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A Bibliometric Analysis of the International Literature in Supercapacitors

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This study is a bibliometric analysis of worldwide scientific literature on research activity in the field of supercapacitors. To analyze the quality, quantity and influence of published scientific papers in this field, we have performed a search in the Scopus database and have analysed the relevant records. We then proceeded with rankings of authors and countries on the basis of different indicators: number of papers, citations, Hirsh index, and citations per paper. The analysis of aggregate records shows that the number of publications has increased remarkably since 2004. This is because in the last few years, there has been a rapid growth in publications coming from China and other Asian countries (Korea, Taiwan and India). China was found to be the leading country with 459 published papers and five authors on the list of the 30 most prolific scientists per number of publications. However, the Western countries also such as the United States, Canada and Europe, along with France, Poland, Italy and Germany have showed a high level of productivity on the basis of other metric indicators. The bibliometric analysis of data shows that the United States is the leading country after which Japan, France, Canada and Poland follow. Other countries such as Korea, Taiwan, India and Italy also have excellent results and appear often in the "top ten" countries or high ranking authors.

Keywords: Supercapacitor; Double layer capacitor; Electrochemical capacitors; Bibliometric analysis; Citation analysis

1. INTRODUCTION

Supercapacitors are electrochemical energy storage devices that provide high power density and remarkable energy density. Because of these characteristics, they are attracting increased interest for many applications such as electric vehicles, power backup systems, and electronic components. Supercapacitors are positioned between batteries and traditional capacitors; specifically they exhibit, a

longer cycling life and power density than batteries, and higher energy density than traditional capacitors.

The first electrochemical supercapacitors were developed by researchers of Standard Oil at the Ohio Research Center in the early 1960s. These researchers discovered that two electrodes of activated carbon immersed in an aqueous electrolyte solution and connected across the terminals of a battery acted as a capacitor. Subsequently, during the 1980s, Matsushita Electric, a Japanese Company, patented a method of manufacturing a type of capacitor called ultracapacitor, which had electrodes with improved features. As engineers and designers became more familiar with the technology, applications proliferated, especially for coin cell type supercapacitors, such as those manufactured by Nippon Electric Company, Elna and Matsushita, all in Japan. Nowadays, coin cell capacitors that are similar in appearance to small button cell batteries are currently used in digital cameras, cell phones, personal digital assistants [PDAs], notebook computers, pagers, etc. In a recent report [1] research showed that in the worldwide market of supercapacitors (2005), about 400 products were available, and these were mainly produced by 14 companies. Most of the products are single-cell units with voltage from 2.3 to 2.7 V. However, a number of companies also offer power products of modular design with voltage up to 450 Vdc. These higher voltage power systems are particularly interesting for electric vehicles and utility applications. Although commercial devices are available [2], their relative high cost (level 0.005 $ /Farad) and low energy density, compared to rechargeable batteries, push academic research towards the development of cheaper, high performance materials and more advanced devices. Specifically, the research of many scientists in the field of supercapacitors has addressed their researches to the development of materials with higher specific capacitances, to the improvement of the design of single-cell devices, and the development of higher voltage, modular products with energy densities close to rechargeable batteries.

To determine who the most active scientists in the field of supercapacitors are and in which countries their research is conducted, we have carried out an accurate analysis of scientific literature in this field. The analysis has also allowed us to highlight the current international status of research in this field.

2. METHODOLOGY

Bibliometric investigation is currently used for evaluating the qualitative and quantitative interest in a specific field through the analysis of publications. This method is currently used in the sciences of information to describe patterns of publications within a given field.

The present study was performed by searching into scopus® database (www.scopus.com; Scopus® is a registered trademark of Elsevier BV Netherlands), inserting a combination of different keywords that helped to identify current literature in the field of supercapacitors; the following keywords in Title-abstracts-keywords were used: **"double layer capacitor" OR "double layer capacitors" OR "Electrochemical capacitor" OR "Electrochemical capacitors" OR supercapacitor OR supercapacitors OR ultracapacitor OR ultracapacitors).** The search was performed on 15 July 2008.

With the data extracted from Scopus, a "supercapacitor" database was created from which different lists of published papers, authors, and countries were generated. The rankings of the authors and countries were determined from the number of papers, citations, Hirsh index, and citations per paper. Very recently, the Hirsch-index (*h*-index) was introduced as a new type of indicator for the quantification of the productivity of researchers [3], and it has been used to perform comparisons between scientific institutions, countries and journals [4-7]. The *h*-index means that, for example, a scientist that has *h*-index = 20 has published 20 papers that have obtained at least 20 citations and that his 21st paper has received less than 21 citations. Here, we have also used the *h*-index to asses the quality and quantity of the scientific output of authors and countries.

