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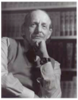
NEW TOOLS FOR NAVIGATING THE MATERIALS SCIENCE LITERATURE*



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Good afternoon. I would like to thank Rustum Roy for inviting me to participate in this symposium. As many of you may know, Rustum has been an outspoken advocate of the ethical responsibilities of research scientists toward the vast archive of published knowledge. Rightly so, he has championed the idea that it is a professional duty of publishing scientists to actively search the literature-and explicitly cite relevant prior sources. The current controversy over biomimesis notwithstanding, he has consistently advocated an important ethical point. Scientists are indeed obliged to know, and check, the published record in conducting their research.

Since I started out 40 years ago as an information scientist, I've believed that authors should be held by journal editors to the same "due diligence" standards required by U.S. patent examiners of inventors. That is, authors should formally assert to their best

Address at the Materials Research Society Meeting, November 29, 1993, Boston, Massachusetts.

knowledge that their ideas are original. This implies they do not duplicate discoveries already filed in the archives. Consequently, authors should be required to acknowledge the “prior art” that influenced their research directly or indirectly.

This concept may soon become a reality. Representative George Brown, Chairman of the House Committee on Science, Space, and Technology, is considering legislation that would require researchers to formally state they had completed a literature search as part of their grant proposals. These developments indicate a widespread perception within the scientific community that researchers today are failing to search and cite the older literature. These feelings parallel similar perception of widespread misconduct.

What are the facts? The *Science Citation Index* consistently demonstrates that in very year from 1964 to 1992, 50 percent of the millions of references each year are to papers published in the previous 6 to 7 years. And 90 percent are to papers published in the last 25 to 30 years. These data suggest that not much has changed in the citation behavior of publishing scientists over the past three decades. As in earlier decades, the majority of citations are to relatively current papers. But authors also continue to cite relatively older works-in fact, 10 percent of references cited were published 25 years or more ago.

Keep in mind that these data are for science as a whole. It might be possible that in materials science or other disciplines, the age distribution of the cited literature may be different, perhaps been skewed towards more current publications. As an example, the following table shows the citation distribution for the Journal of *Materials Science,* one of the highest impact journals in the field.

FIG. 1: 1992 *JCR* Citing Journal Listing

This table is taken from the 1992 Journal *Citation Reports (JCR)* that accompany the *Science Citation Index (SCI).* The first line shows the total number of references cited by this journal in 1992, followed by the number or each year in reverse chronological order in 1992, 1991, and so on. As you can see, there were 18,400 cited references in the 1992 Journal of Science. Of these, about 9,300 (50 percent) were to papers published over the last 10 years. The remaining 50 percent were older than 10 years. This would suggest that materials science is not significantly different than other fields in the age distribution of its cited references. So perceptions of changed citation behavior may not conform to reality.

But getting back to our discussion-of the many reasons why scientists should get into the habit of literature searching, the most obvious is to avoid the unwitting duplication of research-and the wasted time, effort, and research funds such duplication involves. This is not a new but rather long-standing problem.

In 1964, John Martyn showed how unintentional duplication of research is related to ignored or missed sources in the literature. He surveyed about 650 British scientists and asked if they had later discovered information in the literature they wished they had at the beginning of their projects. Twenty-two percent said yes and cited 245 specific instances. Of these, 18 percent involved unintentional research duplication. And in 43 percent of these instances, the researchers felt that time, money, or work was wasted.

It would be relevant to fund a follow-up study. And there are other methods for obtaining a quantitative basis to verify-or challenge-the general impression that researchers today are remiss in searching and citing the literature.

What perhaps has discouraged authors from searching the literature in the past was the time and effort involved in using the then available printed indexes to Chemical *Abstracts, Physics Abstracts, Engineering Abstracts,* etc. While electronic on-line access in the 1970s made it easier for researchers to search the literature, they continued to rely on library specialists to deal with the techno-Babel of search languages "spoken" by each database.

However, the revolution in personal computer and compact disk (CD-ROM) technologies has enabled researchers for the first time to access-directly, conveniently, and rapidly-vast bibliographic databases. These technologies also offer many more search options than are available with printed indexes. To demonstrate this, I will use ISI's new *Materials Science Citation Index (MSCI)* on CD-ROM with

S C I J O U R N A L C I T A T I O N R E P O R T S

V. CITING JOURNAL LISTING 1992

	CITING JOURNAL / CITED JOURNAL	TOTAL	1992	1991	1990	1989	1988	1987	1986	1985	1984	1983	REST
		<-----			NUMBER OF TIMES THIS YEAR WAS CITED IN 1992								----->
.79	J MATER SCI	18434*	===85	==423	=1064	=1388	=1366	=1229	=1121	==971	==841	==797	=9149
.79	J MATER SCI	1355	47	76	117	123	101	111	88	74	69	45	504
1.68	J AM CERAM SOC	1121	----0	---20	---89	--129	---75	---48	---71	---63	---63	---39	--524
1.97	ACTA METALL MATER	441	2	6	20	39	31	34	21	25	27	28	208
1.53	J APPL PHYS	432	----0	---11	---22	---17	---24	---21	---10	---13	---17	---17	--280
1.36	METALL TRANS A	323	0	12	23	26	26	21	17	20	21	19	138
1.17	J NON-CRYST SOLIDS	273	----0	----1	---12	----8	---28	---18	---31	---16	---18	---18	--123
.51	J MATER SCI LETT	245	1	16	31	40	30	29	34	21	17	10	16
1.33	SCRIPTA METALL MATER	214	----0	----9	---32	---48	---15	---19	---18	----6	---15	---11	---41
.50	AM CERAM SOC BULL	205	0	1	7	13	14	21	26	19	4	21	79
3.25	PHYS REV B	203	----0	----3	---10	---19	---30	---28	----6	----4	----9	---17	---77
1.62	J ELECTROCHEM SOC	175	3	4	15	2	3	8	13	11	6	2	108
1.36	JPN J APPL PHYS	165	----0	----1	----7	---13	---67	---19	----1	----4	----5	----5	---43
	MATER SCI ENG	158	0	0	0	0	29	9	16	17	9	4	74
1.54	POLYMER	131	----1	----3	----4	----4	---13	----8	----8	----8	----7	---19	---56
1.02	THIN SOLID FILMS	131	0	1	2	2	6	8	1	12	7	17	75
3.43	J CHEM PHYS	127	----0	----0	----0	----0	----1	----2	----0	----2	----3	----3	--116
.96	J APPL POLYM SCI	124	2	3	3	9	10	7	4	5	4	7	70
3.53	APPL PHYS LETT	121	----0	----3	---15	----9	---19	---18	----6	----3	----7	----4	---37
1.52	J POLYM SCI POL PHYS	110	2	2	1	5	0	3	6	5	4	9	73
.94	POLYM ENG SCI	109	----0	----4	----3	----9	---10	----8	----5	----6	----3	----2	---59
	T AIME	105	0	0	0	0	0	0	0	0	0	0	105
	PHILOS MAG	100	----2	----0	----0	----0	----1	----0	----0	----0	----0	----1	---96
	ADV CERAM	94	0	0	0	0	11	8	2	2	39	9	23
7.37	PHYS REV LETT	92	----0	----0	----1	----3	----2	---22	----4	----8	----5	----2	---45
1.36	SOLID STATE COMMUN	87	0	0	6	3	14	12	1	1	4	4	42
1.59	J CRYST GROWTH	86	----0	----3	----2	----4	----6	----5	----4	----4	----5	----4	---49
	MATER RES SOC S P	86	0	0	10	11	20	14	13	5	12	1	0
.49	PHYS STATUS SOLIDI A	86	----0	----2	----4	----8	----7	----2	----6	----8	----4	----5	---40
.68	Z METALLKD	85	0	5	3	2	2	1	1	3	3	2	63
	ASTM SPEC TECH PUBL	84	----0	----0	----1	----2	----1	----4	----9	----5	----3	----6	---53
.80	MAT SCI ENG A-STRUCT	84	1	17	20	33	13	0	0	0	0	0	0
22.13	NATURE	82	----0	----1	----3	----3	----6	----4	----2	----2	----1	----1	---59
1.42	J COLLOID INTERF SCI	80	0	1	1	6	1	4	4	2	2	5	
.11	WELD J	79				----1	----4	----4	----7	----4	----1	----?	
1.67	P ROY SOC LOND A MAT						3	2	0	0	0		
.68	JOM-J MIN MET MAT						-7	---10	----6	----1	---		
	MET SCI							0	0				

FIG. 1

Non-journal materials like books or proceedings may be much more used in materials sciences; see full tables to get *totals* for "other."

abstracts. Following this demonstration, I'll illustrate how ISI's databases can be used to identify the most-cited materials science papers of the past decade as well as the most productive and highest impact nations and institutions.

