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Introduction

Energy is captured and stored in devices known as accumulator or battery for all kinds of potential use. Energy manifests itself in several forms, including chemical energy, potential energy, heat from burning of fossil fuels etc. The development of energy storage technologies has become a thrust area for scientists, researchers and engineers, globally. Efforts are underway for identifying highly promising energy storage materials from a range of potential combinations. Importantly, the stored energy should ideally be accessible on a larger scale and also available easily at the point-of-use[1-4]. In the present study, we have applied the popular Scientometrics approach to analyze both quantitatively and qualitatively a range of scientific publications and citations to understand the structural aspects and growth of scientific research in energy storage materials at global level;

performance of countries; performance of institutions; and also understand the eminence of scientists working in this domain. The study also helped ascertain the information seeking behavior of scientists, researchers and engineers by way of identifying the platforms across which scholarly work is mostly published and the data cited usually in these works[5-6].

Globally, China, the United States, South Korea, and Japan lead the list of countries in terms of scientific research on energy storage materials. As per Scopus database, India is placed fifth in terms of number of publications, and several prominent Indian institutions are involved in high quality R&D on energy storage materials. The present study aims to scientometrically analyze the Indian journal articles published during the last 20 years in this interesting field of science and technology.

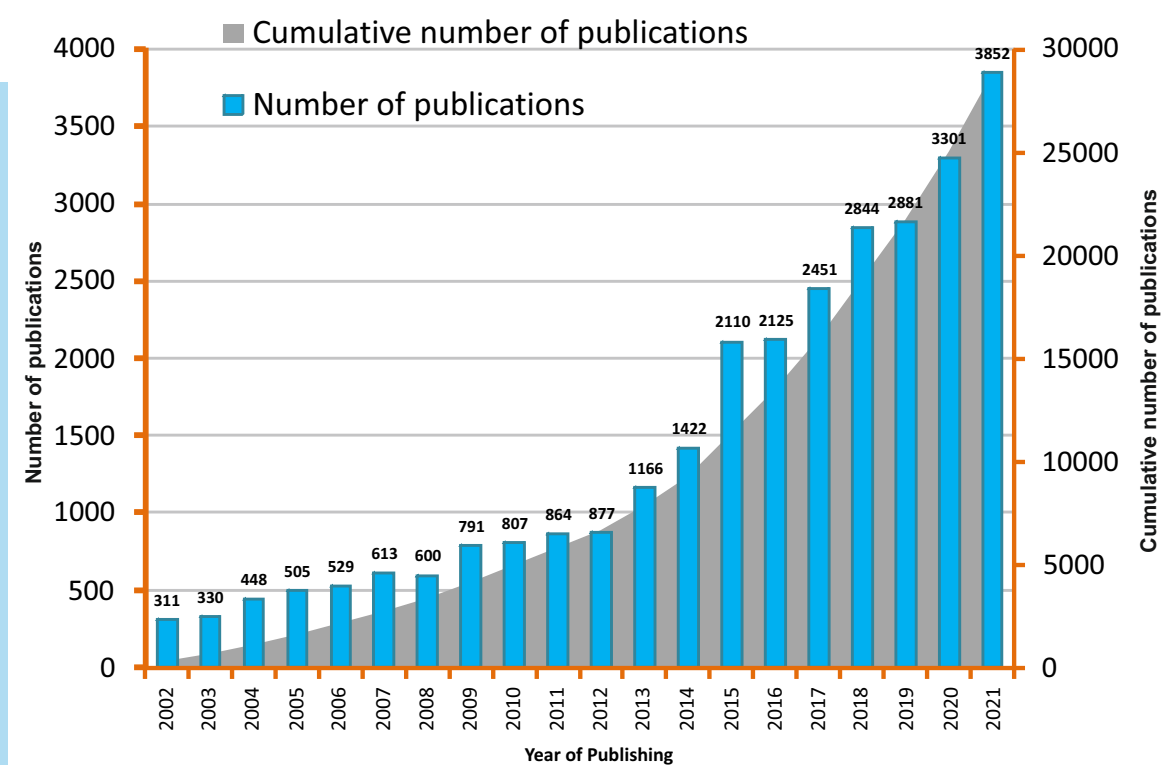
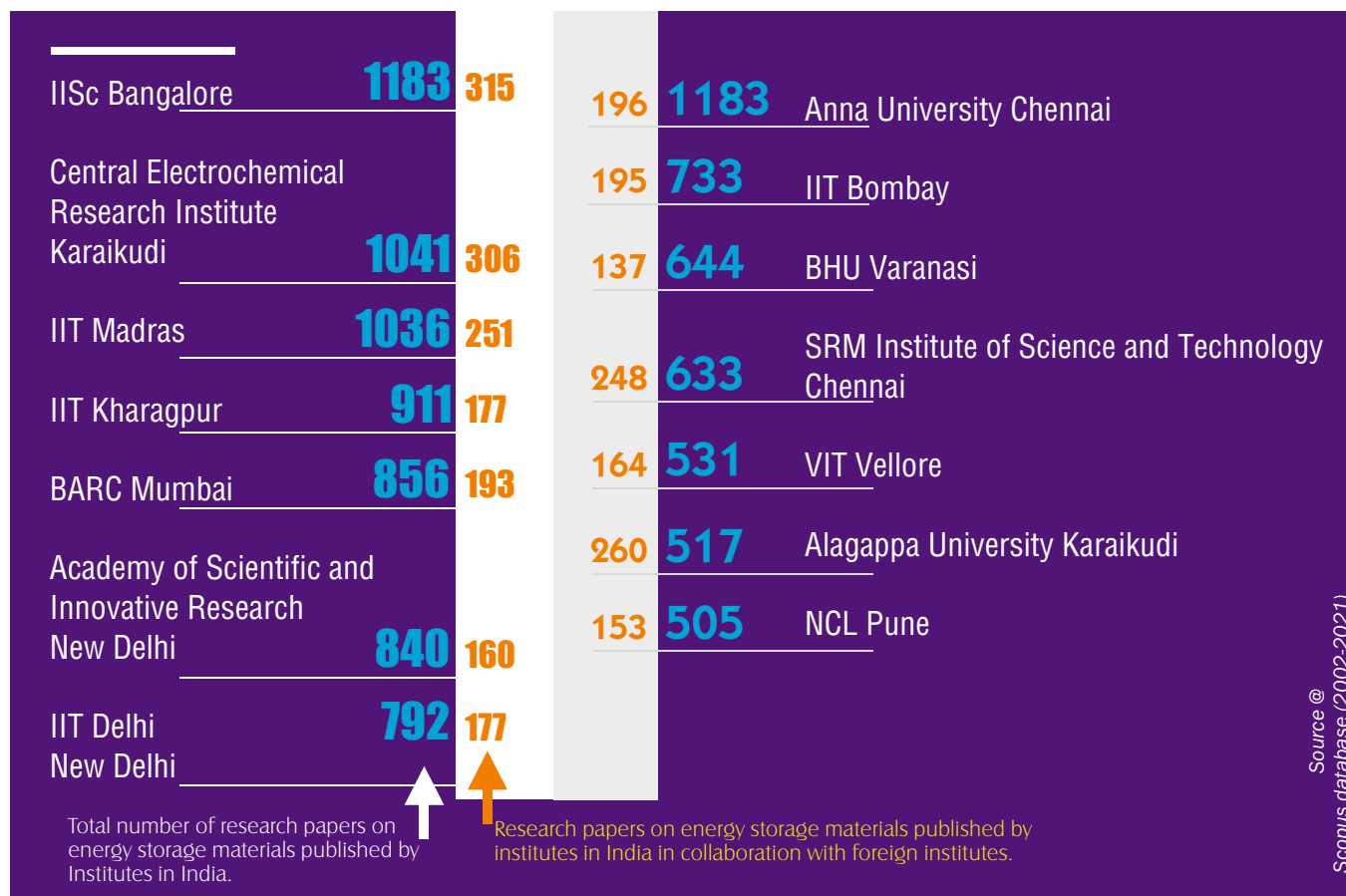


Fig.1: Year-wise distribution of Indian research papers on energy storage materials.