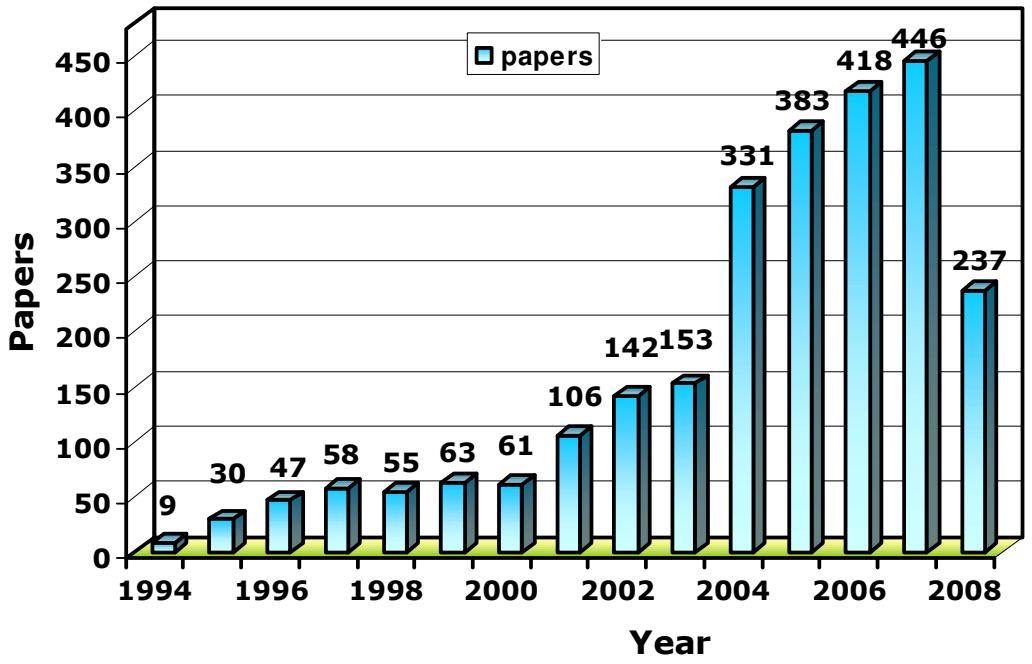

Figure 1. Supercapacitor research publications from 1994 to 2008 on Scopus database (www.scopus.com). The data for 2008 is incomplete (until July, 15).

3. RESULTS AND DISCUSSION

A total of 2593 publications was selected for the analysis, of which 1902 are papers from journals, 588 are publications from conference proceedings, 80 are trade publications and 23 are book series and reports. In addition to these publications, from Scopus another 1438 records were selected, which were papers cited in the references of the above-mentioned 2593 papers but were not present in the database. Most of these records are citations of papers published in conference proceedings or in journals that aren't included in Scopus. As these citations are sometimes incorrect and incomplete, they have not been considered in this analysis. Figure 1 reports the annual production of scientific papers in the field of supercapacitors from 1994 to 2008. From Figure 1, we can observe that there is a

gradual increase in the number of publications from 1994 to 2003 and that in 2004, a strong jump is evident. In 2006 and 2007, 418 and 446 papers were published, respectively, which is about three times what was published in 2003. The growth of scientific publications shows that there is a strong interest in this research subject. From the 2593 papers chosen, scientists were ranked on the basis of their number of papers, citations, Hirsh index and citations per paper. Moreover, analysis of the results shows that the strong growth in the number of papers in the last four years is almost totally due exclusively to scientists in emerging countries such as China, Korea, Taiwan and India.

Table 1. Ranking of top 30 authors for number of publications

Rank	Authors	Pubs	Citations	*h* index	Cites per papers
1	**Hu, C.C.**	49	938	17	19.1
2	**Simon, P.**	33	615	14	18.6
3	**Beguin, F.**	32	992	16	31.0
4	**Frackowiak, E.**	31	1072	19	34.6
5	**Kim, K.B.**	28	292	10	10.4
6	**Li, H.L.**	28	235	6	8.4
7	**Morita, M.**	26	138	8	5.3
8	**Mastragostino, M.**	25	583	13	23.3
9	**Belanger, D.**	25	579	13	23.2
10	**Liang, J.**	25	213	7	8.5
11	**Conway, B.E.**	23	921	13	40.0
12	**Kotz, R.**	23	522	8	22.7
13	**Zheng, J.P.**	22	1256	10	57.1
14	**Takasu, Y.**	22	301	10	13.7
15	**Cao, G.P.**	21	42	3	2.0
16	**Jurewicz, K.**	19	576	12	30.3
17	**Wu, N.L.**	19	182	8	9.6
18	**Yang, Y.S.**	19	46	4	2.4
19	**Wu, F**	19	31	3	1.6
20	**Taberna, P.L.**	18	304	8	16.9
21	**Murakami, Y.**	18	299	10	16.6
22	**Endo, M**	18	195	8	10.8
23	**Naoi, K**	18	114	7	6.3
24	**Popov, BN**	17	459	9	27.0
25	**Miura, N**	17	224	10	13.2
26	**Soavi, F**	16	297	9	18.6
27	**Brousse, T**	16	277	7	17.3
28	**Chang, KH**	16	219	7	13.7
29	**Sugimoto, W**	16	194	8	12.1
30	**Kim, Y.J.**	16	188	7	11.8

Table 1 shows the ranking of the most prolific authors. The number of publications for the first 30 authors range from 49 (the 1st) to 16 (the 30th). The full names, affiliations and countries of the most prolific authors are reported in appendix 1. To individuate the names and affiliations of authors from

far-east Asian countries was quite problematic because these scientists have same family names and abbreviated first names, which are indistinguishable [8].

Table 2. Top 20 most-cited authors.