The *MSCI* was launched a little over a year ago to meet the specific information needs of materials science researchers. It fully covers more than 400 of the leading journals in this specialty, including many publications and conference material not covered as sources in the *Science Citation Index*. Additionally, the *MSCI* includes selective coverage of the thousands of other source journals in ISI's database. A variety of algorithmic selection criteria are used. On an annual basis, the MSCI indexes about 90,000 papers together with author abstracts in English.

I'd like to deflate a few popular myths about the scientific literature. We are all familiar with the claims that researchers are being overwhelmed by a flood of millions of papers published in many thousands of journals every year. A popular-but unsubstantiated-estimate claims that there are 40,000 scientific journals in existence today. However, this estimate includes not just primary research journals but also trade publications, popular magazines, newsletters, annual reports, and so on. Without a proper definition, both quantitative and qualitative, these estimates of primary research journals are meaningless. The reason is simple: ISI's data consistently show that a comparatively small number of journals accounts for the majority of both what is published and what is cited. This is demonstrated in the following graph.

FIG. 2: Source / Citation Concentration, 1989 *JCR*

The data shown here are based on about 4,500 journals that were covered in the 1989 ***SCI*** *Journal Citation Reports*. The dotted line shows that just 100 journals account for more than 20 percent of what is published. Even more interesting, the solid line shows that 100 journals also account for more than 40 percent of what is *cited*. Only 600 journals account for more than half of what is published—and over 75 percent of what is cited. Keep in mind that the source

Distribution of published items and citations among science journals, 1989 SCI.

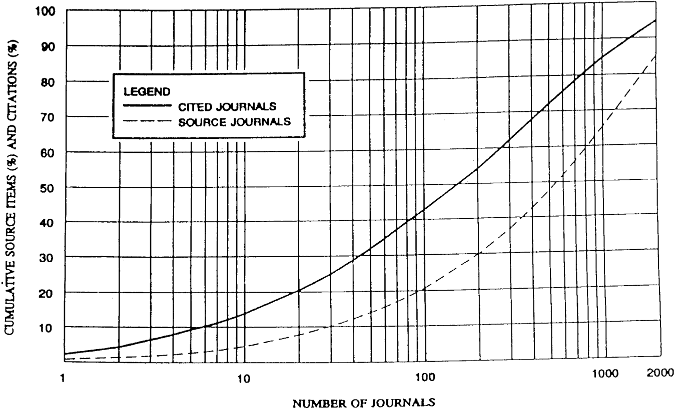

FIG. 2

and cited journals are not necessarily one and the same. In any case, by indexing 7,000 journals, IS1 is confident that it is capturing the most significant journals of international research.

Let's now move on to demonstrate how the Materials Science Citation Index can help you navigate the literature of this research specialty. The following examples use the latest edition of the *MSCI,* covering the first eight months of 1993.

FIG. 3: ***MSCI*** CD-ROM Opening Screen

This is the opening screen for a search session on the *MSCI* CD-ROM. It automatically starts with the "Basic Index" search. This allows you to simultaneously search terms that appear either as title words or author-supplied keywords, or ISI's unique Key Words Plus, or in the author's abstract.

And there are other search options. These can be seen by selecting the "Fields" option from the menu at the bottom of the screen.

FIG. 4: ***MSCI*** CD-ROM Search Fields

In addition to the "Basic Index" field, you can also search separately for title words, by author keywords, KeyWords Plus or abstract text. Other search fields include author name, cited author or cited reference, author address, abbreviated and full journal title. The last field is used to combine sets.

Key Words Plus is an innovative search capability that represents a breakthrough in information discovery and retrieval. It is designed to help overcome the limitations of traditional title-word and author-keyword indexing by more fully describing what a paper is about. It does so by automatically supplying additional search terms taken from the titles of papers cited by authors in their references. These titles are retrieved from ISI's data bank. The KeyWords Plus terms are selected by an algorithm that parses title words or phrases, groups them by frequency of occurrence, identifies the most significant terms, and adds them as descriptors to the source paper record. KeyWords Plus terms not only provide a more complete description of the source

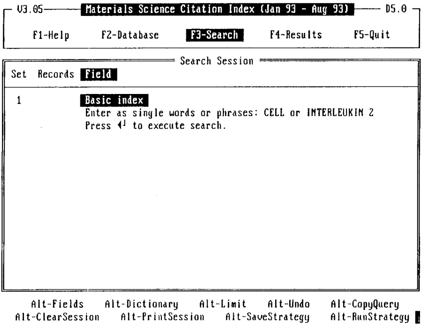
V3.05
Materials Science Citation Index (Jan 93 - Aug 93)
D5.0
F1-Help
F2-Database
F3-Search
F4-Results
F5-Quit
Search Session
Set Records Field
1
Basic index
Enter as single words or phrases: CELL or INTERLEUKIN 2
Press ↵ to execute search.
Alt-Fields Alt-Dictionary Alt-Limit Alt-Undo Alt-CopyQuery
Alt-ClearSession Alt-PrintSession Alt-SaveStrategy Alt-RunStrategy

FIG. 3

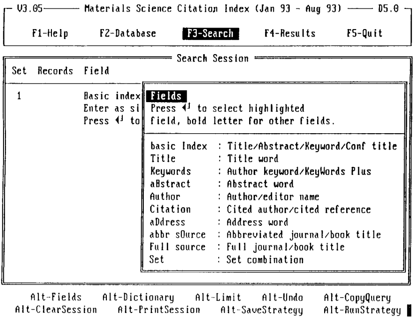
V3.05
Materials Science Citation Index (Jan 93 - Aug 93)
D5.0
F1-Help
F2-Database
F3-Search
F4-Results
F5-Quit
Search Session
Set Records Field
1
Basic index
Enter as si
Press ↵ to
Fields
Press ↵ to select highlighted
field, bold letter for other fields.
basic Index : Title/Abstract/Keyword/Conf title
Title : Title word
Keywords : Author keyword/KeyWords Plus
aBstract : Abstract word
Author : Author/editor name
Citation : Cited author/cited reference
aDdress : Address word
abbr sOurce : Abbreviated journal/book title
Full source : Full journal/book title
Set : Set combination
Alt-Fields Alt-Dictionary Alt-Limit Alt-Undo Alt-CopyQuery
Alt-ClearSession Alt-PrintSession Alt-SaveStrategy Alt-RunStrategy

FIG. 4

paper, they also reveal topical or methodological aspects that would otherwise go unnoticed. These points will be illustrated later.

