SOLAR CELL RESEARCH OUTPUT: A BIBLIOMETRIC STUDY

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Abstract: - *This study analysis the research output on Solar cell using Scopus database during the period of 1978 to 2017 (40 years). The analysis put forth the Type of Source, Chronological growth , Subject wise contribution, Document type preferred, Collaborated Country, Collaborated Institutions, Contributed Journal, Highly contributed author, Keywords Preferred and Language of the paper A total of 150201 record have been identified and the same has been analyzed using bibliometric study. Out of 1,50,201 solar cell research publicationss, 4430 (2.95%) were from open access sources and 1,45,771 (97.5%) were from other sources. On an average, there were 111 open access papers per year and 3,755 papers in a year. There exists study growth of publications. 55% of articles appeared during the last six years of 2012 and 2017. More than 10000 articles can be seen only from 2012 (10854, 7.23%). In the year 2017 it raises to one and half times i.e. 15113 (10.06%). Nearly 14 countries contributed more than 2750 publications. 96,377 (64.17%) papers were published as Journal Article. Average publication per year works out to 3755 papers per year. 59 sources have more than 500 contributions. 63 institutions that have contributed a minimum of 500 research papers. Nearly 35 authors have contributed more than 200 publications. 24 keywords were used maximum of 5000 times in Solar cell research publications.*

Keywords : ***Solar cell, Research output on solar cell, Bibliometrics, Literature on solar cell, photovoltaic cell***

INTRODUCTION

The growth of literature has been normally identified in a given domain using metric studies specifically bibliometric analysis. A quantitative measurement of research contributions is an innovative way of correlating numerous gestures of research revealing trends and is considered as an aid to map research productivity. These quantitative methods in Science includes metric studies which are known as Bibliometrics in 1960's, Scientometrics in 1970's and Informetrics in the midst of 1980's. The measure of research output has been carried out using bibliometric method

Bibliometric method, a common research tool, has already been widely applied in scientific production and research-trend studies in many disciplines of Science and Engineering (Almind&

Ingwersen, 1997; Cronin, 2001; Moed, Debruin, & Vanleeuwen, 1995). The popularity in the adaptation of bibliometric techniques in various disciplines stimulated stupendous growth of literature on bibliometrics and its related areas. In this study the authors have employed bibliometric analysis in analyzing Solar Cell Research output in Scopus database during the period of 1978 to 2017 (40 years).

SOLAR CELL

Solar cells are devices for converting sunlight into electricity. Their primary element is often a semiconductor which absorbs light to produce carriers of electrical charges. An applied electric field can then sweep these carriers out of the semiconductor, thus producing an electrical current. Assemblies of solar cells are used to make solar modules that generate electrical power from sunlight, as distinguished from a "solar thermal module" or "solar hot water panel". A solar array generates solar power using solar energy.

A **solar cell**, or **photovoltaic cell**, is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon.[1] It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage, or resistance, vary when exposed to light. Individual solar cell devices can be combined to form modules, otherwise known as solar panels. In basic terms a single junction silicon solar cell can produce a maximum open-circuit voltage of approximately 0.5 to 0.6 volts.[2]

BIBLIOMETRIC STUDY

Bibliometric is defined as the application of statistical and mathematical methods to books and other communication. Pritchard (1969)[1] .

Lotka's law (1926) of scientific productivity, Bradford's law (1934) of scattering and Zips law (1949) on frequency of words were the few famous laws of Bibliometric. These Bibliometric studies were started in late sixties.

Research output of individual scientists, universities, research institutes, and research areas have been conducted based on Bibliometic study. The Conventional bibliometric methods are generally evaluate the research trend. Some of the studies that investigating the publication outputs of different countries (Rahman, Haque, & Fukui, 2005) , research institutes (Rajendram, Lewison, & Preedy, 2006 , Nagarajan and others, 2014), journals (Javed M (2008), subjects (Rajendran , Ramesh Babu , & Gopalakrishnan , 2005) and research fields (Krishnamoorthy, Ramakrishnan, & Devi, 2009) .

REVIEW OF LITERATURE

Keerti Bala Jain and Kumar (2011) studied the measurement of research productivity of Indian scientists contributing to world soybean research. Karpagam et al (2011) analyzed the growth pattern of Nanoscience and Nanotechnology literature in India during 1990 – 2009. Gupta, Mueen Ahmed and Gupta (2017)

studied the growth India's research output in arthritis research during 2007-2016.