Rank	Authors	Pubs	Citations	*h* index	Cites per papers
1	**Zheng, J.P.**	22	**1256**	10	57.1
2	**Frackowiak, E.**	31	**1072**	19	34.6
3	**Jow TR**	9	**1072**	7	119.1
4	**Beguin, F.**	32	**992**	16	31.0
5	**Hu, C.C.**	49	**938**	17	19.1
6	**Conway, B.E.**	23	**921**	13	40.0
7	**Simon, P.**	33	**615**	14	18.6
8	**Mastragostino, M.**	25	**583**	13	23.3
9	**Belanger, D.**	25	**579**	13	23.2
10	**Jurewicz, K.**	19	**576**	12	30.3
11	**Ferrarsi, J.P.**	12	**530**	7	44.2
12	**Kotz, R.**	23	**522**	8	22.7
13	**Anderson, M.A.**	7	**490**	4	70.0
14	**Popov, B.N.**	17	**459**	9	27.0
15	**Hyeon, T.**	7	**459**	4	65.6
16	**Fauvarque, J.F.**	13	**436**	11	33.5
17	**Lee, J.**	4	**420**	4	105.0
18	**Gottesfeld, S.**	3	**403**	3	134.3
19	**Arbizzani, C.**	14	**401**	9	28.6
20	**Shi, H.**	2	**395**	2	197.5

Professor Hu Chi-Chang (Taiwan) is the most prolific author with 49 published papers in the field of supercapacitors. In second and third position are two French scientists that have 33 (Simon, P.) and 32 (Beguin, F.) papers, respectively, then a Polish scientist (Frackowiak, E.) with 31 papers. Moreover, analysis of Table 1 indicates that among the 30 most prolific scientists, eight are Japanese, five Chinese, four French, 3 Taiwanese, 2 American, 2 Canadian, 2 Italian, 2 of Polish, 1 Korean and 1 Swiss. Table 2 reports the top score authors for global number of citations. The leader is Prof. Zheng Jainping of the University of Florida, who is followed by Frackowiak Elzbieta of the Poznan University of Technology – Poland, then there is Jow, T.R. who co-author with Zheng, J.P.; Prof. Beguin Francois of the CNRS-University of Orleans, a French scientist, is ranked fifth. The ranking of authors is different if the comparison is made by the Hirsh index. In the rankings of the *h*-index (Table 3), Frackowiak, E., is the first (*h*=19) followed by Hu, C.C. (17) and Beguin, F. (16). The first and third authors in this ranking are often co-authors of publications. This ranking shows Prof. Simon P. (H=14) in fourth place, followed by Prof. Conway. B.E. with *h*=13 then Prof. Mastragostino M. (Italy) and Prof. Belanger D. (*h*=13). Comparing data in Table 3, although there are six scientists with the same Hirsch index (*h*=10), the quality or influence of their papers can not be considered the same because, for example, Prof. Zheng, J.P. has from 4.17 to 5.6 times more citations that the other five

scientists; moreover, he has two papers in the ten most-cited and five in 50 most-cited papers. Thus, the score of Zheng is highly superior to that of other scientists with the same *h*-index. Hence, this is a typical case in which the Hirsh index is misleading for the ranking of authors. This observation is in agreement with some criticisms reported in the literature [9], cases in which where the Hirsch index was found to be an inaccurate tool for comparing the quality of different scientists.

Table 3. Ranking of authors for Hirsch index.

Rank	Authors	Pubs	Citations	*h* index	Cites per papers
1	**Frackowiak, E.**	31	1072	**19**	34.6
2	**Hu, C.C.**	49	938	**17**	19.1
3	**Beguin, F.**	32	992	**16**	31.0
4	**Simon, P.**	33	615	**14**	18.6
5	**Conway, B.E.**	23	921	**13**	40.0
6	**Mastragostino, M.**	25	583	**13**	23.3
7	**Belanger, D.**	25	579	**13**	23.2
8	**Jurewicz, K.**	19	576	**12**	30.3
9	**Fauvarque J.F.**	13	436	**11**	33.5
10	**Zheng, J.P.**	22	1256	**10**	57.1
11	**Takasu, Y.**	22	301	**10**	13.7
12	**Murakami, Y.**	18	299	**10**	16.6
13	**Pell, W.G.**	15	293	**10**	19.5
14	**Kim, K.B.**	28	292	**10**	10.4
15	**Miura, N**	17	224	**10**	13.2
16	**Popov, B.N.**	17	459	**9**	27.0
17	**Arbizzani, C**	14	401	**9**	28.6
18	**Soavi, F**	16	297	**9**	18.6
19	**Kotz, R.**	23	522	**8**	22.7
20	**Fricke, J**	11	349	**8**	31.7
21	**Taberna, P.L.**	18	304	**8**	16.9
22	**Endo, M.**	18	195	**8**	10.8
23	**Sugimoto, W.**	16	194	**8**	12.1
24	**Wu, N.L.**	19	182	**8**	9.6
25	**Morita, M.**	26	138	**8**	5.3

Global analysis of Tab. 1, 2, and 3 shows that the authors Hu C.C., Frackowiak E., Beguin F., and Simon P. are positioned among the top-five in various rankings and that Prof. Zheng, J.P., who is the top scientist for citations, must be recognized as the leading author in the field of supercapacitors. Nevertheless, others scientists with lower scores are listed and are making important contributions to research in this field.

Table 4. Top 20 most-cited papers in the field of supercapacitors.