Let's now conduct a "Basic Index" search of the *MSCI* CD-ROM. Our search example will focus on light-emitting polymers, a currently "hot" topic. This was recently identified by *Science Watch, ISI's* monthly subscription report on citation-based trends in research.

FIG. 5: Sample Search Statement

In this example, we have used Boolean logic and root truncation to retrieve all papers whose titles, keywords, or abstract words include all three terms shown here: LIGHT, any variants of EMI* (such as emit, emits, emitted, emitting, emission, and so on), and any variants of POLYMER*.

The search could be limited by language and/or type of document by selecting the "Limit" option at the bottom of the screen. That is, you can specify the retrieval of only those papers published in English, French, German, Russian or 15 other languages. And you can specify the retrieval of only original research papers, review articles, correction or retraction notices, or 13 other types of source items.

However, we will not limit the search in this example. By simply hitting the "Enter" key, the computer searches and retrieves all papers with these terms.

FIG. 6: Number of Hits Displayed

In virtually an instant, the computer displays 47 "hits" that match our search statement. By simply pressing the F4 key, the first record in this set will be displayed.

FIG. 7: First Sample Hit-M. Uchida et al.

Complete bibliographic information is provided-all authors; full article title; language and type of document; complete journal title; volume, issue, page spread, and year; the *Genuine Article* number in parentheses, which can be used to order a reprint through ISI's document delivery service; and the number of references and Related Records. Related Records are another innovative tool for information discovery and retrieval, which will be discussed later.

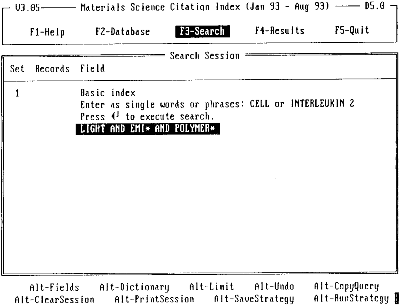
V3.05 Materials Science Citation Index (Jan 93 - Aug 93) D5.0
F1-Help F2-Database F3-Search F4-Results F5-Quit
Search Session
Set Records Field
1 Basic index
Enter as single words or phrases: CELL or INTERLEUKIN 2
Press ↵ to execute search.
LIGHT AND EMI* AND POLYMER*
Alt-Fields Alt-Dictionary Alt-Limit Alt-Undo Alt-CopyQuery
Alt-ClearSession Alt-PrintSession Alt-SaveStrategy Alt-RunStrategy

FIG. 5

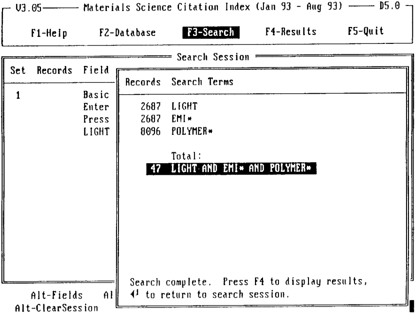
V3.05 Materials Science Citation Index (Jan 93 - Aug 93) D5.0
F1-Help F2-Database F3-Search F4-Results F5-Quit
Search Session
Set Records Field
1 Basic
Enter
Press
LIGHT
Records Search Terms
2687 LIGHT
2687 EMI*
8096 POLYMER*
Total:
47 LIGHT AND EMI* AND POLYMER*
Search complete. Press F4 to display results,
↵ to return to search session.
Alt-Fields Al
Alt-ClearSession

FIG. 6

As you can see, the record display also highlights our search terms in the paper's title. We can view the paper's abstract and keyword by selecting the relevant option at the bottom of the screen.

FIG. 8: KW/Abstract Display for M. Uchida et al.

The search terms are also highlighted here in the paper's keywords and abstract. The authors have provided many keywords, but half of them already appear in the title—"color-variable light emitting diode" and "conducting polymer." ISI has supplied two ***Key Words Plus*** terms—"electroluminescent diodes" and "films." These suggest other useful terms to expand our search—electroluminescent is synonymous with light-emitting. Following these keywords, the complete abstract is displayed.

We can quickly see where the authors are based by selecting the "Addresses" option on the MSCI CD-ROM.

```
V3.05——— Materials Science Citation Index (Jan 93 - Aug 93) ——— D5.0

   F1-Help     F2-Database     F3-Search     F4-Results     F5-Quit

Set 1: Basic index
LIGHT AND EMI* AND POLYMER*
                     Records: 1 of 47
                                                              <PgUp>
 Uchida-M  Ohmori-Y  Noguchi-T  Ohnishi-T  Yoshino-K

 Color-Variable Light-Emitting Diode Utilizing Conducting Polymer
 Containing Fluorescent Dye (English) => Article

 JAPANESE JOURNAL OF APPLIED PHYSICS PART 2-LETTERS
 Vol 32  Iss 7A  pp L921-L924  1993 (LL371)




 Related Records: 20    Cited References: 17
                                                              <PgDn>

   citedRefs     aBstract/Keywords     Addresses     publ/confereNce
        RelatedRecords      View      Collect      Print      Save
```

FIG. 7

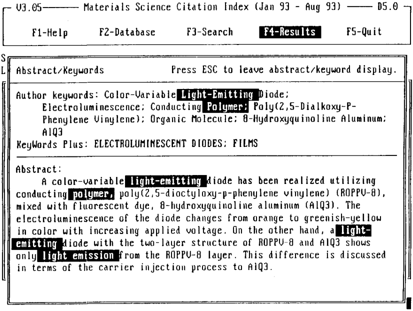
V3.05 Materials Science Citation Index (Jan 93 - Aug 93) D5.0
F1-Help F2-Database F3-Search F4-Results F5-Quit
Abstract/Keywords Press ESC to leave abstract/keyword display.
Author keywords: Color-Variable Light-Emitting Diode; Electroluminescence; Conducting Polymer; Poly(2,5-Dialkoxy-P-Phenylene Vinylene); Organic Molecule; 8-Hydroxyquinoline Aluminum; AlQ3
KeyWords Plus: ELECTROLUMINESCENT DIODES; FILMS
Abstract:
A color-variable light-emitting diode has been realized utilizing conducting polymer, poly(2,5-dioctyloxy-p-phenylene vinylene) (ROPPV-8), mixed with fluorescent dye, 8-hydroxyquinoline aluminum (AlQ3). The electroluminescence of the diode changes from orange to greenish-yellow in color with increasing applied voltage. On the other hand, a light-emitting diode with the two-layer structure of ROPPV-8 and AlQ3 shows only light emission from the ROPPV-8 layer. This difference is discussed in terms of the carrier injection process to AlQ3.

FIG. 8

FIG. 9: Address Display for M. Uchida et al.

The authors are affiliated with Osaka University and the Sumitomo Chemical Company, Ibaraki, Japan. We can also check the address of the journal publisher, which is useful when you want subscription or other information.

FIG. 10: Publisher/Conference Address Display

A complete address is provided, along with the ISSN serial number for the journal. If the paper has been presented at a conference, the title of the conference, location, dates, and sponsors would be displayed for easy reference.

Let's now view another paper from the set of 47 articles on light-emitting polymers.