OBJECTIVES

The objectives of the study are

1. To know the contribution of open access journal on Solar cell research
2. To identify the country wise and language wise
3. To identify the document type contribution on solar cell research
4. To know language wise distribution
5. To identify the related growth rate and chronological growth of literature on Solar cell.
6. To identify the primary source on Solar cell publication
7. To identify the predominant organisation and preferred bibliographic form for the research output for Solar Cell.
8. To identify the highly contributed authors in Solar cell.
9. To find out the keywords used in Solar cell research.

HYPOTHESES

The hypotheses formulated for the study are

1. There exists substantial growth output on Solar cell research.
2. There exists more contribution by developed nations on Solar cell.
3. Among various bibliographical forms, a Journal article seems to be most preferred for publication of Solar cell research.
4. English seems to be the preferred language for Solar cell research.

DATA COLLECTION

The study uses 40 years publications data from 1978 to 2017 on Solar cell research collected from Scopus database. A total of 1,51,328 records were identified in the field of "Solar cell", of which 1,50,201 research literatures (99.23%) are directly related to Solar Cell. The search term used for retrieving the bibliographic records as follows:

Query: (TITLE-ABS-KEY (solar cells) AND PUBYEAR > 1977 AND PUBYEAR < 2018)

These bibliographic records were downloaded for further analysis.

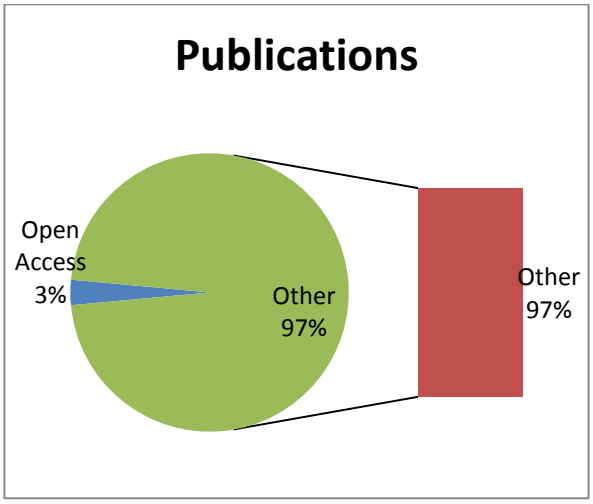
DATA ANALYSIS

Source type

The Scopus has also including the open access sources in their data base. The data of 1, 50,201 records thus retrieved from Scopus data base has been analysed based on source type and the same has been shown in Table 1

Table 1: Source type

S.No	Type of access	Publications	%	Average publication per year
1	Open Access	4430	2.95	111
2	Other	145771	97.05	3644
	Total	150201	100.00	3755



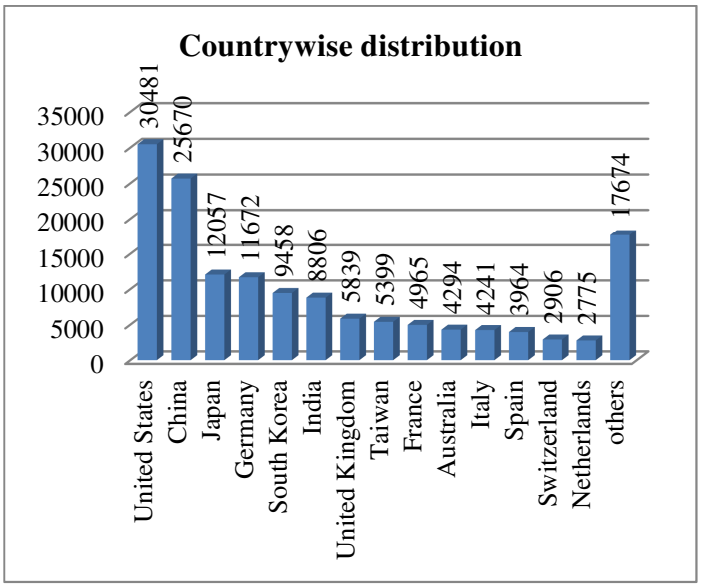
Out of 1, 50,201 solar cell research publications, 4430 (2.95%) were from open access sources and 1, 45,771 (97.5%) were from other sources. On an average, there were 111 open access papers per year and 3,755 papers in a year.

Country wise Distribution

The country wise distribution of the solar cell publications were analysed and the same has been shown in Table 2.