Rank	Papers	Citations	Country
1	Zheng JP, Cygan PJ, Jow TR. Hydrous ruthenium oxide as an electrode material for electrochemical capacitors. Journal of the Electrochemical Society. 1995;142(8):2699-703.	464	USA
2	Conway BE. Transition from 'supercapacitor' to 'battery' behavior in electrochemical energy storage. Journal of the Electrochemical Society. 1991;138(6):1539-48.	455	Canada
3	Niu C, Sichel EK, Hoch R, Moy D, Tennent H. High power electrochemical capacitors based on carbon nanotube electrodes. Applied Physics Letters. 1997; 70(11):1480-2.	387	USA
4	Attard GS, Bartlett PN, Coleman NRB, Elliott JM, Owen JR, Wang JH. Mesoporous platinum films from lyotropic liquid crystalline phases. Science. 1997 278(5339):838-40.	364	UK
5	Ko□tz R, Carlen M. Principles and applications of electrochemical capacitors. Electrochimica Acta. 2000;45(15-16):2483-98.	361	CH
6	Lao JY, Wen JG, Ren ZF. Hierarchical ZnO nanostructures. Nano Letters. 2002;2(11):1287-91.	309	USA
7	McEwen AB, Ngo HL, LeCompte K, Goldman JL. Electrochemical properties of imidazolium salt electrolytes for electrochemical capacitor applications. Journal of the Electrochemical Society. 1999;146(5):1687-95.	298	USA
8	Zheng JP, Jow TR. New charge storage mechanism for electrochemical capacitors. Journal of the Electrochemical Society. 1995;142(1):L6-8.	292	USA
9	Burke A. Ultracapacitors: Why, how, and where is the technology. Journal of Power Sources. 2000;91(1):37-50.	276	USA
10	Sarangapani S, Tilak BV, Chen C-P. Materials for electrochemical capacitors theoretical and experimental constraints. Journal of the Electrochemical Society. 1996;143(11):3791-9.	256	USA
11	Lee J, Yoon S, Hyeon T, Oh SM, Kim KB. Synthesis of a new mesoporous carbon and its application to electrochemical double-layer capacitors. Chemical Communications. 1999 (21):2177-8.	228	Korea
12	Qu D, Shi H. Studies of activated carbons used in double-layer capacitors. Journal of Power Sources. 1998;74(1):99-107.	225	CA, USA
13	Lev O, Wu Z, Bharathi S, Glezer V, Modestov A, Gun J, Rabinovich L, Sampath S, Sol-gel materials in electrochemistry. Chemistry of Materials. 1997;9(11):2354-75.	218	Israel
14	Pang S-C, Anderson MA, Chapman TW. Novel electrode materials for thin-film ultracapacitors: Comparison of electrochemical properties of sol-gel-derived and electrodeposited manganese dioxide. Journal of the Electrochemical Society. 2000; 147(2):444-50.	205	USA
15	Aricò AS, Bruce P, Scrosati B, Tarascon J.-M., Van Schalkwijk W. Nanostructured materials for advanced energy conversion and storage devices. Nature Materials. 2005;4(5):366-77.	198	IT,UK FR, USA
16	Liu K-C, Anderson MA. Porous nickel oxide/nickel films for electrochemical capacitors. Journal of the Electrochemical Society. 1996;143(1):124-30.	179	USA
17	Rudge A, Davey J, Raistrick I, Gottesfeld S, Ferraris JP. Conducting polymers as active materials in electrochemical capacitors. Journal of Power Sources. 1994;47(1-2):89-107.	178	USA
18	Shi H. Activated carbons and double layer capacitance. Electrochimica Acta. 1996;41(10):1633-9.	170	USA
19	Lee HY, Goodenough JB. Supercapacitor behavior with KCl electrolyte. Journal of Solid State Chemistry. 1999;144(1):220-3.	170	USA
20	Rudge A, Raistrick I, Gottesfeld S, Ferraris JP. A study of the electrochemical properties of conducting polymers for application in electrochemical capacitors. Electrochimica Acta. 1994; 39 (2):273-87.	159	USA

Table 4 reports the 20 most cited papers in field of supercapacitors. The ranking of these papers is a useful tool to know, which papers are basic to the research and which are references, or which authors are more influential in the specific field of supercapacitors. The most cited paper of 20 ranked publications has 464 citations; six papers have more than 300 citations. In total, all 20 papers listed in Table 4 have more of 159 citations and fifteen of these papers and authors have affiliations in the United States. However, to be precise not all these 20 papers have supercapacitors as their specific subject; some are review papers focused on wider topics or are papers on other subjects but they contain one of keywords used in the Scopus search. The papers ranked #4 #6 #13 and #15 are not specific to the field of research in supercapacitors. In fact, it is important to remember that some papers that do not contain at least one of these keyword are not recognized in the "supercapacitors" database. Moreover, the analysis of 2593 publications not includes the citation of the monograph of Prof. Conway, B.E. [10] entitled "Electrochemical Supercapacitors: Scientific Fundamentals and Technological Applications" which, until now, has received more than 910 citations. This book was published in 1999 is a reference text for anyone doing research in this field. Unfortunately, the author, Prof. Conway, passed away on July 9, 2005. He was 78 years old.