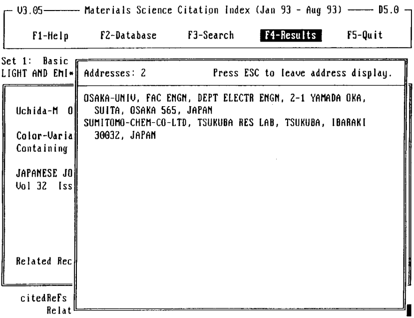
V3.05 Materials Science Citation Index (Jan 93 - Aug 93) D5.0
F1-Help F2-Database F3-Search F4-Results F5-Quit
Set 1: Basic
LIGHT AND EMI*
Addresses: 2 Press ESC to leave address display.
OSAKA-UNIV, FAC ENGN, DEPT ELECTR ENGN, 2-1 YAMADA OKA,
SUITA, OSAKA 565, JAPAN
SUMITOMO-CHEM-CO-LTD, TSUKUBA RES LAB, TSUKUBA, IBARAKI
30032, JAPAN
Uchida-M O
Color-Varia
Containing
JAPANESE JO
Vol 32 Iss
Related Rec
citedRefs
Relat

FIG. 9

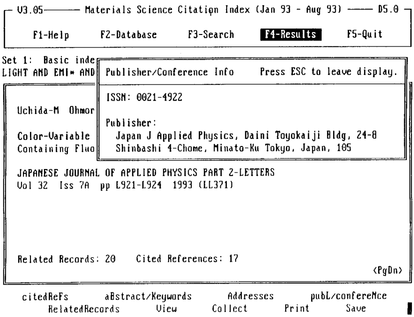
V3.05 Materials Science Citation Index (Jan 93 - Aug 93) D5.0
F1-Help F2-Database F3-Search F4-Results F5-Quit
Set 1: Basic inde
LIGHT AND EMI* AND
Publisher/Conference Info Press ESC to leave display.
ISSN: 0021-4922
Publisher:
Japan J Applied Physics, Daini Toyokaiji Bldg, 24-8
Shinbashi 4-Chome, Minato-Ku Tokyo, Japan, 105
Uchida-M Ohmor
Color-Variable
Containing Fluo
JAPANESE JOURNAL OF APPLIED PHYSICS PART 2-LETTERS
Vol 32 Iss 7A pp L921-L924 1993 (LL371)
Related Records: 20 Cited References: 17
<PgDn>
citedRefs aBstract/Keywords Addresses publ/confereNce
RelatedRecords View Collect Print Save

FIG. 10

FIG. 11: Second Sample Hit-D. Braun et al,

This paper is by D. Braun and colleagues at the University of California at Santa Barbara. One of the co-authors, Alan Heeger, discovered a class of conjugated polymers that could act like metals or semiconductors while working at the University of Pennsylvania with Alan MacDiarmid and Hideki Shirakawa. This discovery was one of the early advances leading up to current work on light-emitting polymers.

With the *MSCI* CD-ROM, you can view the references cited by a paper. This is done simply by selecting the "CitedRefs" option at the bottom of the screen.

FIG. 12: References Displayed for D. Braun et al.

The screen shows all 15 references cited by Braun and colleagues. You can automatically do a citation index search on any of the references shown here simply by scrolling down to the desired reference and hitting the return kev. The computer will then retrieve all other records in the database which cited that reference.

The Related Records feature is a powerful tool that exploits the associations and connections made by authors in the references they cite. Related records searching is based on the principle of "bibliographic coupling," which identifies current papers that cite one or more references in common. While hundreds of papers may be related by bibliographic coupling, ISI's algorithm limits retrieval to the 20 papers most strongly coupled by shared references.

The unique advantage of Related Records searching-like all citation-based searching-is that it can retrieve relevant articles regardless of whether they have any title words in common. And it permits you to navigate from one interesting connection to another.

When you select the "RelatedRecords" option, the computer will retrieve other papers in the database that are coupled bibliographically by one or more shared references. The related records are displayed in descending order of the number of shared references.

```
V3.05 ——— Materials Science Citation Index (Jan 93 - Aug 93) ——— D5.0

   F1-Help     F2-Database     F3-Search     F4-Results     F5-Quit

Set 1:  Basic index
LIGHT AND EMI* AND POLYMER*
=========================== Records:  2 of 47 ===========================
                                                                  <PgUp>
  Braun-D  Moses-D  Zhang-C  Heeger-AJ

  Nanosecond Transient Electroluminescence from Polymer Light-Emitting-
  Diodes  (English)  => Article

  APPLIED PHYSICS LETTERS
  Vol 61  Iss 26  pp 3092-3094  1992 (KD924)



  Related Records: 20    Cited References: 15
                                                                  <PgDn>

   citedRefs      aBstract/Keywords      Addresses      publ/confereNce
        RelatedRecords      View      Collect      Print      Save
```

FIG. 11

```
V3.05 ——— Materials Science Citation Index (Jan 93 - Aug 93) ——— D5.0

   F1-Help     F2-Database     F3-Search     F4-Results     F5-Quit

Set 1:  Basic inde
LIGHT AND EMI* AND  Press ↵ to search on highlighted reference.
                    Press ESC to leave cited reference display.
                    Cited References: 15
 Braun-D  Moses-
                    ADACHI-C-1990-APPL-PHYS-LETT-V57-P531
 Nanosecond Tran    BRAUN-D-1991-APPL-PHYS-LETT-V58-P1982
 Diodes  (Englis    BRAUN-D-1992-J-APPL-PHYS-V72-P564
                    BROWN-AR-0000-IN-PRESS-APPL-PHYS-L
 APPLIED PHYSICS    BURN-PL-1992-J-CHEM-SOC-CHEM-COMM-V32
 Vol 61  Iss 26     BURN-PL-1992-NATURE-V356-P47
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                    GREM-G-1992-ADV-MATER-V4-P36
                    GUSTAFSSON-G-1992-NATURE-V357-P477
                    HOSOKAWA-C-1992-APPL-PHYS-LETT-V60-P1220
                    MOORE-JH-1989-BUILDING-SCI-APPARAT-P372
 Related Records    OHMORI-Y-1991-JPN-J-APPL-PHYS-V30-P1941
                    OHMORI-Y-1991-SOLID-STATE-COMMUN-V80-P605
                    OHMORI-Y-1992-JPN-J-APPL-PHYS-V31-PL568
  citedRefs         WONG-KS-1987-J-PHYS-C-SOLID-STATE-V20-PL187
     RelatedRe
```

FIG. 12

FIG. 13: First Related Record for D. Braun et al.

The first related paper is also by the same authors. Of the 18 references cited, 11 were also cited in the parent paper. Notice that the title includes our search terms, which are highlighted So it would have also turned up in the list of 47 papers retrieved by the title word search. However this is not the case for the next related record.

FIG. 14: Second Related Record for D. Braun et al.

This paper is by A. Kraft and colleagues at Cambridge University, England. Note that its title does not include any of our search terms. It cited 22 references, of which 8 were also cited by Braun. And by using the "SharedRefs" option, those 8 references cited in common can be displayed.

Let's view its abstract to learn more about it.

```
V3.05 —— Materials Science Citation Index (Jan 93 - Aug 93) —— D5.0

   F1-Help     F2-Database     F3-Search     F4-Results     F5-Quit

Parent Record:  2 of 47
Braun-D  Nanosecond Transient Electroluminescence from Polymer Light-Emittin...
                         Related Records: 1 of 20          (Level 1)

  Braun-D  Moses-D  Zhang-C  Heeger-AJ

  Transient Electroluminescence from Polymer Light-Emitting-Diodes
  (English)  => Article

  SYNTHETIC METALS
  Vol 57  Iss 1  pp 4145-4150  1993 (LK890)




  Related Records: 20    Cited References: 18    Shared References: 11
                                                                  <PgDn>

citedReFs    sHaredRefs    aBstract/Keywords    Addresses    pubL/confereNce
     RelatedRecords     View     Collect     Print     Save     MakeSet
```

FIG. 13

```
V3.05——— Materials Science Citation Index (Jan 93 - Aug 93) ——— DS.0

   F1-Help      F2-Database      F3-Search      F4-Results      F5-Quit

Parent Record: 2 of 47
Braun-D  Nanosecond Transient Electroluminescence from Polymer Light-Emittin...
═══════════════ Related Records: 3 of 20 ═══════════ (Level 1)
                                                            <PgUp>
 Kraft-A  Burn-PL  Holmes-AB  Bradley-DDC  Brown-AR  Friend-RH  Gymer-RW

 Chemical Control of Color and Electroluminescent Device Efficiency in
 Copolymeric Poly(Arylenevinylenes) (English)  => Article

 SYNTHETIC METALS
 Vol 55  Iss 2-3  pp 936-941  1993 (LH620)




 Related Records: 20    Cited References: 22    Shared References: 8
                                                            <PgDn>

citedRefs    sHaredRefs    aBstract/Keywords    Addresses    publ/confereNce
     RelatedRecords    View    Collect    Print    Save    MakeSet
```

FIG. 14

FIG. 15: KW/Abstract Display for A. Kraft et al.