Table 2: Country wise distribution

S.No.	Country	Publications	%	Average publication per year
1	United States	30481	20.29	762
2	China	25670	17.09	642
3	Japan	12057	8.03	301
4	Germany	11672	7.77	292
5	South Korea	9458	6.30	236
6	India	8806	5.86	220
7	United Kingdom	5839	3.89	146
8	Taiwan	5399	3.59	135
9	France	4965	3.31	124
10	Australia	4294	2.86	107
11	Italy	4241	2.82	106
12	Spain	3964	2.64	99
13	Switzerland	2906	1.93	73
14	Netherlands	2775	1.85	69
15	others	17674	11.77	442
	Total	**150201**	**100.00**	**3755**



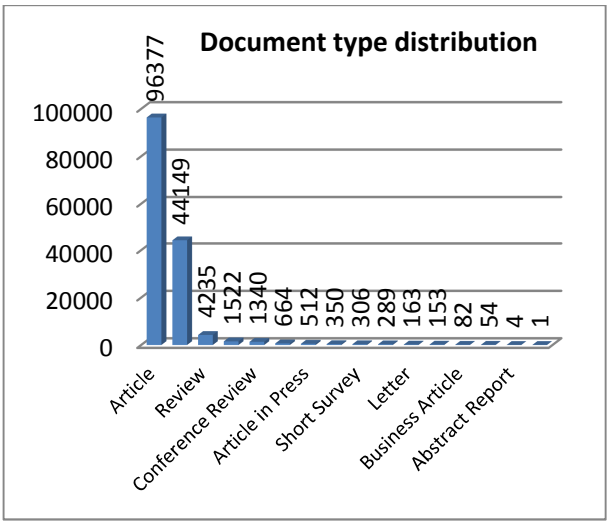
Nearly 14 countries contributed more than 2750 publications. Out of 14 countries, United States contributed 30481 (20.29%) papers with an average of 762 publications for the year. It is followed by China (25670, 17.09%); Japan (12057, 8.03%) and Germany (11672, 7.77%). India positioned itself in sixth place in solar cell research output with 8806 (5.86%) publications with an average of 220 publications per year.

Document type

The document type in which the contributions were appeared during the study period has been analysed and the same has been shown in Table 3.

Table 3 : Document type distribution

S.No.	Document type	Papers	%
1	Article	96377	64.17
2	Conference Paper	44149	29.39
3	Review	4235	2.82
4	Book Chapter	1522	1.01
5	Conference Review	1340	0.89
6	Note	664	0.44
7	Article in Press	512	0.34
8	Erratum	350	0.23
9	Short Survey	306	0.20
10	Book	289	0.19
11	Letter	163	0.12
12	Editorial	153	0.10
13	Business Article	82	0.06
14	Report	54	0.04
15	Abstract Report	4	0.00
16	Retracted	1	0.00
	Total	**150201**	**100**



Out of 1, 50,201 papers, 96,377 (64.17%) papers published as Journal Article. It is followed by Conference Paper (44149, 29.39%); Review (4235, 2.82%) and Book Chapter (1522, 1.01%).

Language Wise Distribution

The language preferred for communicating solar cell research has been analysed and the same has been shown in Table 4.

Table 4 : LANGUAGE WISE DISTRIBUTION PUBLICATIONS

S.No	Language	Papers	%
1	English	142723	95.02
2	Chinese	3795	2.53
3	Japanese	517	0.34
4	German	307	0.20
5	Korean	260	0.17
6	Russian	215	0.14
7	French	211	0.14
8	Spanish	132	0.09
9	Others	2041	1.36
	Total	150201	100.00

Nearly 95.02% of publications were published in English. Besides English, the authors have contributed in more than 30 languages. Among the several languages, the other three most preferred were Chinese (3795, 2.53%); Japanese (517, 0.34%) and German (307, 0.20%).

