CHAPTER 5

MAJOR FINDINGS AND CONCLUSION

5.1 INTRODUCTION

This chapter deals with the major finding of the study pertaining to the literature in MEMS based on the analysis and interpretation discussed in the previous Chapter 4. The findings pertain to the comparison of the top countries, citation, uncitations on MEMS literature shows the impact of the literature growth.

5.2 MAJOR FINDINGS

5.2.1 General

- SCOPUS database has been taken up for the study. SCOPUS is an international database which contains 45.5 million records, 70% with abstracts and covering nearly 19,500 titles from 5,000 publishers worldwide, includes over 4.6 million conference papers, offers sophisticated tools to track analyzed and visualized research.

5.2.2 Year Wise

- A total of 2,94,573 contributions can be seen on MEMS during the period of 44 years (i.e.) 1970-2013. The cumulative output of MEMS are increasing every year by one percentage from 1970 to 1996 and further there was an increase of 3% and above till
2013. The Ratio of Growth is very high in the year 1996. The CAGR values are high between the years 1983 and 1995. The last two years had shown the minus value (Table. 4.1).

- The block year wise calculations, one fourth publications published in the third block years and two third of publications in the fourth block. It is noticed that CAGR is very high in the first block years, RoG and AAGR are very high during the third block. Years.(Table 4.2)

- RGR value is high in the year 1974 and 1996, otherwise the trend is decreasing in peak years. Dt() is in increasing trend from 1970 to 1984 and fluctuated during the period upto 1996 and fell down to 3.12 again showing an increasing trend (Table 4.3 and Figure 4.4).

- RGR is in increasing trend whereas Dt() is in decreasing trend pertaining to the block year wise study concerned (Table 4.4 and Figure 4.5).

### 5.2.3 Country Wise

- Out of these contributions, USA contributed 25.74% of the total publications which tops the rank; India’s contribution is 2.33% and holds 9th rank among the top 10 countries (Table 4.5 and Figure 4.6)

- It is found that less than 1000 publications are from the countries like UK, Italy, Canada, India and Brazil during the study period (Table 4.6).
The output reaches maximum in the fourth block years i.e. 2003-2013 (Table 4.7 and Figure 4.7).

The Growth Ratio during the period 1981-2013 is low compared to the period 2003-2013 (Table 4.8 and Figure 4.8).

The Activity Index (AI) was peak in 1st Block of United States (233.09%) and followed by second block of France (185.45), again second block of US (150.80) and fourth block of China (144.96). More than 100% of AI is shown in the second block of Canada, third block of US, France, India and Brazil, and almost all countries in the fourth blocks (Table 4.9 and Figure 4.9).

### 5.2.4 Language Wise

The maximum of 81.6% of the total research output were only in English. This is followed by Chinese (1.8%) and Japanese (0.4%) Languages (Table 4.10 and Figure 4.10).

The maximum of 81.6% of the total research output were only in English. This is followed by Chinese (1.8%) and Japanese (0.4%) Languages (Table 4.10 and Figure 4.10).

Less than 100 publications have been published in the languages except Chinese and English only after 1996 onwards. Less than 1000 publications are seen only in Chinese language during 2004 – 2013 (Table 4.11).

9% of the total publications in the fourth block period were published in languages other than English (Table 4.12).
• The United States scientists published their articles in Chinese, Japanese, German, Russian, French, Korean, Spanish, etc. In the case of India, it can be seen that the publication appeared in Chinese, Japanese, German, Russian and Spanish. It can be indicated that publication existed other than English language too (Table 4.13).

5.2.5 Bibliographic Form Wise

• More than half of the contributions (66.80%) are journal articles, and 22.55% were conference papers. By and large it is found that the scholarly communication of MEMS research output is mostly through journals and conferences (Table 4.14 and Figure 4.11).

• Journal articles are very high in the fourth block years (40%). It is followed by the third block of journal articles and the fourth block of conference papers are 19.84 and 19.69 respectively (Table 4.15).