The author-supplied keywords do not include any of our search terms. But note that the ***KeyWords Plus*** terms include them all, as indicated by highlights. That is, by another citation-based search connection, this paper has been identified as relevant to the topic of light-emitting polymers. However, this paper would not have been retrieved by traditional title word, author keyword, or abstract word searches.

Let's move on to another related record.

FIG. 16: Third Related Record for D. Braun et al.

This paper by G. Gustafsson and colleagues, including Alan Heeger, at the UNIAX Corporation in Santa Barbara, which was founded by Heeger in 1990 to produce and market conjugated polymers. The title suggests another useful term to expand our search-plastic, which is synonymous with polymer, and LED, the acronym for light-emitting diode.

```
V3.05——— Materials Science Citation Index (Jan 93 - Aug 93) ——— D5.0

F1-Help     F2-Database     F3-Search     F4-Results     F5-Quit

P
B Abstract/Keywords          Press ESC to leave abstract/keyword display.

Author keywords: Poly(P-Phenylenevinylene); Poly(2,5-Dimethoxy-P-
    Phenylenevinylene); Copolymer; Electroluminescence
KeyWords Plus: LIGHT-EMITTING-DIODES; POLYMERS

Abstract:
    We report here that copolymeric poly(arylenevinylenes) have
considerable advantages over their corresponding homopolymers in
electroluminescent devices. We focus on the organic chemistry aspects of
the design and properties of poly(p-phenylenevinylene)-based copolymer
derivatives, especially poly(p-phenylenevinylene)/poly(2,5-dimethoxy-p-
phenylenevinylene) copolymers and partially converted poly(p-
phenylenevinylene).
```

FIG. 15

```
V3.05——— Materials Science Citation Index (Jan 93 - Aug 93) ——— D5.0

F1-Help     F2-Database     F3-Search     F4-Results     F5-Quit

Parent Record: 2 of 47
Braun-D  Nanosecond Transient Electroluminescence from Polymer Light-Emittin...
═══════════════ Related Records: 13 of 20 ═══════════ (Level 1)
                                                                  <PgUp>
Gustafsson-G  Treacy-GM  Cao-Y  Klavetter-F  Colaneri-N  Heeger-AJ

The Plastic LED - A Flexible Light-Emitting Device Using a Polyaniline
Transparent Electrode  (English)  => Article

SYNTHETIC METALS
Vol 57  Iss 1  pp 4123-4127  1993 (LK890)

Related Records: 20    Cited References: 10    Shared References: 5
                                                                  <PgDn>

citedRefs    sHaredRefs    aBstract/Keywords    Addresses    publ/confereNce
    RelatedRecords    View    Collect    Print    Save    MakeSet
```

FIG. 16

I should point out that a paper retrieved by Related Records searching can itself be the subject of a Related Records search. For example, there are 20 related records linked by bibliographic coupling with this Gustafsson paper. In fact, Related Records searching can be iterated through five stages or levels. The next example shows a related record linked to the Gustafsson paper.

FIG. 17: First Related Record to Gustafsson

This paper is by N. S. Sariciftci and colleagues at UC-Santa Barbara, including Heeger and Braun. Interestingly, this paper makes a connection between light-emitting polymers and buckminsterfullerene, another very hot area of current research following the discovery of this third natural form of carbon in 1985 by Harold Kroto, University of Sussex, England, and Richard Smalley and colleagues at Rice University. By examining the 20 records related to it by bibliographic coupling, we could identify another 7 papers directly relevant to buckyballs and light-emitting polymers.

```
V3.05——— Materials Science Citation Index (Jan 93 - Aug 93) ——— D5.0

   F1-Help     F2-Database     F3-Search     F4-Results     F5-Quit

Parent Record: 13 of 20
Gustafsson-G  The Plastic LED - A Flexible Light-Emitting Device Using a Pol...
═════════════════ Related Records: 11 of 20 ═════════════ (Level 2)
                                                                  <PgUp>
  Sariciftci-NS  Braun-D  Zhang-C  Srdanov-VI  Heeger-AJ  Stucky-G  Wudl-F

  Semiconducting Polymer-Buckminsterfullerene Heterojunctions - Diodes,
  Photodiodes, and Photovoltaic Cells  (English)  => Article

  APPLIED PHYSICS LETTERS
  Vol 62  Iss 6  pp 585-587  1993 (KK924)




  Related Records: 20    Cited References: 20    Shared References: 4
                                                                  <PgDn>

citedRefs    sHaredRefs    aBstract/Keywords    Addresses    publ/confereNce
     RelatedRecords    View    Collect    Print    Save    MakeSet
```

FIG. 17

Let's return now to our original search set and examine another retrieved record.

FIG. 18: Third Sample Hit-F. Meyers et al.

This paper is by F. Meyers and Heeger at UC-Santa Barbara, and J. L. Bredas at the University of Mons Hainaut, Mons, Belgium. Note that none of our search terms appear in the title. Let's now display its abstract.

FIG. 19: KW/Abstract Display for F. Meyers et al.

The author-supplied also do not include our search terms. However, all the search terms do appear as KeyWords Plus terms. In addition, the search terms also appear in the abstract. The obvious overlap demonstrates the relevance of KeyWords Plus terms to the content of the paper.

Let's move on to another "hit" from the search set.

Navigating the Materials Science Literature

```
V3.05 —— Materials Science Citation Index (Jan 93 - Aug 93) —— D5.0

   F1-Help     F2-Database     F3-Search     F4-Results     F5-Quit

Set 1:  Basic index
LIGHT AND EMI* AND POLYMER*
                         Records: 3 of 47
                                                                  <PgUp>
  Meyers-F  Heeger-AJ  Bredas-JL

  Electronic-Structure of Conjugated Regular Copolymers - Fine-Tuning of
  Band-Gap Value  (English)  => Article

  SYNTHETIC METALS
  Vol 57  Iss 2-3  pp 4308-4313  1993 (LP138)




  Related Records: 20    Cited References: 11
                                                                  <PgDn>

   citedReFs      aBstract/Keywords      Addresses      publ/confereNce
       RelatedRecords      View      Collect      Print      Save
```

FIG. 18

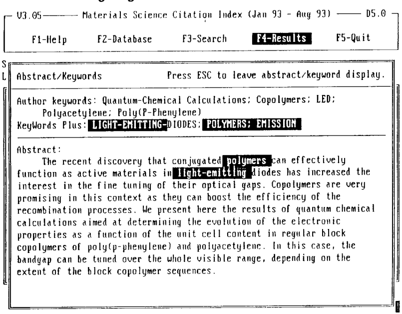
V3.05 Materials Science Citation Index (Jan 93 - Aug 93) D5.0
F1-Help F2-Database F3-Search F4-Results F5-Quit
Abstract/Keywords Press ESC to leave abstract/keyword display.
Author keywords: Quantum-Chemical Calculations; Copolymers; LED; Polyacetylene; Poly(P-Phenylene)
KeyWords Plus: LIGHT-EMITTING-DIODES; POLYMERS; EMISSION
Abstract:
The recent discovery that conjugated polymers can effectively function as active materials in light-emitting diodes has increased the interest in the fine tuning of their optical gaps. Copolymers are very promising in this context as they can boost the efficiency of the recombination processes. We present here the results of quantum chemical calculations aimed at determining the evolution of the electronic properties as a function of the unit cell content in regular block copolymers of poly(p-phenylene) and polyacetylene. In this case, the bandgap can be tuned over the whole visible range, depending on the extent of the block copolymer sequences.