Research Method and Data Collection

The 'Secondary Research' method was adopted in the present study. Scopus, an international bibliographical database of references to scientific and research articles with citation data, was used for eliciting publication records pertaining to 'energy storage materials' published by Indian

scientists during 2002 to 2021. The study is restricted to only journal articles and a total of 28,827 research papers are found in the Scopus database and these were subjected to scientometric analysis as per the objectives of the study.

Results and Discussion

Year-wise Trend of Publications: As per Scopus database, a

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|------------------------------------------|------|-------|-----------------|-----|--------------------------------------------------------|
| International Journal of Hydrogen Energy | 1017 | 5.816 | 2.478 | 561 | Journal of Materials Science: Materials in Electronics |
| Journal of Alloys and Compounds | 699 | 5.316 | 9.127 | 528 | Journal of Power Sources |
| Electrochimica Acta | 680 | 6.901 | NA [#] | 392 | International Journal of Applied Engineering Research |
| RSC Advances | 654 | 3.361 | 6.583 | 377 | Journal of Energy Storage |
| Ionics | 584 | 2.817 | 5.742 | 377 | Solar Energy |

Total number of research articles on energy storage materials published by Indian scientists in popular journals.

Impact factor of the journals in which these articles have been published

Impact factor not available

Source @ Scopus database (2002-2021)

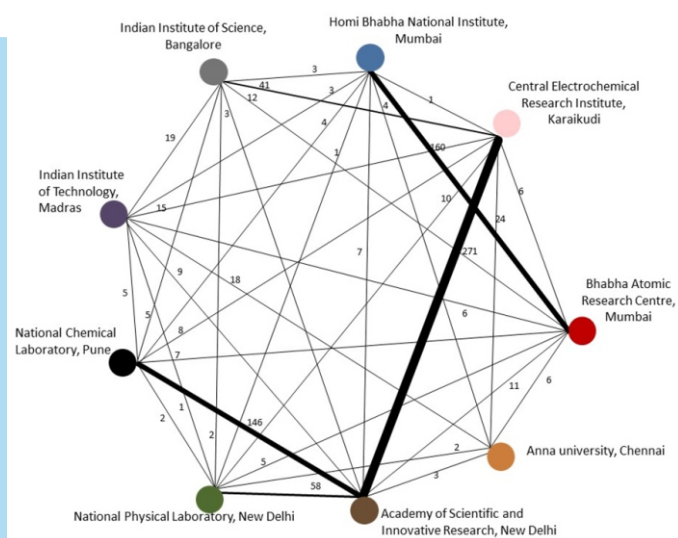


Fig.2: Collaboration network of highly-collaborated Indian Institutes involved in research on energy storage materials.

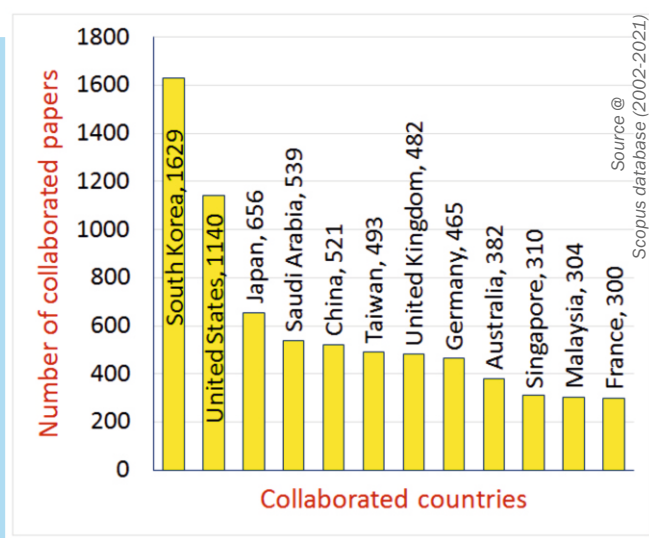


Fig.3: Highly collaborated countries with Indian research institutes involved in research on energy storage materials.