• Journal articles are predominant in MEMS irrespective of the countries (Figure 4.12). It is followed by Conference paper, Review, Book Chapter, Conference Review, Editorial, short survey, Book, Note, Letter, and Report are less contribution on MEMS irrespective of the country (Table 4.16 and Figure 4.12).

5.2.6 Authorship Pattern

• 14.1% of the publications are from single author and the remaining are collaboration in nature and the contributions are as follows: two authors (21.8%), three authors (18.8%) and four authors (16.3%) respectively (Table 4.17 and Figure 4.13).
Collaborative coefficient for all the years was below 0.67 except in the year 1998. The collaborative coefficient for the year 1987 is 0.49, for 1974 is 0.44 and for the year 1973 is 0.42. This reveals that the research persist in these years (Table 4.18 and Figure 4.14).

Authorship pattern indicators are in increasing trends in the block years (Table 4.19 and Figure 4.15).

The degree of collaboration between top countries ranges between 0.82 and 0.94. The collaborative research is more in China. The collaborative index among top countries lies between 2.88 and 3.61. Similarly the collaborative coefficient ranges between 0.55 and 0.66 (Table 4.20 and Figure 4.16).

**5.2.7 Co-authorship Index Vs Year**

Co-authorship Index for single author papers was 293 in the 1970 which enhanced to 362 in the 1971. Subsequently it shows the declining trend wherein it was 56 in 2013 (Table 4.21)

Publications by single authored are dominant up to the year 2005 and then it has been co-authored with three and four authorship. The collaboration exists only in the single, two and three authors only (Table 4.22).

CAI is in the range of 87 to 113 in US, in France the range between 84 and 100, in China it is between 42 and 117, in Canada it is between 61 and 132 (Table 4.23).

Three Authors category from all the countries are having more than 100 with symbol of ‘++’. The single author representations
are from only US, France, UK and Canada further, the following countries have the publications of co-authorship of more than four authors – China, Japan, Italy and Brazil (Table 4.24).

- The Co-authorship index is very high in Russian language (394), followed by German (259) in the single author category and thirdly in Chinese language (166) in the four author category (Table 4.25).

- CAI value for single author in Spanish, Japanese, German and Italian languages secured above average of CAI and Two authors CAI value are from English, Spanish, German, Russian and Korean languages (Table 4.26).

- The Co-authorship index is very high in the Conference Review (703) in the single author category and followed by Note (368) and Book Chapter (253) (Table 4.27).

- The above average of CAI for two authors in article type of publications and in the case of Conference Paper it is three authors and four authors. The remaining bibliographic forms have above average for single author and two authors (Table 4.28).

### 5.2.8 Highly Published by Authors

- United States’ contribution is high in the production of MEMS research and followed by China, but in the case of ranking the authors Japan tops with highest number of contributors followed by Taiwan and Singapore and United States as shown in Table 4.29. The highest number of contributors 312, 243 and 236 were
Fujita, Hiroyuki, Esashi, Masayoshi, Maeda, Ryutaro from Japan, followed by Fang, Weileun, from Taiwan with 181, Liu, Aiqun from Singapore with 165 contributions (Table 4.29).

- Among the top 40 highly contributed authors, the top rank goes to United States followed by Japan and China. (Table 4.30).

### 5.2.9 Author Productivity

- The average authors between 2 and 8 and average pages as between 7 and 48 during the year of study. The author average is very high in years of 1998 and 1999, the trend is increasing trend from 2 authors to 4 authors. The average page range is between 10 and 14 for all the years except for the year 2002 (Table 4.31 and Figure 4.17).

- Overall authors’ collaboration is 4 and pages are 14 (Table 4.32).

- The highest collaborated authors is two and their contribution is 21.79% and followed by three authors with 18.76% and the four authors with 16.34 and the single author contribution is 14%. It is concluded that two authors combination is dominated in this field (Table 4.33).