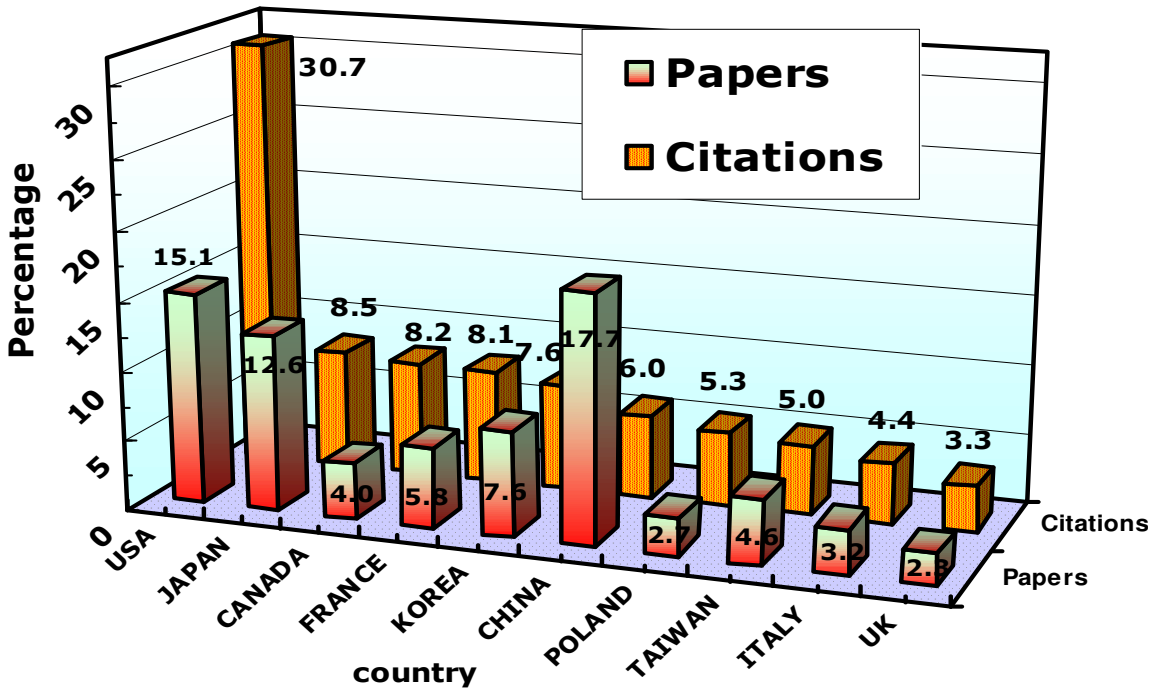

Figure 2. Comparison among top 10 countries ranked for percentage of citations and for percentage of published papers in the field of supercapacitors.

Table 5. Ranking of top 20 countries for number of publications.

Rank	Country	Papers	Citations	h-index	Cites per paper
1	**CHINA**	**459**	1695	20	3.7
2	**UNITED STATES**	**391**	8687	47	22.2
3	**JAPAN**	**327**	2402	25	7.3
4	**KOREA**	**196**	2140	23	10.9
5	**FRANCE**	**150**	2292	27	15.3
6	**TAIWAN**	**120**	1422	22	11.9
7	**CANADA**	**105**	2316	23	22.1
8	**INDIA**	**100**	600	12	6.0
9	**ITALY**	**84**	1234	21	14.7
10	**GERMANY**	**77**	927	16	12.0
11	**POLAND**	**70**	1514	24	21.6
12	**SWITZERLAND**	**59**	895	12	15.2
13	**UNITED KINGDOM**	**59**	945	12	16.0
14	**SPAIN**	**50**	535	14	10.7
15	**AUSTRALIA**	**38**	214	8	5.6
16	**BRAZIL**	**15**	89	6	5.9
17	**SWEDEN**	**14**	164	5	11.7
18	**RUSSIAN FEDERATION**	**13**	11	2	0.8
19	**MEXICO**	**13**	73	6	5.6
20	**ESTONIA**	**12**	85	5	7.1
Total papers	**2593**	**2352**			

After analysis of the results of the search on the basis of scientists and papers, the aggregation of publications from the same country was taken in consideration. China is the top-scoring country with a total of 459 publications, followed by the USA with 391, Japan with 327, Korea with 196, France with 150, Taiwan with 120, and Canada 105. The ranking of the countries changes with the type of indicator, for example, the USA is the country with the highest number of citations (8687) followed by Japan (2402), Canada (2316), France (2292) and Korea (2140). China ranked #6 with a total of 1695 citations. Figure 2 shows the ranking of the 10 most-cited countries for percentage of citations. The percentage of publications for each country is also reported for comparison in the Figure. The ranking for citations shows that the United States has 30.7% of global citations; they are the leading country in this field of research even if countries from the Asian region, such as China, Korea, Taiwan and India, are becoming very active and prolific in terms of publications, as shown in Table 5. Japan is also still a leading country in research field of supercapacitors with 8.5% of global citations. The third country for citations is Canada (8.2), after which France (8.1), Korea (7.6), China (6.0), Poland (5.3), Taiwan (5.0), Italy (4.4) and UK (3.3) follow. Moreover, from the figure, it is evident that nine of the first 20 ranked countries for number of citations are in the European Union and Switzerland. These results indicate that high quality research in this field is coming from Western European countries. Further analysis of this data indicates that outside the big three geographic areas, (North America, Europe and Asia), there are a few other countries (Australia, Brazil, Mexico) with a significant number of publications.

Table 6. Ranking of Top 20 countries for number of citations.

