Research Article

Educational Administration Theory and Practice

A Bibliometric Review on Ternary Chalcogenides Materials for Opto-Electronic Properties

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ARTICLE INFO	ABSTRACT
	(max 150 words) This paper reveals the analyses of the past and present research in the field of ternary chalcogenide materials for Opto-Electronic applications based on the Scopus database review from 2010 to 2022, using the bibliometric method. In recent decades, material research has blossomed with the invention of the ternary chalcogenides and made efficient by various methods of synthesis and using optimized processing parameters for various optoelectronics applications due to having unique properties such as structural, morphological, optical, and electrical properties. In this review, the author constructed a citation network of research to investigate the emerging research domains in ternary chalcogenides deposition and presented a bibliometric survey using VOS viewer Version 1.6.15 tool through the Scopus database. From the review, Half Heusler alloys (HHAs) performed more than 50% of the TiNiSn performance and exhibited 10% more efficiency than CZTs(copper-Zinc-tin-sulphur). **Keywords:** Chalcogenides, VOS viewer, thin film deposition, Phase transition, Opto-electronic properties, Nanocomposites.

Specifications Table

Subject area	Opto-Electronic applications, ternary chalcogenides, bibliometric survey, VOS viewer Version 1.6.15 tool, Physical Chemistry, Material science, thin film deposition, etc.
Compounds	inorganic semiconductor, Half Heusler alloys, copper-Zinc-tin-sulphur, TiNiSn
Data category	The bibliometric survey, material research, VOS viewer, etc.
Data acquisition format	Statistical analysis of Bibliographic studies
Data type	Raw, Review, analyzed.
Procedure	Bibliographic studies by using the Scopus database through VOS viewer
Data accessibility	Data is from this article

1. Rationale

Metal chalcogenides are an inorganic semiconductor compound group consisting of at least one chalcogen anion and at least one more electropositive metal element. Although all of the elements in the periodic table of the VIA group are called chalcogens. Generally, the term metal chalcogenide is more commonly reserved for sulfides, selenites, and tellurites instead of oxides and polonium compounds. The metallic character of these elements increases with the decrease of element order in the periodic table of the VIA group. However, the properties of the three chalcogens (S, Se, Te) are extremely different from the oxygen and Polonium (Po) materials group. There are many metal chalcogenides with different structures and compositions such as Na_2S, $CaTe$, Ti_2S, and Cu_2Se. Metal chalcogenides encompass a large family of 2D materials, which are essential materials for achieving higher efficiency optoelectronics devices. The deposition of thin metallic chalcogenide films is of particular interest for the wide range of fabrication of solar cells, sensors, photodiode arrays, and photoconductors.

Chalcogenides (compounds and alloys of sulfur, selenium, and tellurium) display an uncommon array of physical phenomena that range from interesting electronic [1,2], thermal, and optical properties [4,5] to novel forms of superconductivity [6,7] and magnetism. Density functional theory (DFT) is applied first time on Ternary chalcogenides AlX_2Te_4 (X = Zn, In) crystals by using first-principles calculations. The electronic and optical properties were studied by ab-initio calculations via the full potential linearized augmented plane wave method.

This study aims to investigate the research findings in the metal chalcogenides for various applications. The present work investigated the deposition of metal chalcogenides thin films using bibliometric studies.
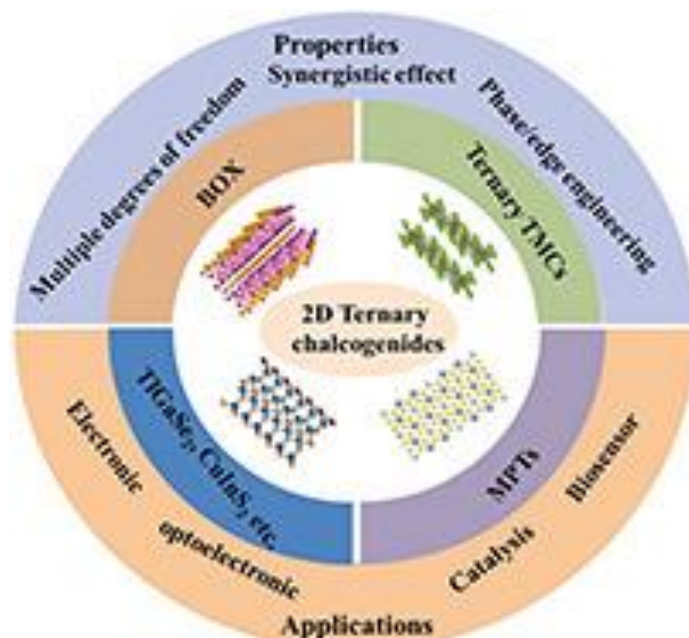

Fig. 1 Schematic of the Ternary Chalcogenides

2. Procedure

2.1 Initial Collection of Databases

Worldwide, there are numerous well-known databases including Scopus, Web of Science, Google Scholar, Scimago, etc. These databases include a huge variety of articles. The largest and most well-known database among them is Scopus, which is used for the analysis. The core database collection of keywords is crucial for the investigation of metal chalcogenide compounds. The various keywords are used to search databases all across the world. Author, nation, citations, papers, sources, and other terms are utilized as keywords in this study to analyze the materials and their features. The ternary chalcogenide materials' principal and secondary keywords are displayed in Table.1. From the Scopus database analysis, there are 511 metal chalcogenide thin film depositions are published. Table 2 shows the language trends of publications. From the table, noticed that the largest number of publications were published in the English language.