Year wise distribution

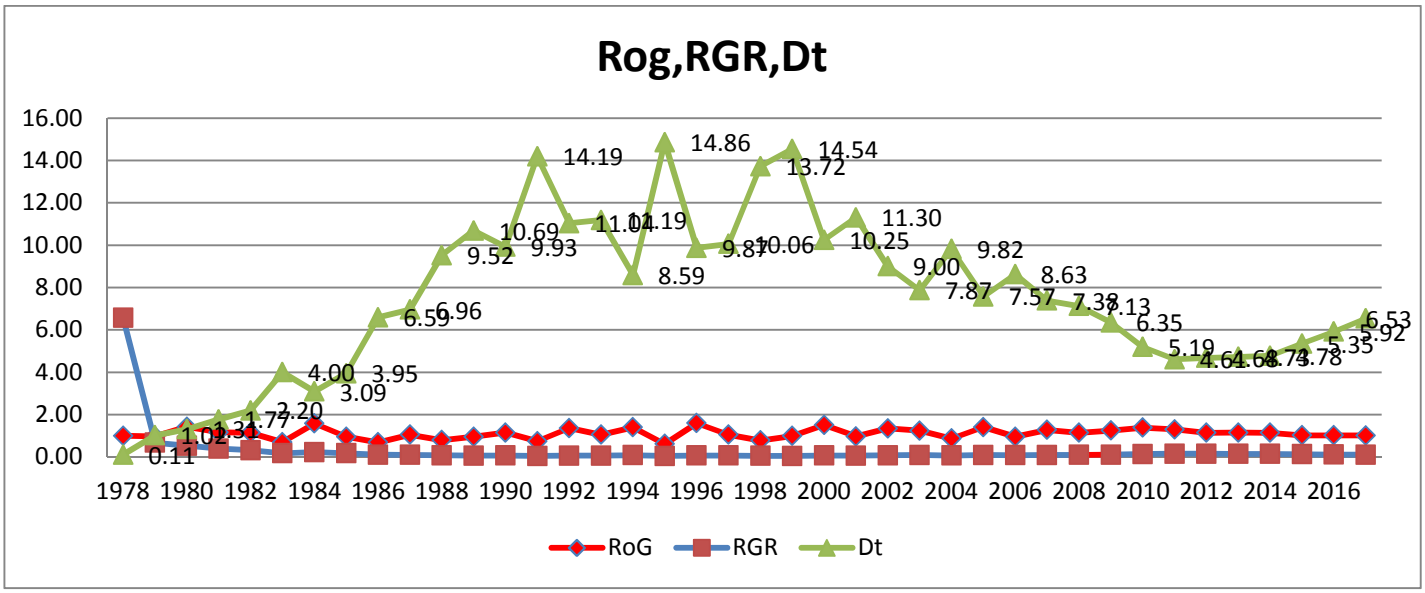
The year wise distribution of solar cell research output has been analysed and the same has been shown in Table 5. Further the Ratio of Growth (RoG), Relative Growth Rate (RGR) and doubling time (Dt) of the publications have also been calculated and shown in Table 5.

Table 5: Year wise distribution Publications

S.No.	Year	Papers	%	Cum Papers	Cum %	RoG	RGR	Dt
1	1978	713	0.47	713	0.47	1.00	6.57	0.11
2	1979	690	0.46	1403	0.93	0.97	0.68	1.02
3	1980	979	0.65	2382	1.59	1.42	0.53	1.31
4	1981	1143	0.76	3525	2.35	1.17	0.39	1.77
5	1982	1308	0.87	4833	3.22	1.14	0.32	2.20
6	1983	914	0.61	5747	3.83	0.70	0.17	4.00
7	1984	1445	0.96	7192	4.79	1.58	0.22	3.09
8	1985	1380	0.92	8572	5.71	0.96	0.18	3.95
9	1986	951	0.63	9523	6.34	0.69	0.11	6.59
10	1987	997	0.66	10520	7.00	1.05	0.10	6.96
11	1988	794	0.53	11314	7.53	0.80	0.07	9.52
12	1989	758	0.50	12072	8.04	0.95	0.06	10.69
13	1990	873	0.58	12945	8.62	1.15	0.07	9.93
14	1991	648	0.43	13593	9.05	0.74	0.05	14.19
15	1992	881	0.59	14474	9.64	1.36	0.06	11.04
16	1993	925	0.62	15399	10.25	1.05	0.06	11.19
17	1994	1294	0.86	16693	11.11	1.40	0.08	8.59
18	1995	797	0.53	17490	11.64	0.62	0.05	14.86
19	1996	1272	0.85	18762	12.49	1.60	0.07	9.87
20	1997	1338	0.89	20100	13.38	1.05	0.07	10.06
21	1998	1041	0.69	21141	14.08	0.78	0.05	13.72
22	1999	1032	0.69	22173	14.76	0.99	0.05	14.54
23	2000	1551	1.03	23724	15.79	1.50	0.07	10.25
24	2001	1500	1.00	25224	16.79	0.97	0.06	11.30
25	2002	2019	1.34	27243	18.14	1.35	0.08	9.00
26	2003	2508	1.67	29751	19.81	1.24	0.09	7.87
27	2004	2176	1.45	31927	21.26	0.87	0.07	9.82
28	2005	3061	2.04	34988	23.29	1.41	0.09	7.57
29	2006	2927	1.95	37915	25.24	0.96	0.08	8.63
30	2007	3732	2.48	41647	27.73	1.28	0.09	7.38
31	2008	4254	2.83	45901	30.56	1.14	0.10	7.13