Rank	Country	Papers	Citations	*h*-index	Cites per paper
1	**UNITED STATES**	391	**8687**	47	22.2
2	**JAPAN**	327	**2402**	25	7.3
3	**CANADA**	105	**2316**	23	22.1
4	**FRANCE**	150	**2292**	27	15.3
5	**KOREA**	196	**2140**	23	10.9
6	**CHINA**	459	**1695**	20	3.7
7	**POLAND**	70	**1514**	24	21.6
8	**TAIWAN**	120	**1422**	22	11.9
9	**ITALY**	84	**1234**	21	14.7
10	**UNITED KINGDOM**	59	**945**	12	16.0
11	**GERMANY**	77	**927**	16	12.0
12	**SWITZERLAND**	59	**895**	12	15.2
13	**INDIA**	100	**600**	12	6.0
14	**SPAIN**	50	**535**	14	10.7
15	**AUSTRALIA**	38	**214**	8	5.6
16	**SWEDEN**	14	**164**	5	11.7
17	**AUSTRIA**	10	**152**	4	15.2
18	**BRAZIL**	15	**89**	6	5.9
19	**ESTONIA**	12	**85**	5	7.1
20	**SINGAPORE**	10	**82**	4	8.2
Total papers	**2593**		**28308**		

The ranking of countries by *h*-index reported in Table 7 shows that the United States is in first place with *h*=47, after which France (27), Japan (25), Poland (24), Canada and Korea (23) follow. Taiwan ranks # 7 with *h* = 22, then there is Italy (21), China (20) and Germany (16). A comparison of the productivity of countries for citations per paper is reported in Table 8. The USA is the leading country with 22.2 citations per paper, after which Canada (22.1), Poland (21.6), UK (16) and France (15.3) follow. A graphical comparison of the data from Tables 7 and 8 is reported in 3D bar plots in Figure 3, in which countries are ranked for Hirsch index. The average values of citations per paper are also included for comparison in the same Figure. A visual analysis of the figure shows that there are some countries with huge differences between the Hirsh index and citations per papers. These differences are significant for China, Japan and little less for Korea and indicate that although these countries have a high output of publications and reach a high level in Hirsch index, their papers have received few citations. Also, the United States shows a big difference notwithstanding this it has highest Hirsch index and is the first country for citations per papers. The remaining six countries (in the top-ten) show both high Hirsch index and high value of citations per paper.

Table 7. Ranking of countries for Hirsch index.

Rank	Country	Papers	Citations	h-index	Cites per paper
1	**UNITED STATES**	391	8687	**47**	22.2
2	**FRANCE**	150	2292	**27**	15.3
3	**JAPAN**	327	2402	**25**	7.3
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6	**KOREA**	196	2140	**23**	10.9
7	**TAIWAN**	120	1422	**22**	11.9
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15	**AUSTRALIA**	38	214	**8**	5.6
16	**BRAZIL**	15	89	**6**	5.9
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19	**ESTONIA**	12	85	**5**	7.1
20	**AUSTRIA**	10	152	**4**	15.2
Total papers	**2593**				

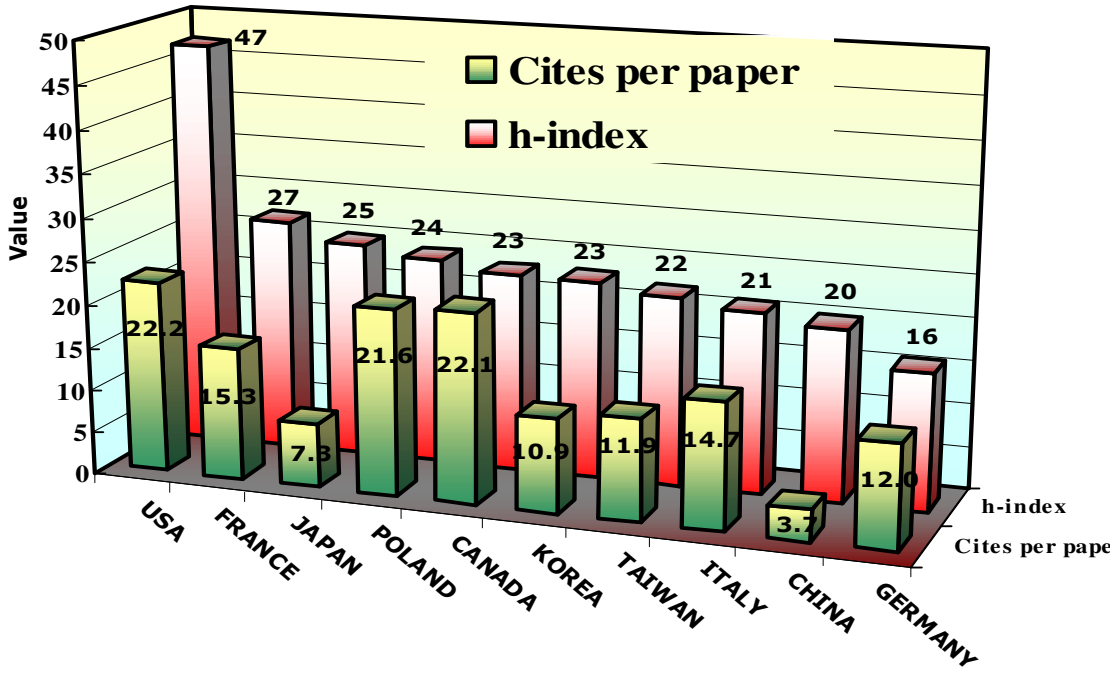

Figure 3. Comparison among top 10 countries ranked for *h*-index. The average values of citations per papers are also enclosed for comparison in the 3D bar plot.

Table 8. Top 20 countries ranked for number of citations per papers.