Table 1: List of Main and Supporting Keywords

Keyword	Ternary Chalcogenides
Main Keyword	Thin film deposition
Secondary Keyword	Opto-electronics properties

Table 2: Trends in Publications' Languages

Language of Publishing	Publication Count
English	505
Chinese	5
Spanish	1

2.2 Results of publications based on the top 5 keywords

Along with the primary keywords, other keywords are also discovered during the search. The top 5 keywords are displayed in table 3 below. These keywords are discovered to be connected to science and engineering. This analysis showed that Chalcogenides as a keyword is used in most articles up until September 2022.

Table 3: Analysis of publications using the top 5 keywords

S.No.	Keyword	Publications
1	Chalcogenides	279
2	Ternary Chalcogenides	275
3	Energy gap	103
4	Selenium Compounds	98
5	Inorganic compounds	91

(Source: http://www.scopus.com (assessed on 2ndSeptember. 2022)

2.3. PERFORMANCE ANALYSIS

VOS viewer Software version 1.6.15 is utilized for database analysis as well as Scopus database analysis. The bibliometric couplings, co-citations, co-occurrences, and other data may be analyzed extremely effectively using this method. It can be used for the analysis as follows:

Database Statistical Analysis
1. Source documents
2. Year-by-year documents
3. Documents organized by subject
4. Types of Documents
5. Documents authored by
6. Information by Country
7. Subject-specific documents and documents by affiliation
8. Records from leading funding organizations.
Databases that use network analysis
1. Authors, organizations, and national co-author
2. Keywords from the index, the author's keywords, and all keywords
3. Citation analysis by authors, organizations, sources, and nation

3. Results and discussions

The two methods of analysis are network analysis and statistical analysis of databases.

Analytical Statistics
3.1.1 Source-Based Analysis of Documents
Various sources, including conferences, journals, book chapters, conference reviews, and reviews, are listed in the database. Fig 2 shows the graphical representation based on the number of documents per year by different sources.
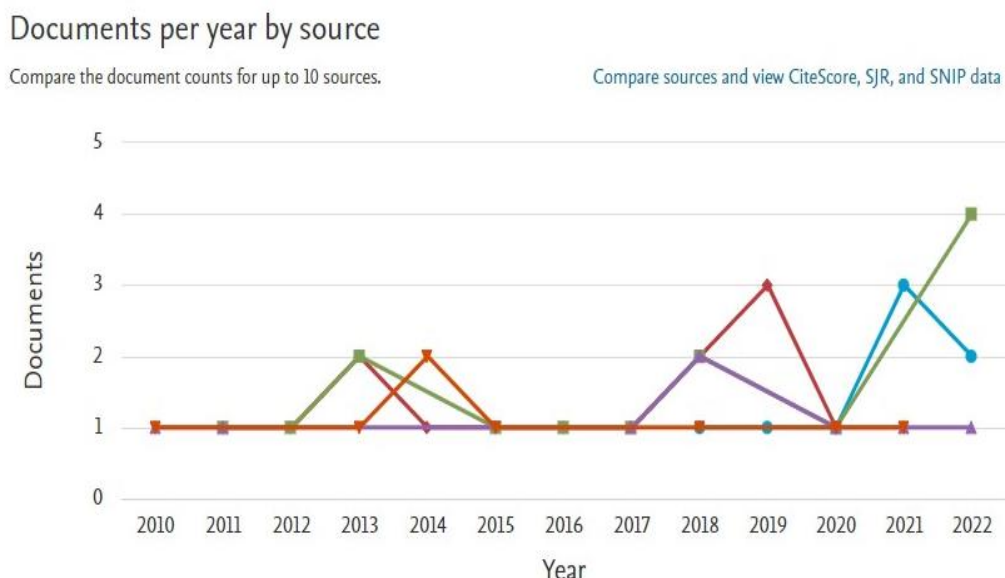
Fig 2: Document Analysis by Sources
(Source: http://www.scopus .com (assessed on 2nd September 2022)

3.1.2 Analysis of Documents by Year
From 2010 to 2022, documents from the Scopus database were collected.

These documents came from a variety of sources, including conferences, journals, book chapters, etc. The statistics for the papers are displayed in table 3.

Fig 2 shows the graphical representation of the documents. From this analysis, it is observed that the highest number of articles are published in the year 2021 and followed by 2020. From this analysis, the authors confirm that metal chalcogenide materials are emerging technology in the preceding years.