32	2009	5296	3.53	51197	34.09	1.24	0.11	6.35
33	2010	7314	4.87	58511	38.96	1.38	0.13	5.19
34	2011	9485	6.31	67996	45.27	1.30	0.15	4.61
35	2012	10854	7.23	78850	52.50	1.14	0.15	4.68
36	2013	12454	8.29	91304	60.79	1.15	0.15	4.73
37	2014	14252	9.49	105556	70.28	1.14	0.15	4.78
38	2015	14603	9.72	120159	80.00	1.02	0.13	5.35
39	2016	14929	9.94	135088	89.94	1.02	0.12	5.92
40	2017	15113	10.06	150201	100.00	1.01	0.11	6.53
	Total	**150201**	**100.00**	**Average**	**Paper:3755**	**1.11**	**0.3**	**7.41**

There exists study growth of publications. 55% of articles appeared during the last six years of 2012 and 2017. More than 10000 articles can be seen only from 2012 (10854, 7.23%). In the year 2017 it raises to one and half times i.e. 15113 (10.06%). The ratio of growth (RoG) ranges between 0.62 and 1.58. Steep fall of publications can be seen during the year 1986-1989, 1991, 1995, 1998 and 1999. RGR ranges between 0.05 and 0.68. The doubling time ranges between 0.90 and 7.57. The publication doubles once in seven years. Average publication per year works out to 3755 papers per year.



Source Title

The source title that has minimum of 500 articles in solar cell research contribution has been analysed and the same has been shown in Table 6.

Table 6 : SOURCE TITLE

S.No	Source Title	No. of Papers	%
1	Conference Record Of The IEEE Photovoltaic Specialists Conference	8224	5.48
2	Solar Energy Materials And Solar Cells	5260	3.50
3	Proceedings Of SPIE The International Society For Optical Engineering	3188	2.12
4	Applied Physics Letters	2714	1.81
5	Thin Solid Films	2695	1.79
6	Journal Of Applied Physics	2144	1.43
7	Journal Of Physical Chemistry C	1928	1.28
8	Materials Research Society Symposium Proceedings	1888	1.26
9	Solar Energy	1858	1.24
10	ACS Applied Materials And Interfaces	1774	1.18
11	Journal Of Materials Chemistry A	1741	1.16
12	Energy Procedia	1510	1.01
13	Rsc Advances	1451	0.97
14	Progress In Photovoltaics Research And Applications	1433	0.95
15	Electrochimica Acta	1104	0.74
16	Japanese Journal Of Applied Physics	1068	0.71
17	IEEE Journal Of Photovoltaics	1054	0.70
18	Organic Electronics Physics Materials Applications	1023	0.68
19	Advanced Energy Materials	975	0.65
20	Aip Conference Proceedings	954	0.64
21	Advanced Materials	936	0.62
22	Physical Chemistry Chemical Physics	901	0.60
23	Advanced Materials Research	863	0.57
24	Journal Of Power Sources	841	0.56
25	Solar Cells	812	0.54
26	Applied Surface Science	782	0.52
27	Taiyangneng Xuebao Acta Energiae Solaris Sinica	776	0.52
28	Journal Of Nanoscience And Nanotechnology	765	0.51
29	Renewable Energy	765	0.51
30	Energy And Environmental Science	762	0.51
31	Optics Infobase Conference Papers	746	0.50
32	Journal Of Crystal Growth	738	0.49