Rank	Country	Papers	Citations	h-index	Cites per paper
1	**UNITED STATES**	391	8687	47	**22.2**
2	**CANADA**	105	2316	23	**22.1**
3	**POLAND**	70	1514	24	**21.6**
4	**UNITED KINGDOM**	59	945	12	**16.0**
5	**FRANCE**	150	2292	27	**15.3**
6	**AUSTRIA**	10	152	4	**15.2**
7	**SWITZERLAND**	59	895	12	**15.2**
8	**ITALY**	84	1234	21	**14.7**
9	**GERMANY**	77	927	16	**12.0**
10	**TAIWAN**	120	1422	22	**11.9**
11	**SWEDEN**	14	164	5	**11.7**
12	**KOREA**	196	2140	23	**10.9**
13	**SPAIN**	50	535	14	**10.7**
14	**SINGAPORE**	10	82	4	**8.2**
15	**JAPAN**	327	2402	25	**7.3**
16	**ESTONIA**	12	85	5	**7.1**
17	**INDIA**	100	600	12	**6.0**
18	**BRAZIL**	15	89	6	**5.9**
19	**AUSTRALIA**	38	214	8	**5.6**
20	**MEXICO**	13	73	6	**5.6**
Total papers	**2593**				

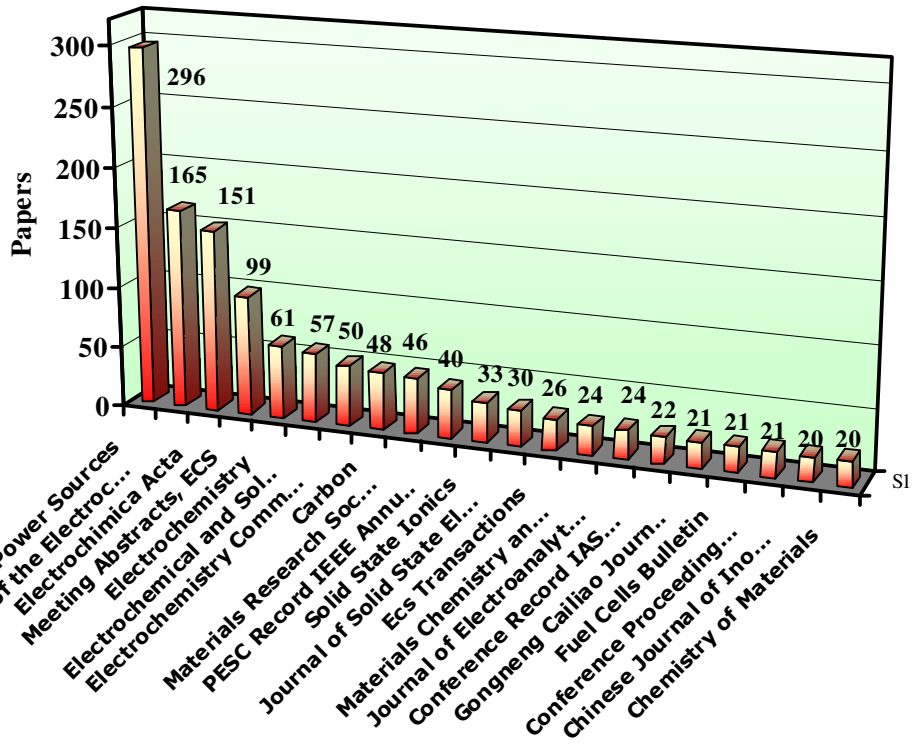

Figure 4. Ranking of journals for number of published papers in the field of supercapacitors from 1980 to July, 15 2008.

Hence, a high volume of data in the Hirsch index and citations per paper seem to be complimentary indicators in terms of measuring the quality and quantity of papers for a country publishes in a specific field of research.

Figure 4 shows the ranking of journals; it is evident in the figure that the highest number of publications in the field has been published in electrochemistry journal. Journal of Power Sources is the top-scoring journal with 296 published papers, after which Journal of the Electrochemical Society (165), Electrochimica Acta (151) and the Meeting abstracts of Electrochemical Society, Electrochemistry (61), Electrochemical Solid State Letters (57), Electrochemistry Communications (50) and Carbon (48) follow.

4. CONCLUSIONS

This study shows that research activities and publishing output in the field of supercapacitors has been increasing significantly especially in the last four years. The most prolific countries for publications fall into following order: China, USA, Japan, Korea, France, Taiwan and Canada. This ranking varies and the United States becomes the leading country whether overall citations (30.7% of total), Hirsh index (h=47) and citations per paper (22.2) are considered. Excellent results have been achieved by countries such as France, Japan, Poland and Canada which are often among the first five in different indicators. Among the 20 most influential countries in terms of quality and quantity of published papers, there are some in the geographic region of North America and Europe but China is the leader for total number of publications and shows the highest rate of annual growth. Other countries in Asia, such as, Korea, Taiwan, and India also show high rates in the increase in publications over the last few years. In many indicators Japan is also a leading country because it has a great number of scientists with high scores for publications and citations. Analysis of the results also shows that countries such as Poland and Taiwan are surprisingly present in many of the rankings in this bibliometric analysis while the United Kingdom and Germany do not hold a prominent position in the top-ranked countries.