FIG. 19

FIG. 20: Fourth Sample Hit-R. 0. Garay et al.

This paper is by R. 0. Garay and colleagues at the Max Planck Institute for Polymer Research, Mainz, Germany. The title does not include any of our original search terms. Let's now display its abstract.

FIG. 21: KW/Abstract Display for R. 0. Garay et al.

As you can see, no author keywords are provided. This makes the ***KeyWords Plus*** terms even more valuable as additional descriptors of the paper's content. Indeed, seven ***Key WordsPlus*** terms have been added, which include all of the original search terms. The abstract also includes the search terms, again confirming the relevance of ***KeyWords Plus*** terms as subject descriptors for this paper.

Let's move on to the final record from our search set.

```
V3.05 —— Materials Science Citation Index (Jan 93 - Aug 93) —— D5.0

   F1-Help     F2-Database     F3-Search     F4-Results     F5-Quit

Set 1:  Basic index
LIGHT AND EMI* AND POLYMER*
                              Records:  4 of 47
                                                              <PgUp>
  Garay-RO  Baier-U  Bubeck-C  Mullen-K

  Low-Temperature Synthesis of Poly(P-Phenylenevinylene) by the Sulfonium
  Salt Route  (English)  => Note

  ADVANCED MATERIALS
  Vol 5  Iss 7-8  pp 561-564  1993 (LQ704)




  Related Records: 20    Cited References: 24
                                                              <PgDn>

  citedReFs      aBstract/Keywords       Addresses      publ/confereNce
       RelatedRecords       View      Collect      Print      Save
```

FIG. 20

```
V3.05 —— Materials Science Citation Index (Jan 93 - Aug 93) —— D5.0

   F1-Help     F2-Database     F3-Search     F4-Results     F5-Quit

S
L Abstract/Keywords          Press ESC to leave abstract/keyword display.

  KeyWords Plus: NONLINEAR OPTICAL-PROPERTIES; LIGHT-EMITTING-DIODES;
     POLY(PARA-PHENYLENE VINYLENE); ELECTRONIC-PROPERTIES; CONJUGATED
     POLYMERS; ELIMINATION; FILMS

  Abstract:
     Poly(p-phenylenevinylene), PPV, is one of the most promising
  candidates among the conjugated polymers for use in all-optical signal
  processing or as the active layer in light emitting diodes. Here, a low-
  temperature route to PPV is reported which makes the synthesis compatible
  with many of the thermoplastic polymers used in microelectronics and
  optics. The applicability of this route to device fabrication is also
  addressed.
```

FIG. 21

FIG. 22: Fifth Sample Hit—S. Maiti et al.

This is a review paper by S. Maiti and colleagues at the Indian Institute of Technology, West Bengal. The title itself is rather brief and uninformative, indicating only that the paper is an overview on conducting polymers. Let's display its abstract to see how much more information is provided.

FIG. 23: KW/Abstract Display for S. Maiti et al.

All of our original search terms only appear among the *KeyWords Plus* terms assigned to this paper. The abstract is rather brief but still informative. But note that there are almost as many *KeyWords Plus* terms as there are abstract words. This illustrates a point I've often made previously—that *KeyWords Plus* terms in effect are a "mini-abstract." They add significantly to the vocabulary of words and phrases which describe a paper more fully, and they increase your ability to retrieve papers relevant to your interests.

We could continue to explore other features and capabilities offered by the *Materials Science Citation Index*. But time is running short and I think this demonstration has made its point. That is, citation-based searching on ISI's CD-ROM databases offer unique, convenient, and effective new tools for information discovery and knowledge navigation.

Having reviewed the use of *MSCI* for information discovery and recovery, I'd like to conclude with a few illustrations of how citation data are used for research analyses and evaluation. The examples will be taken from more than 150 journals included under the "materials science" category of *Current Contents* (CC). The time period covered will be 1981-1992 to give a *current* citationist perspective on the field. This materials science database includes more than 161,000 papers.

Let's begin by examining the most-cited materials science papers during this period.

```
V3.05 ——— Materials Science Citation Index (Jan 93 - Aug 93) ——— D5.0

  F1-Help      F2-Database      F3-Search      F4-Results      F5-Quit

Set 1:  Basic index
LIGHT AND EMI* AND POLYMER*
                              Records:  5 of 47
                                                              <PgUp>
  Maiti-S  Rahman-MDS  Kundu-S

  Conducting Polymers - An Overview  (English)  => Review

  BULLETIN OF ELECTROCHEMISTRY
  Vol 8  Iss 11  pp 556-573  1992 (LU133)



  Related Records: 20    Cited References: 286
                                                              <PgDn>

  citedRefs      aBstract/Keywords      Addresses      publ/confereNce
      RelatedRecords      View      Collect      Print      Save
```

FIG. 22

```
V3.05 ——— Materials Science Citation Index (Jan 93 - Aug 93) ——— D5.0

  F1-Help      F2-Database      F3-Search      F4-Results      F5-Quit

S
L Abstract/Keywords          Press ESC to leave abstract/keyword display.

  Author keywords: Conducting Polymer; Electrochemical Polymerization;
      Plasma Polymerization; Molecular Electronics
  KeyWords Plus: FIELD-EFFECT TRANSISTOR; SODIUM-DOPED POLYACETYLENE;
      ELECTRON-SPIN-RESONANCE; METAL-LIKE CONDUCTIVITY; MULTILAYER THIN-
      FILMS; LIGHT-EMITTING-DIODES; CONJUGATED POLYMERS; POLYSULFUR
      NITRIDE; MOLECULAR-WEIGHT; BLOCK COPOLYMERS

  Abstract:
      Conducting polymers are novel class of compounds and find
  applications in various fields such as battery, sensors, biological,
  microelectronics etc. This review presents an extensive account of their
  preparation, properties, conducting mechanism and applications.
```

FIG. 23

FIG. 24A: Most-Cited Mat Sci Papers, 1981-1992

In this series of tables are listed 22 papers published from 1981 through 1992 that received at least 160 citations during this period.

The most-cited paper is by A. Ishizaka and Y. Shiraki of the Hitachi Corporation, Tokyo. It concerns a method for surface cleaning of silicon and its use in silicon molecular beam epitaxy (MBE). Published in 1986, it has received 327 citations through 1992.

In the time remaining, we can only scan the titles of the papers on these tables. Most of you are better familiar with the topics covered here so my comments will focus on bibliographic details.

As you can see, three of the most-cited papers shown here are by authors based in Japan. For the 22 most-cited papers, 15 were by authors based in the U.S. Japan follows with 4 papers. The following nations each accounted for one: Australia, India, and the U.K.

FIG. 24B: Most-Cited Mat Sci Papers, 1981-1992 (cont.)

The 22 most-cited materials science papers were published in 11 journals. The *Journal of the Electrochemical Society* accounted for 5 papers. The following journals each accounted for 3 papers: *Journal of the American Ceramic Society, Journal of Vacuum Science and Technology A-Vacuum Surfaces and Films,* and the *Journal of Materials Science.* Two papers each were published in the *Journal of Vacuum Science & Technology B-Microelectronics Processing and Phenomena* and *Thin Solid Films.* The following journals published one each: *Advanced Ceramic Materials, IEEE Transactions on Magnetics, Progress in Materials Science,* and *Solar Energy Materials.*

FIG. Most-Cited Mat Sci Papers, 1981-1992 (cont.)