33	Advanced Functional Materials	705	0.47
34	Journal Of Materials Chemistry	678	0.45
35	Journal Of The American Chemical Society	670	0.45
36	Journal Of The Electrochemical Society	641	0.43
37	Journal Of Materials Science Materials In Electronics	638	0.42
38	ACS National Meeting Book Of Abstracts	625	0.42
39	Synthetic Metals	607	0.40
40	Chemical Communications	605	0.40
41	Proceedings Of The Intersociety Energy Conversion Engineering Conference	603	0.40
42	European Space Agency Special Publication ESA SP	599	0.40
43	Journal Of Alloys And Compounds	589	0.39
44	2015 IEEE 42nd Photovoltaic Specialist Conference Pvsc 2015	587	0.39
45	Nanoscale	587	0.39
46	Commission Of The European Communities Report Eur	583	0.39
47	Chemistry Of Materials	568	0.38
48	Nano Letters	560	0.37
49	Applied Solar Energy English Translation Of Geliotekhnika	558	0.37
50	Journal Of Non Crystalline Solids	557	0.37
51	Scientific Reports	547	0.36
52	Optics Express	534	0.36
53	2014 IEEE 40th Photovoltaic Specialist Conference Pvsc 2014	532	0.35
54	International Journal Of Hydrogen Energy	529	0.35
55	Proceedings Of The 3rd World Conference On Photovoltaic Energy Conversion	527	0.35
56	Journal Of Physical Chemistry Letters	521	0.35
57	Physica Status Solidi A Applications And Materials Science	518	0.34
58	Materials Letters	514	0.34
59	Ecs Transactions	507	0.34

Among the 59 sources that have more than 500 contributions, “Conference Record of the IEEE Photovoltaic Specialists Conference” has 8224 (5.48%) papers. It is followed by “Solar Energy Materials and Solar Cells” (5260, 3.50%); “Proceedings of SPIE the International Society for Optical Engineering” (3188, 2.12%); “Applied Physics Letters” (2714, 1.81%) and “Thin Solid Films” (2695, 1.79%).

Organizations contributed Solar Cell research

The Institutions that has contributed more than 500 papers has been analysed and the same has been shown in Table 7.

Table 7 : AFFILIATION OF CONTRIBUTORS

S.No.	Organization	Papers	%
1	Chinese Academy of Sciences	5166	3.44
2	Ministry of Education China	3000	2.00
3	National Renewable Energy Laboratory	2600	1.73
4	CNRS Centre National de la Recherche Scientifique	1604	1.07
5	University of New South Wales UNSW Australia	1556	1.04
6	Fraunhofer Institute for Solar Energy Systems ISE	1538	1.02
7	Helmholtz-Zentrum Berlin fÃ¼r Materialien und Energie HZB	1384	0.92
8	Ecole Polytechnique Federale de Lausanne	1274	0.85
9	National Taiwan University	1204	0.80
10	National Institute of Advanced Industrial Science and Technology	1088	0.72
11	University of Tokyo	945	0.63
12	Imperial College London	943	0.63
13	Sungkyunkwan University	906	0.60
14	National Chiao Tung University Taiwan	905	0.60
15	Consiglio Nazionale delle Ricerche	901	0.60
16	Beijing National Laboratory for Molecular Sciences	882	0.59
17	Korea University	867	0.58
18	Stanford University	864	0.58
19	Georgia Institute of Technology	851	0.57
20	Nanyang Technological University	844	0.56
21	National University of Singapore	844	0.56
22	Nankai University	842	0.56
23	Forschungszentrum JÃ¼lich FZJ	800	0.53
24	Osaka University	784	0.52
25	Japan Science and Technology Agency	782	0.52
26	Tsinghua University	781	0.52
27	South China University of Technology	775	0.52
28	Peking University	772	0.51
29	Massachusetts Institute of Technology	734	0.49
30	Seoul National University	733	0.49
31	Universidad Politecnica de Madrid	729	0.49
32	Tokyo Institute of Technology	712	0.47

33	Zhejiang University	709	0.47
34	Korea Institute of Science and Technology	681	0.45
35	Uppsala Universitet	678	0.45
36	University of Delaware	678	0.45
37	Interuniversity Micro-Electronics Center at Leuven	678	0.45
38	Shanghai Jiao Tong University	671	0.45
39	National Cheng Kung University	650	0.43
40	University of Washington, Seattle	644	0.43
41	Russian Academy of Sciences	639	0.43
42	Soochow University	637	0.42
43	Lawrence Berkeley National Laboratory	634	0.42
44	Korea Advanced Institute of Science & Technology	626	0.42
45	Kyoto University	620	0.41
46	Pusan National University	616	0.41
47	Jilin University	612	0.41
48	Huazhong University of Science and Technology	610	0.41
49	NASA Glenn Research Center	609	0.41
50	National Tsing Hua University	600	0.40
51	Arizona State University	596	0.40
52	UC Berkeley	592	0.39
53	Delft University of Technology	576	0.38
54	University of Cambridge	567	0.38
55	Technische Universiteit Eindhoven	556	0.37
56	Friedrich-Alexander-UniversitÃ¤t Erlangen-NÃ¼rnberg	546	0.36
57	Australian National University	542	0.36
58	California Institute of Technology	540	0.36
59	Hanyang University	531	0.35
60	Pennsylvania State University	528	0.35
61	Xi'an Jiaotong University	523	0.35
62	University of Science and Technology of China	523	0.35
63	Indian Institute of Technology Delhi	506	0.34