References

1. Electrochemical Capacitors for Utility Applications, 1012151, Technical report. EPRI, Palo Alto, CA USA (2005).
2. A. Burke, *Electrochimica Acta* 53 (2007) 1083
3. J.E. Hirsch, *Proc. Natl. Acad. Sci*. USA 102 (46) (2005) 16569.
4. P. Ball, *Nature*, 436 (2005) 900.
5. E. Csajbok, A. Berhidi, L. Vasas, A. Schubert, *Scientometrics*, 73 (1) (2007) 91
6. T. Braun, W. Glanzel, A. Schubert, *Scientometrics*, 69 (1) (2006) 169.
7. A.F.J. van Raan, *Scientometrics*, 67 (2006) 491.
8. J. Qiu, *Nature*, 451 (7180) (2008): 766-7.
9. L. Egghe, *Scientometrics*, 69 (1) (2006) 131.
10. B.E. Conway, Electrochemical Supercapacitors: Scientific Fundamental and Technological Applications, Kluwer Academic/Plenum Press, New York 1999.

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Appendix 1. Full name and affiliation of main authors publishing in the field of supercapacitors.

Rank	Country	Affiliation	Author	Author1
1	Taiwan	National Tsing Hua University, Hsinchu	Hu, Chi Chang	Hu, C.C.
2	France	Université Paul Sabatier, CIRIMAT, CNRS, Toulouse	Simon, Patrice	Simon, P.
3	France	CRMD, CNRS-University, Orleans	Beguin, Francois	Beguin, F.
4	Polad	Poznan University of Technology, Poznan	Frackowiak, Elzbieta	Frackowiak, E.
5	Korea	Yonsei University Seoul	Kim, Kwang Bum	Kim, K.B.
6	China	Lanzhou University, Lanzhou	Li, Hu-Lin	Li, H.L.
7	Japan	Yamaguchi University, Yamaguchi	Morita, Masayuki	Morita, M.
8	Italy	Università di Bologna, Bologna	Mastragostino, Marina	Mastragostino, M.
9	Canada	University of Quebec in Montreal, Montreal	Belanger, Daniel	Belanger, D.
10	China	Tsinghua University, Beijing	Liang, Ji	Liang, J.
11	Canada	University of Ottawa, Ottawa	Conway, Brian E.	Conway, B.E.
12	Switzerland	Paul Scherrer Institut, Villigen PSI	Kotz, Rudiger	Kotz, R.
13	United States	Florida State University, Tallahassee FL	Zheng, Jian ping	Zheng, J.P.
14	Japan	Shinshu University, Ueda	Takasu, Yoshio	Takasu, Y.
15	China	Research Institute Chemical Defense China, Beijing	Cao, GaoPing	Cao, G.P.
16	Polad	Poznan University of Technology, Poznan	Jurewicz, Krzysztof	Jurewicz, K.
17	Taiwan	National Taiwan University, Taipei	Wu, Nae Lih	Wu, N.L.
18	China	Research Institute of Chemical Defense, Beijing	Yang, Yusheng	Yang, Y.S.
19	China	Beijing Institute of Technology, Beijing	Wu, Feng	Wu, F.
20	France	Université Paul Sabatier, CIRIMAT, CNRS Toulouse	Taberna, Pierre Louis	Taberna, P.L.
21	Japan	Shinshu University, Ueda	Murakami, Yasushi	Murakami, Y.
22	Japan	Shinshu University, Matsumoto	Endo, Morinobu	Endo, M.
23	Japan	Tokyo University Agriculture Technology Tokyo	Naoi, Katsuhiko	Naoi, K.
24	United States	University of South Carolina, Columbia	Popov, Branko N.	Popov, B.N.
25	Japan	Kyushu University, Fukuoka	Miura, Norio	Miura, N.
26	Italy	Università di Bologna, Bologna	Soavi, Francesca	Soavi, F.
27	France	l'université de Nantes, Nantes	Brousse, Thierry	Brousse, T.
28	Taiwan	National Chung Cheng University, Chia-Yi	Chang, Kuo-Hsin	Chang, K.H.
29	Japan	Shinshu University, Ueda	Sugimoto, Wataru	Sugimoto, W.
30	Japan	Shinshu University, Matsumoto	Kim, Yong Jung	Kim, Y.J.
31	Canada	University of Ottawa, Ottawa	Pell, Wendy G.	Pell, W.G.
32	Switzerland	Paul Scherrer Institut, Villigen PSI	Hahn, Matthias	Hahn, M.
33	China	Tsinghua University, Beijing	Wang, Xiao Feng	Wang, X.F.
34	Italy	Università di Bologna, Bologna	Arbizzani, Catia	Arbizzani, C.
35	China	Xinjiang University, Urumqi	Zhang, Xiao Gang	Zhang, X.G.
36	France	Laboratoire d'Electrochimie Industrielle, CNAM, Paris	Fauvarque, Jean Francois	Fauvarque, J.F.
37	United States	University California Davis,	Burke, Andrew F.	Burke, A. F.
38	China	Xiangtan University, Xiangtan	Li, Jun	Li, J.
39	United States	University of Texas at Dallas, Richardson, TX	Ferraris, John Patrick	Ferraris, J.P.
40	Germany	Universitat Wuurzburg, Wurzburg	Fricke, Jochen	Fricke, J.
41	Polad	Poznan University of Technology, Poznan	Lewandowski, Andrzej	Lewandowski, A.
42	Korea	Seoul National University, Seoul	Hyeon, Taeghwan	Hyeon, T.
43	Korea	Seoul National University, Seoul	Lee, Jinwoo	Lee, Y.H.
44	United States	Consultant	Gottesfeld, Shimshon	Gottesfeld, S.