliates indicates that the semiconductor researches are widely dispersed in research division of private companies, major universities and research institutions.

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