There were 63 institutions that have contributed a minimum of 500 research papers. Chinese Academy of Sciences has contributed 5166 (3.44%) papers. It is followed by Ministry of Education China (3000, 2.00%); National Renewable Energy Laboratory (2600, 1.73%) and University of New South Wales UNSW Australia (1556; 1.04%).

Highly contributed Authors

The authors who has contributed more 200 papers that has been included in Scopus database has been analysed and the same has been shown in Table 8.

Table 8 : TOP AUTHORS

S.No	Author Name	No. of Papers	%
1	Gratzel, M.	729	0.49
2	Green, M.A.	532	0.35
3	Nazeeruddin, M.K.	405	0.27
4	Li, Y.	401	0.27
5	Poortmans, J.	371	0.25
6	Hagfeldt, A.	349	0.23
7	Zhao, Y.	340	0.23
8	Yamaguchi, M.	324	0.22
9	Konagai, M.	321	0.21
10	Ballif, C.	317	0.21
11	Rohatgi, A.	309	0.21
12	Brabec, C.J.	302	0.20
13	Krebs, F.C.	289	0.19
14	Zakeeruddin, S.M.	280	0.19
15	Schropp, R.E.I.	279	0.19
16	Ho, K.C.	273	0.18
17	Rau, U.	273	0.18
18	Schock, H.W.	272	0.18
19	Rech, B.	263	0.18
20	Luque, A.	255	0.17
21	Zeman, M.	248	0.17
22	Yi, J.	245	0.16
23	Aberle, A.G.	238	0.16
24	Guha, S.	230	0.15
25	Brendel, R.	229	0.15
26	Snaith, H.J.	227	0.15
27	Lux-Steiner, M.C.	220	0.15
28	Kondo, M.	215	0.14
29	Sariciftci, N.S.	215	0.14
30	Dai, S.	214	0.14
31	Han, L.	214	0.14
32	Wu, J.	205	0.14
33	Leo, K.	204	0.14
34	Glunz, S.W.	203	0.14
35	Yang, J.	200	0.13

Nearly 35 authors have contributed more than 200 publications. Out of 35 authors "Gratzel, M." contributed 729 (0.49%) papers. It is followed by "Green, M.A." (532, 0.35%); "Nazeeruddin, M.K."(405, 0.27%); and "Li, Y.." (491, 0.27%).

Keywords used in Solar Cell Research

The keywords used by the authors in their articles and appeared more than 5000 times were ascertained and the same has been shown in Table 9.

Table 9 : KEY WORDS USED

S.No.	Key words	Papers	%
1	Solar Cells	69159	46.04
2	Photovoltaic Cells	21027	14.00
3	Solar Energy	17184	11.44
4	Solar Power Generation	13769	9.17
5	Thin Films	13566	9.03
6	Conversion Efficiency	10875	7.24
7	Silicon Solar Cells	10736	7.15
8	Dye-sensitized Solar Cells	10374	6.91
9	Heterojunctions	10336	6.88
10	Power Conversion Efficiencies	10262	6.83
11	Silicon	10099	6.72
12	Open Circuit Voltage	8826	5.88
13	Efficiency	8768	5.84
14	Titanium Dioxide	8429	5.61
15	Photoelectrochemical Cells	8249	5.49
16	Photovoltaic Effects	7867	5.24
17	Article	7420	4.94
18	Solar Cell	6905	4.60
19	Nanostructured Materials	6159	4.10

20	Electrodes	6128	4.08
21	Energy Gap	6117	4.07
22	Substrates	6065	4.04
23	Zinc Oxide	5748	3.83
24	Dye-Sensitized Solar Cell	5000	3.33

24 keywords were used maximum of 5000 times in Solar cell research publications. Out of 24 keywords, 11 key words were used more than 10000 times. Among the 11 Key words, the key word "Solar Cells" has been used 69159 (46.04%) of papers. It is followed by "Photovoltaic cells" (21027,14.00%); "Solar Energy" (17184, 11.44%); "Solar Power Generation" (13769, 11.44%) and "Thin Films" (13566, 9.03%). Nearly 90% of articles carry appropriate Keywords. The use of proper keywords will naturally get visibility among the researchers.