This table shows the remaining most-cited materials science papers for the period 1981-1992.

It is relatively straightforward to derive various rankings from these lists of papers. In the following table, the most-productive nations are listed, ranked by the number of papers they produced in the *entire* materials science database of 161,000 papers.

Most-Cited Materials Science Papers, 1981-1992 SCI

Cites	Bibliographic Data
327	Ishizaka A & Shiraki Y. Low-temperature surface cleaning of silicon and its application to silicon MBE._*J. Electrochem. Soc.* 133:666-71, 1966. Hitachi Ltd., Tokyo, Japan
324	Anstis GR, Chantikul P, Lawn BR & Marshall DB. A critical evaluation of Indentation techniques for measuring fracture toughness. 1. Direct crack measurements._*J. Am. Ceram. Soc .* 64:533-8, 1961. Univ New South Wales, Kensington, Australia
314	Takayanagi K, Tanishiro Y, Takahashi M & Takahashi S. Structural analysis of Si(lll)-7x7 by UHV transmission electron diffraction and microscopy. *J. Vacuum Sci. Tech. A* 3:1502-6, 1965. Tokyo Inst Technol, Japan
279	Bean JC, Feldman LC, Flory AT, Nakahara S & Robinson IK. Ge_xSi_{1-x}/Si strained layer superlattice grown by molecular beam epltaxy. *J. Vacuum Sci. Tech. A 2:436-40,* 1984. AT&T Bell Labs, Murray Hill, NJ
270	Sagawa M, Fujimura S, Yamamoto H, Matsuura Y & Hiraga K. Permanent magnet material based on the rare earth-Iron-boron tetragonal compounds. *IEEE Trans. Magnetics 20:1584-9, 1984.* Sumitomo Special Metals Co Ltd, Osaka, Japan Tohoko Univ, Miyagl, Japan
253	Fritrsche H. Characterization of glow discharge deposited A-Si-H. *Solar Energy Mater. 3:447-501,* 1960. Univ. Chicago, IL
239	Nigrey PJ, Macinnes D, Nairns DP, MacDiarmid AG & Heeger AJ. Lightweight rechargeable storage batteries using polyacetylene, $(CH)_x$ as the cathode-active material.*J. Electrochem. Soc.* 126:1651-4, 1961. Univ. Pennsylvania, Philadelphia

Ma

Most-Cited Materials Science Papers, 1981-l 992 SC/ (Cont.)

Cites	Bibliographic Data
233	Ehrlich DJ & Tsao JY. A review of laser-microchemical processing. *J. Vacuum Sci.* Tech. *B 1:969-84,* 1983. MIT, Lincoln Lab, Lexington, MA
227	Johnson WL. Thermodynamic and kinetic aspects of the crystal-to-glass transformation in metallic materials. *Prog. Material Sci.* 30:81-134, 1986. Caltech, Pasadena, CA
226	Roth RS, Davis KL & Dennis JR. Phase equilibria and crystal chemistry in the system Ba-Y-Cu-0. Adv. Ceramic Mater. 2:303-12, 1987. Natl Bureau Standards (NBS), Gaithersburg, MD
217	Aspnes DE. Optical propertles of thin films. *Thin Solid Films* 89:249-62, 1982. Bell Tel Labs Inc, Murray HIll, NJ
211	McMeeking RM & Evans AG. Mechanics of transformation toughening in brittle materials. *J. Am. Ceramic Soc. 65:242-6,* 1982. Univ Illinois, Urbana UC-Berkeley, CA
196	Van Hove JM, Lent CS, Puklte PR& Cohen PI. Damped oscillations In reflection high-energy electron diffraction during GaAs MBE. *J. Vacuum Sci. Tech. B* 1983. Unlv Mlnnesota, Minneapolis
193	Bull RA, Fan FRF & Bard AJ. Polymer films on electrodes. 7. Electrochemical behavior at polypyrrole-coated platinum and tantalum electrodes. *J. Electrochem. Sac.* 129:1009-15, 1982. Unlv Texas, Austln
189	Matsumoto S, Sato Y, Tsutsumi M & Setaka N. Growth of diamond particles from methane- hydrogen gas. *J. Mater. Sci.* 17:3108-12, 1982. *Inst* Res lnorgan Mat (NIRIM), Ibaraki, *Japan*

FIG. 24B

Most-Cited Materials Science Papers, 1981-1992 *SCI* (Cont.)

Cites	Bibliographic Data
188	Gibbs MRJ, Evetts JE & Leake JA. Activation energy spectra and relaxation in amorphous materials. *J. Mater. Sci.* 18:278-88, 1983. Univ Cambridge, England
180	Chopra KL, Major S & Pandya DK. Transparent conductors—a status review. *Thin Solid Films* 102:1-46, 1983. Indian Inst Technol, New Delhi
178	Coltrin ME, Kee RJ & Miller JA. A mathematical model of the coupled fluid mechanics and chemical kinetics In a chemical vapor deposition reactor. *J. Electrochem. Soc.* 131:425-34, 1984. Sandia Natl Labs, Llvermore, CA
174	Tsai HC & Bogy DB. Characterization of diamondlike carbon films and their application as overcoats on thin film media for magnetic recording. *J. Vacuum Sci. Tech.* A 5:3267-312, 1967. UC-Berkeley, CA
166	Reep DH & Ghandhl SK. Deposition of GaAs epitaxlal layers by organometallic CVD-temperature and orientation dependence. *J. Electrochem. Soc.* 130:675-80, 1963. Rensselaer Polytech Inst, Troy, NY
166	Lange FF. Transformation toughening. 1. Size effects associated with the thermodynamics of constralned transformation. *J. Mater. Sci.* 17:225-34, 1962. Rockwell Intl Corp, Thousand Oaks, CA
162	Marshall DB & Evans AG. Failure mechanisms in ceramic fiber ceramic matrix composites. *J. Am. Ceram. Soc.* 68:225-31, 1985. Rockwell Intl Corp UC-Berkeley

FIG. 24C

FIG. 25: Most-Productive Nations, 1981-1992

Twenty-two nations that produced at least 1000 materials science papers during the period 1981-1992 are listed. As you can see, the U.S. accounted for the most papers. Authors based in the U.S. appeared on 61,000 papers that received 236,000 citations, giving an overall impact of 3.87.

Japan is the second most-productive nation with about 17,000 papers. The old Federal Republic of Germany and the United Kingdom are next, each with more than 10,000 papers. However, the overall impact of U.K. papers (3.19) is appreciably higher than that of Germany (2.50).

The following table identifies the highest impact nations in the materials science database.

FIG. 26: Highest Impact Nations, 1981-1992

The table shows 24 nations that published at least 250 papers over the 12-year period and achieved an impact of at least 2.0. By setting a threshold of 250 or more papers, we effectively “censor” the occasional statistical “outliei’-that is, nations that may achieve high impact on the basis of just a few highly cited papers.

The rankings here are significantly different than in the previous table of the most-productive nations. The highest impact nation is the Netherlands, with a 12-year impact of 4.02. While it ranks first on impact, the Netherlands ranked 13th in terms of productivity.

The U.S. is second with an impact of 3.87, and Australia and Israel have virtually the same impact-3.35 and 3.33, respectively.

Nine of the highest impact nations listed here were not among the most-productive nations in the previous table. They are indicated by asterisks-Argentina (3.231, Denmark (3.221, Austria (2.651, Belgium (2.58), Hungary (2.52), South Africa (2.31), Norway Greece (2.04), and New Zealand (2.01)

The following table identifies the most-productive *institutions in* the 1981-1992 materials science database.