total of 4,42,452 publications were published during 2002 to 2022 on 'energy storage materials'. China is placed at the top amongst the countries with the highest number of research papers followed by the United States, South Korea and Japan. India occupied fifth position with a total of 28,827 research papers published during this period. Chronological distribution of these papers is depicted in Fig.1. The citations to these papers have been analyzed and it has been found that the average to maximum citations is 40 and 3,806 (in case of review paper).

Indian Research Institutes and Collaboration: Research papers originating from India on 'energy storage materials' is predominantly on account of joint collaboration between several research institutes based within the country. Institutes in India with over 500 research papers published on energy storage materials are listed in the Table 1.

The Scopus records were carefully analyzed to understand the nature of collaboration between the leading research institutes and various other institutes within the country as well as with the foreign institutes in the common domain of energy storage materials. Results showed that

3,527 (12.24%) publications out of the total of 28,827 publications have been as a result of joint collaboration between research institutes situated within the country whereas 7,579 (26.29%) resulted from international collaboration.

The collaboration network of few leading Indian institutes is portrayed in Fig.2. Our analysis showed that the foreign institutes with which Indian institutes collaborated in a large way (most-collaborated) are South Korea, the United States, Japan, Saudi Arabia and China. The number of papers published jointly with these most-collaborated countries is presented in the form of a bar graph in Fig.3.

The chronological trend of collaboration among research institutes situated in India and also with the foreign institutes are depicted in Fig.4. A linear growth has been observed in the rate of collaboration among the Indian research institutes and with the foreign institutes during 2002 to 2021. Average citations received for internationally collaborated papers is 34 and for non-collaborated papers it is 25. The average Impact Factor of the journals publishing internationally collaborated papers is 5.56 whereas for non-collaborated papers it is 4.41.

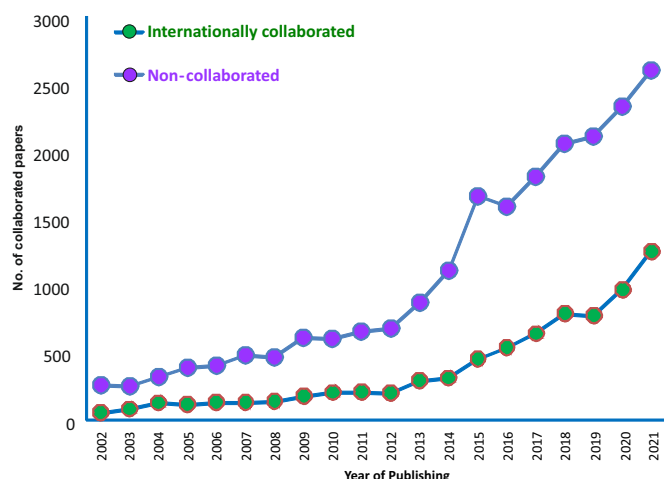


Fig.4: Year-wise distribution of Indian research papers on energy storage materials.

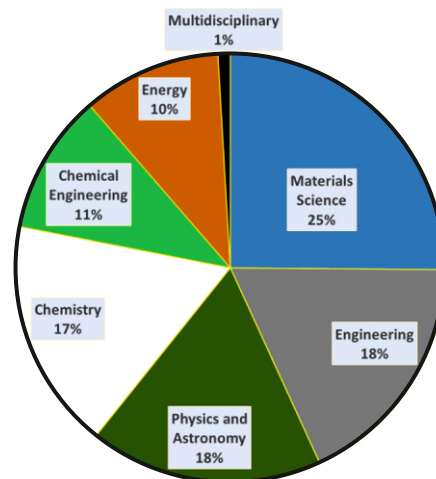


Fig.5: Subject-wise distribution of journals in which scholarly work on energy storage materials are published by Indian scientists & engineers.