FINDINGS

- Total of 150201 publications can be seen in Scopus database for the period 40 years i.e. 1978-2017.
- ut of 1,50,201 solar cell research publications, 4430 (2.95%) were from open access sources and 1,45,771 (97.5%) were from other sources. On an average, there were 111 open access papers per year and 3,755 papers in a year.
- Nearly 14 countries contributed more than 2750 publications. Out of 14 countries, United States contributed 30481 (20.29%) papers with an average of 762 publications for the year. It is followed by China (25670, 17.09%); Japan (12057, 8.03%) and Germany (11672, 7.77%). India positioned itself in sixth place in solar cell research output with 8806 (5.86%) publications with an average of 220 publications per year.
- 96,377 (64.17%) papers were published as Journal Article. It is followed by Conference Paper (44149, 29.39%); Review (4235, 2.82%) and Book Chapter (1522, 1.01%).
- Nearly 95.02% of publications were published in English. Besides English, the authors have contributed in more than 30 languages. Among the several languages, the other three most preferred were Chinese (3795, 2.53%); Japanese (517, 0.34%) and German (307, 0.20%).
- There exists study growth of publications. 55% of articles appeared during the last six years of 2012 and 2017. More than 10000 articles can be seen only from 2012 (10854, 7.23%). In the year 2017 it raises to one and half times i.e. 15113 (10.06%).
- The ratio of growth (RoG) ranges between 0.62 and 1.58. Steep fall of publications can be seen during the year 1986-1989, 1991, 1995, 1998 and 1999. RGR ranges between 0.05 and 0.68. The doubling time ranges between 0.90 and 7.57.
- The publication doubles once in seven years.

- Average publication per year works out to 3755 papers per year.
- Among the 59 sources that has more than 500 contributions, "Conference Record Of The IEEE Photovoltaic Specialists Conference" has 8224 (5.48%) papers. It is followed by "Solar Energy Materials And Solar Cells" (5260, 3.50%); "Proceedings Of SPIE The International Society For Optical Engineering" (3188, 2.12%); "Applied Physics Letters" (2714, 1.81%) and "Thin Solid Films" (2695, 1.79%).
- There were 63 institutions that has contributed a minimum of 500 research papers. Chinese Academy of Sciences has contributed 5166 (3.44%) papers. It is followed by Ministry of Education China (3000, 2.00%); National Renewable Energy Laboratory (2600, 1.73%) and University of New South Wales UNSW Australia (1556; 1.04%).
- Nearly 35 authors have contributed more than 200 publications. Out of 35 authors "GrÃ¤tzel, M." contributed 729 (0.49%) papers. It is followed by "Green, M.A." (532, 0.35%); "Nazeeruddin, M.K."(405, 0.27%); and "Li, Y.." (491, 0.27%).
- 24 keywords were used maximum of 5000 times in Solar cell research publications. Out of 24 keywords, 11 key words were used more than 10000 times. Among the 11 Key words, the key word "Solar Cells" has been used 69159 (46.04%) of papers. It is followed by "Photovoltaic cells" (21027,14.00%); "Solar Energy" (17184, 11.44%); "Solar Power Generation" (13769, 11.44%) and "Thin Films" (13566, 9.03%). Nearly 90% of articles carry appropriate Keywords. The use of proper keywords will naturally get visibility among the researchers.

CONCLUSION

The study thus carried out primarily to examine the research production on solar cell research. Further it aims to identify the document type of the publications preferred by the academics. The contributed countries and organizations in the academic research were identified. The various subject domains that have more research productivity of Anna University one among the objectives of the study and to compare and measure the growth rate of literature published. The publications that appeared in Scopus database alone were taken up for the study. There may be a possibility of more number of publications that are published in other sources. More over the affiliation field alone considered. There may be a possibility of non inclusion of Anna University in the affiliation name by the authors. This study shows the growth in publications on solar energy research out and indicates that there exists substantial research production. Journals are major source of publications in solar research.

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