### 5.2.10 Citation Analysis

- Citations per paper are increasing from 1970 to 1994 with the values from 9.69 to 76.18 and the same is decreasing from 1995 to 2013 with the values from 45.49 to 2.92. The overall citation per paper value is 21.41 (Table 4.34 and Figure 4.18).
• CPP in the third block is very high (32.93) and the first block is very low (12.10). i.e. one fifth of the publications are cited. The citation percentage is increasing in all the block years except last block, where it is little less (45.16%). The third block period is very high for both citation percentage and CPP (Table 4.35 and Figure 4.19).

• Citation per paper among the top ten countries are in the range between 8.75 and 31.14. United States, United Kingdom, Canada are ranked in the top positions. The highly produced publications position differed with citation per paper position from the study (Table 4.36 and Figure 4.20).

5.2.11 Uncited Publications

• Nearly 29% of MEMS literature were uncited during the study period of 1970-2013 whereas 2,09,427 (71.10%) of articles were cited during the same period (Table 4.37 and Figure 4.21).

• Uncited publications are also increasing every year and the cumulative values are shown in the exponential growth (figure 4.22). The year wise uncited publications are from 0.22 % to 15 %. The uncited publications ratio from 0.09 to 0.74, in the year 1998 the uncited publications ratios is very less and while it is high in the year 1970 which is polynomial growth. (Figure 4.23) The overall uncited publications range is in increasing trends (Table 4.38).

• The uncited ratio is in decreasing trend from the first block to the third block period and again increasing in the fourth block
period. The Overall uncited ratio is 0.29 (Table 4.39 and Figure 4.24).

- One fourth of the publications from the United State are not cited. Nearly half of the publications from China are not cited. The highest uncited ratio is shown in publications from China and the lowest (0.22) is from Brazil. In the case of Publications from India, one third of the publications are uncited and the uncited ratio is 0.58 (Table 4.40 and Figure 4.25).

- More than 80% of publications are in the form of articles and nearly 45% of the publications are in the form of conference paper cited. Nearly 20% of publications are in the form of Journal Articles and more than half of the publications are uncited in the conference papers (Table 4.41 and Figure 4.26).

### 5.2.12 Highly Cited Publications

- ‘Book’ occupied first position in the highest number of citations received and followed by reviews. In the case of highly cited articles, the highest numbers of citations received are as follows 4330, 3394, 3097, and 2865 respectively (Table 4.42).

- From the highly cited publications in MEMS, there are 15 articles and 9 reviews and one book in the highly cited (top 25 publications) in MEMS during the study period.

- ‘Fujita, H’ secured high total publications but CPP is 8th position. Tai, Y.C who secured first rank based on CPP but publication production is in 9th position. It concludes that high productivity is differed with citations per publications (Table 4.44 and Figure 4.27).
• The ranking among total publications, cited, uncited and cited ratios are not equal. It differs in the cited and cited ratio. The fifth position in the production based rank came in the first in cited ratio. So it is concluded that cited ratio is not related with total number of publications (Table 4.45 and Figure 4.28).

5.2.13 Relative Quality Index

• RQI values are from 0.24 to 13.51 and it started from 5.99 and goes on to 0.24 and again increased to 13.51. The values are figured in the figure with Polynomial trend line (Table 4.46 and Figure 4.29).

• The first block value for RQI is 2.72 and it goes down and increased to 1.46 in the fourth block (Table 4.47 and Figure 4.30).

• The citation of publication per paper (CPP) and RQI is high among the top countries. RQI values are very high for China and India and other counties are in the range between 20.00 and 17.98 (Table 4.48 and Figure 4.31).

5.2.14 Various Indices

• The total of 1953 articles has been contributed by top 10 authors. These 1953 publications yielded 19657 citations with an average citation per paper works out to 10.06. The average citation per paper ranges from 4.47 to 24.89 of which Tai, Y.C has 24.89 citation per paper whereas number of contribution is only 160 which received a total citation 1888. The author Fujita, H. has published 312 articles with the citation of 2170 and
received h index (23). Among these top 10 authors the property
$h<hg<g$ reflects (Table 4.50).