Highest Output Nations in Materials Science, 1981-1992 SCI

Rank	Nation	1981 Papers	1981-92 Citations	1982-92 Impact
1	US	61,117	236,426	3.87
2	Japan	16,941	54,201	3.20
3	FRG	11,190	27,920	2.50
4	UK	10,587	33,735	3.19
5	USSR	9513	2619	
6	Canada	6428	16,085	2.50
7	France	6235	19,648	3.15
8	India	5997	11,029	1.84
9	Italy	2530	7331	2.90
10	Australia	2269	7592	3.35
11	Sweden	2236	6956	3.11
12	PRC	2098	2311	1.10
13	Netherlands	1855	7464	4.02
14	Poland	1636	3316	2.03
15	Czechoslovakia	1630	2433	1.49
16	GDR	1612	3263	2.02
17	Switzerland	1569	4621	2.95
18	Taiwan (ROC)	1296	2008	1.55
19	Israel	1279	4261	3.33
20	Spain	1245	3086	2.48
21	Egypt	1040	1246	1.20
22	Finland	1010	1974	1.95

FIG. 25

Highest Impact Nations in Materials Science, 1981-1992 SC/ (at least 250 papers)

Rank	Nation	1981-1992 Impact	1981-1992 Papers	1981-1992 Citations
1	Netherlands	4.02	1855	7464
2	US	3.87	61,117	236,426
3	Australia	3.35	2269	7592
4	Israel	3.33	2269	7592
5	*Argentina	3.23	397	1263
6	*Denmark	3.22	430	1383
7	Japan	3.20	16,941	54,201
8	UK	3.19	10,587	33,735
9	France	3.15	6235	19,648
10	Sweden	3.11	2236	6956
11	Switzerland	2.95	1569	4621
12	Italy	2.90	2530	7331
13	*Austria	2.65	724	1917
14	*Belgium	2.58	850	2190
15	*Hungary	2.52	424	1069
16	Canada	2.50	6428	16,085
17	FRG	2.50	11,190	27,920
18	Spain	2.48	1245	3086
19	*South Africa	2.31	564	1302
20	*Norway	2.23	327	728
21	*Greece	2.04	398	811
22	Poland	2.03	1636	3316
23	GDR	2.02	1612	3263
24	*New Zealand	2.01	373	750

FIG. 26

FIG. 27: Most-Productive Institutions, 1981-1992

Twenty-three institutions that published at least 750 papers are listed. IBM is the most productive, with 3,000 papers that received 21,000 citations for an overall impact of 7.06. The former Academy of Sciences of the USSR ranks second with 2,700 papers, but its impact is rather low-0.56. Of course, since the independence of the former Soviet republics, ISI is separately indexing papers produced at the science academies of each new nation. However, it has only been about two years since these republics have gained their independence-too short a time for them to have produced enough papers to appear in these rankings.

In addition to IBM, three other corporations are listed: AT&T Bell Labs (#6, 1,308 papers); General Electric (#9, 1,162 papers); and Hitachi (#19, 785 papers).

Also, several government agencies and national labs are listed: U.S. Navy (#7, 1,288 papers); Sandia National Labs (#ll, 1,009 papers); NASA (#14, 930 papers); Oak Ridge National Lab (#20, 782 papers); and Australia's Commonwealth Scientific and Industrial Research Organization (#22, 755 papers).

Let's now identify the highest impact institutions in the 1981-1992 materials science database.

FIG. 28: Highest Impact Institutions, 1981-1992

Twenty-four institutions that published at least 250 papers during this period and achieved an impact of at least 5.0 are listed. Of these, 16 institutions did not rank among the 23 most-productive institutions in the previous table, and they are indicated by asterisks. In fact, the six highest impact institutions shown here were not among the most productive-Xerox Corporation (10.411, Bell Telephone Labs (9.67), Rockwell International (9.451, Princeton University (8.371, UC-Santa Barbara (8.03), and Caltech (7.25).

This concludes our demonstration of new electronic tools for navigating the materials science literature, and our brief citationist perspective on the field. I hope this presentation has been successful in showing you how flexible, effective, and easy it is today for

Highest Output Institutions in Materials Science, 1981-1992 SC/

Rank	Institution	1981-92 Papers	1981-92 Citations	1982-92 Impact
1	IBM Corp	3020	21,328	7.06
2	Acad Sci USSR	2735	1531	.56
3	Indian Inst Tech	1829	4092	2.24
4	UC-Berkeley	1504	7961	5.29
5	MIT	1498	8308	5.55
6	AT&T Bell Labs	1308	6419	4.91
7	US Navy	1288	5253	4.08
8	Pennsylvania State Univ	1174	5281	4.50
9	GE Corp	1162	4633	3.99
10	Univ Illinois	1067	5604	5.25
11	Sandia Natl Labs	1009	5006	4.96
12	Stanford Univ	978	6870	7.02
13	Tohoku Univ	970	6077	6.26
14	NASA	930	3466	3.73
15	Tokyo Inst Tech	917	3321	3.62
16	Kyoto Univ	905	2708	2.99
17	North Carolina State Univ	855	3805	4.45
18	Univ Tokyo	813	2448	3.01
19	Hitachi Ltd	785	2992	3.81
20	Oak Ridge Natl Lab	782	4007	5.12
21	Max Planck Insts	767	4618	6.02
22	CSIRO (Australia)	755	2718	3.60
23	Case Western Reserve Univ	754	3374	4.47

FIG. 27

Highest Impact Institutions in Materials Science, 1981-1992 SC/ (at least 250 papers)

Rank	Institution	1981-1992 Impact	1981-1992 Papers	1981-1992 Citations
1	*Xerox Corp	10.41	365	3388
2	*Bell Tel Labs Inc	9.67	698	6751
3	*Rockwell Intl Corp	9.45	562	5310
4	*Princeton Univ	0.37	290	2420
5	*UC-Santa Barbara	8.03	296	2378
6		7.25	552	4001
7	IBM Corp	7.06	3020	21,320
8	*Natl Bureau Standards	7.04	678	4770
9	Stanford Univ	7.02	970	8870
10	‘Philips Res Labs	6.50	603	3918
11	Tohoku Univ	6.26	970	6077
12	Max Planck Insts	6.02	767	4618
13	*Cornell Univ	5.63	712	4005
14	MIT	5.55	1498	8308
15	*Solar Energy Res Inst (Colorado)	5.41	254	1373
16	*Univ Pennsylvania	5.34	377	2013
17	UC-Berkeley	5.29	1504	7961
	*Univ Minnesota	5.29	542	2869
19	*Nippon Telegraph & Telephone	5.25	542	2847
20	Univ Illinois	5.25	1067	5604
21	*Univ Cambridge	5.13	565	2901
22	Oak Ridge Natl Lab	5.12	782	4007
23	*Exxon Corp	5.09	323	1645
24	*Univ Wisconsin	5.04	711	3582

FIG. 28

researchers to discover and recover relevant information from the published literature.

By exploiting new personal computer and CD-ROM technologies, researchers can explore the literature without the technical assistance of information specialists-and in the convenience of their offices and labs. With the availability of these databases, there is no reason why researchers should not be able to identify-and formally acknowledge-the “prior art” that has contributed to their current work.

Having recently returned from a series of lectures at undergraduate colleges, it is clear that the problem begins with teaching. That is, too few colleges require undergraduates to learn how to search the literature. But with proper mentoring, students should come to graduate school already “conditioned” to do “prior art” searching-and practice these techniques throughout their research careers, whether in academia or industry.