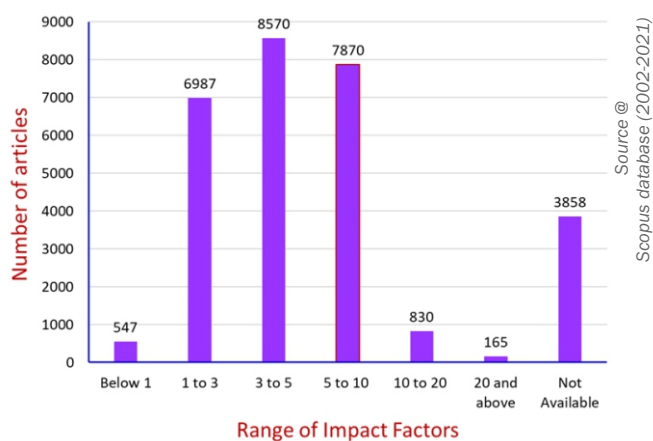


Fig.7: Indian publications in energy storage materials in different impact factor ranges.

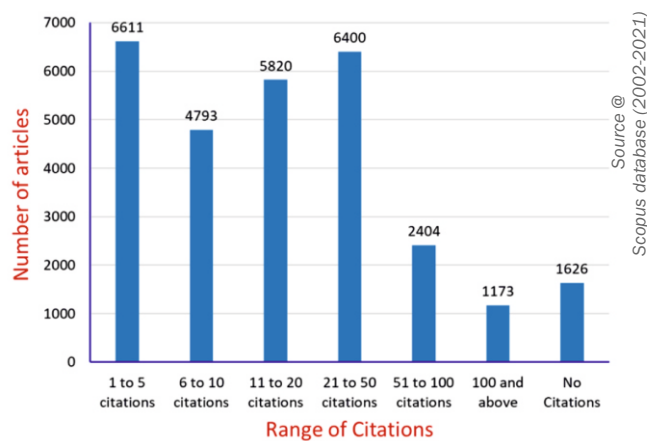


Fig.6: Indian publications in energy storage materials in different citations ranges.

Published journals: The study has identified journals preferred by Indian scientists & engineers to publish their articles on 'energy storage materials'. The papers are published in 1,391 distinct journals and top ten journals are listed in Table 2 with number of articles published in them and impact factors. The average Impact Factor of journals publishing articles on energy storage materials was 4.73.

By analyzing the subject categories of journals, it was found that, maximum number of research papers on energy storage materials are published in journals categorized as materials science (25%), followed by engineering, physics and astronomy 18% each (Fig.5).

Citations and Impact Factors: Citations indicate the impact of individual publications and impact factor suggests the quality of journals in which articles are published when the quality (impact) of published articles are considered. The present study has analyzed citations of individual articles and impact factors of the published journals. The citations impact factors in different ranges are presented in Fig.6 and Fig.7.

Conclusion

The results of the scientometric analyses on 'energy storage materials' provide valuable insights ranging from the nature and the extent of collaboration amongst the leading Indian institutes and inter-institutional collaboration globally, etc. This study may be useful to researchers, science administrators and policy makers. The extent of collaboration by Indian scientists & engineers in the field indicates the societal commitment of them as well as the willingness to share the models and technology in the field.

A detailed study on contributions of other countries in the field and a comparison with Indian publications is suggested. The scope of journals in which articles related to energy storage materials are published varied from materials science to engineering, physics and astronomy, chemistry, chemical engineering, energy indicates the usage of knowledge base from various subjects for the development of energy storage materials.

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