- ‘Tai, Y.C’ and ‘Bright, V.M’ both scientists have occupied the
  first and second rank based on the various indices ranking
  (Table 4.51).

5.2.15 Journals

- ‘Sensors and Actuators A Physical’ with 1,980 contributions
  amounting to 14.01% of total contributions. ‘Journal of
  Micromechanics and Microengineering’ with 14,444
  contributions amounting to 10.22%. ‘Journal of
  Microelectromechanical Systems’ with 1,139 contributions
  amounting to 8.06% (Table 4.52).

5.2.16 Conferences

- ‘Proceedings of SPIE the International Society for Optical
  Engineering’ with 8,390 contributions amounting to 40.06%
  among the top 40 contributions. ‘Proceedings of the IEEE
  International Conference on Micro Electro Mechanical Systems
  MEMS’ with 2,013 contributions amounting to 9.61%.
  ‘Proceedings of IEEE Sensors’ with 1,137 contributions
  amounting to 5.43% (Table 4.53).

5.2.17 Highly Published Organization

- ‘University of Tokyo’ with 1,206 contributions amounting to
  5.15% among the top 40 contributions. ‘US Berkeley’ with
  1,136 contributions amounting to 4.85%. ‘Tsinghua University’
  with 1,001 contributions amounting to 4.28% (Table 4.54).
5.2.18 Indian Publications Vs Year

- There are 8050 publications in MEMS literature during the period 1970-2013 and the average publications is 183 per year (Table 4.55 and Figure 4.32).

- The Growth Ratio of MEMS values varies from 0 to 35. The sudden growth can be seen particularly in year 1973 and 1996. The Growth Ratio is 35 folds in these years. There was fivefold increase in year 1980, otherwise the Growth Ratio is ranged from 1.00 to 2.00 (Table 4.55 and Figure 4.33).

- CAGR is very high (1.96) in the year 2013 (Table 4.55 and Figure 4.34).

5.2.19 Indian Publications Vs Block Years

- The Growth Ratio is up and down in MEMS field. The average annual publication Growth Ratio of Indian contribution is 2.1 during 1981-1991. It shows the growth in high peak in this block years (Table 4.56 and Figure 4.35 and 4.36).

5.2.20 Relative Growth Rate and Doubling Time of Indian Publications

- The Relative Growth Rate is very high during 1984 – 1989 (ranges between 342 and 244) the remaining periods are steady growth value by 1 to 2 (Table 4.57 and Figure 4.37).

- Doubling Time is the period of time required for a quantity to double in size or value. Hence it can be seen that its doubled during the time required 1984-1989 (340 times growth) and the remaining period, the doubling times are from 2 – 89 times. (Table 4.57).
5.2.21 Bibliographic Form of Indian Publications

- Three fourth of publications are in subject periodicals and 16.35% of publications are from conference proceedings (Table 4.58 and Figure 4.38).

5.2.22 Activity Index of Indian Publications

- Activity Index ranges between 0.00 and 189.24. The Activity Index (AI) was peak in 1975 (189.24) and the lowest in the year 1992 (0.00). Further it was observed that the Activity Index (AI) has reflected fluctuation trend during the study period (Figures 4.20).

- It indicates that the activity of MEMS research gaining momentum since 1996.

5.2.23 Collaborative Authorship Pattern in India

- Single authored publications are only one tenth of the total publications. Two third of the publications are from collaboration of two to four authors. The average authors per article is 3.31 and degrees of collaboration is 0.8 (Table 4.60 and Figure 4.40).

5.2.24 Indian Authorship Pattern Vs Year

- The collaborative index ranges between 1.00 and 4.33 and the value of the total publication for the study period is 3.02 (Table 4.61 and Figure 4.41).
• The Collaborative Coefficient is applied to the year and the values are between 0.00 and 0.73 (Table 4.61 and Figure 4.41).

• Modified Collaborative Coefficient values are between 0.00 and 0.76 and the same for the study period is 0.60 (Table 4.61 and Figure 4.41).

5.2.25 Indian Top 10 Authors

• Mr. Chandra, S has published 54 (0.67%) publications in MEMS and secured first position among the Indian contributions. Bhattacharayya, T.K. has published 49 (0.61%) publications and secured second position (Table 4.62).

• Mr. Chandra S has secured first rank in publications, h-index, p-index. Mr. Bhattacharayya, T.K. has secured first rank in citations, g-index, r-index, e-index (Table 4.63).

5.3 FINDINGS IN RELATION TO HYPOTHESES

The study undertaken has indicated that the hypotheses:

• Research productivity in MEMS is comparatively higher in developed countries. There is significant difference on the publications with respect to country wise distribution.

• There exists a significant level of difference between MEMS research performance of Indian scientists and scientists of other countries.

• Journal plays major role in publishing papers on MEMS. There is a significance difference in form of publication in publishing research papers.
• Maximum number of articles published in English language.

• Collaborative research dominates in the field of MEMS.

• Considerable number of literature had not received any citation

• Stated in Chapter 1, under section 7 have been tested in Chapter 4 and found valid.

5.4 SIGNIFICANCE OF THE STUDY

In this study, it is found that the research productivity in MEMS literature is comparatively higher in developed countries. This is identical as stated in other studies carried out by several authors (Markusva et al 2002, Montoya et al 2004, Kademani et al 2005) stated in the review of literature.

In the field of MEMS as like that of other studies collaborative research dominated (Kannappanavar et al 2004, Aswathy and Gopikuttan 2013, Santhanakarthikeyan et al 2014).

In the MEMS literature too, number of uncited articles as like that of other subjects fields. The studies on uncitedness of journals - Journal of American Chemical Society (Ghosh and Neufeld 1974), Nature (Ghosh 1975); discipline - Library and Information Science (Schwarts 1997), Physics, chemistry, biological sciences, geosciences, engineering and medicine (Hamilton 1990); index database – ISI (Hamilton 1991); countrywise (Hamilton 1990, Pendlebury 1991); MEMS literature (Bathrinarayanan et al 2015) are the few.
5.5 DIRECTIONS FOR FURTHER RESEARCH

The present study of research productivity on MEMS offers avenues for further research on the following areas:

- The extent and pattern of collaboration research in the subfields of MEMS research.
- Mapping the literature on MEMS research.
- Impact of MEMS research literature on the branches of medical applications.

5.6 CONCLUSION

The literature output of global MEMS literature has been studied in the light of the Indian research output. The study reported the findings to determine the publication trend with respect to growth of literature on country wise, year wise, block year wise, language wise and document type.

- Publications data included in the Scopus database alone have been taken up for the study.
- 2,94,573 data has been identified from the Scopus data base listed during the period 1970 to 2013 only taken up.

The objectives, stated in the chapter 1, section 1.7 of the study formulated for the purpose were thoroughly investigated and reported in the respective chapters. Further all the hypotheses thus framed and listed in chapter 1 have been proved.

The results computed are quite encouraging particularly on the implications of MEMS research output between global and Indian context in
the facets country wise contribution, language wise contribution, document
type, year wise, block year wise. Further authorship pattern, collaboration
pattern such as collaborative coefficient, collaborative index, relative growth
rate, doubling time. Besides highly cited papers both global and Indian point
of view were computed. The study also considered the uncited papers in
MEMS literature. The growth of uncited publications also analysed year
wise, block year wise and its growth rate. The authorship pattern on uncited
publications has also been studied. Similarly highest number of publications
both global and Indian were identified. But there is always scope for
improvement for betterment of projection of growth of literature output on the
discipline.