Fig 3: Documents by years analysis
(Source: http://www.scopus .com (assessed on 2nd September 2022)

3.1.3 Documents organized by subject
Papers are found under Material Science(31.3%). Although Physics and Astronomy cover (23.3%), the remaining documents have been published in various fields.
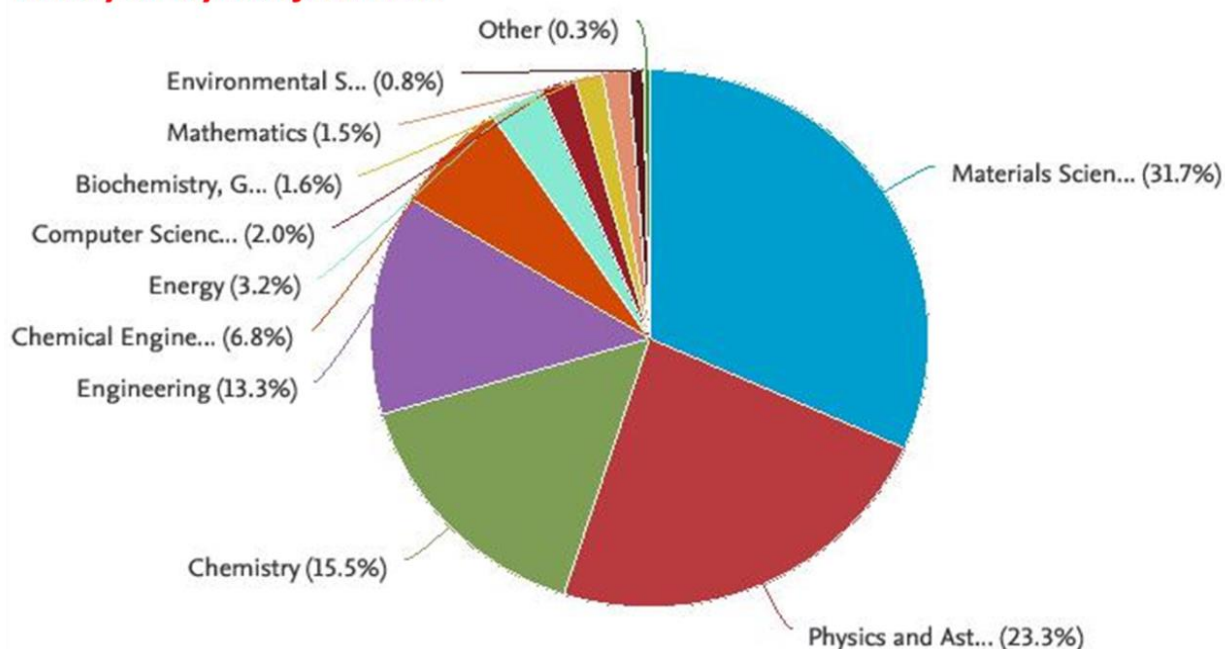
Fig. 4 Documents organized by subject
(Source: http://www.scopus .com (assessed on 2nd September 2022)

3.1.4. Type of Documents From the document by type analysis, noticed that most of the ternary chalcogenide materials are published as articles and followed by conference papers.

Type of Document	No of Documents
Article	449
Conference paper	43
Review	12
Book chapter	05
Book	01
Letter	01
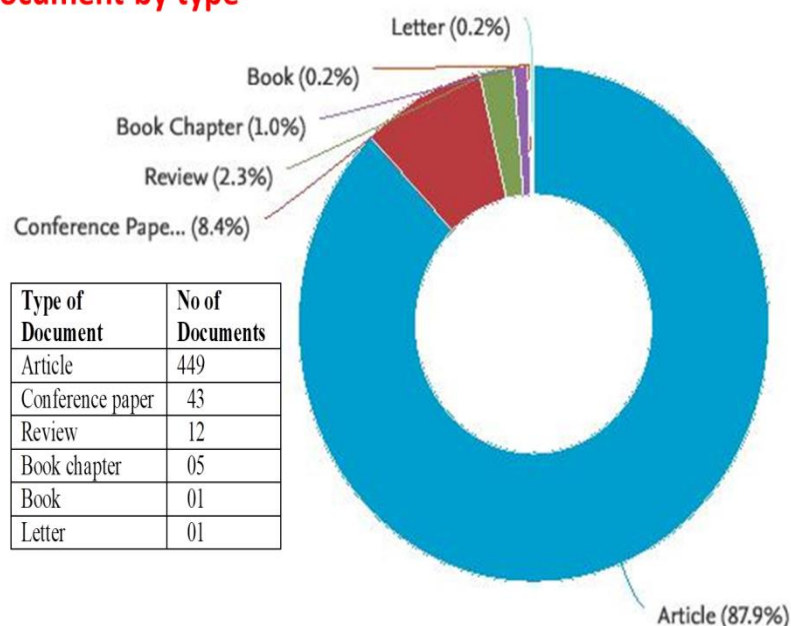
Fig. 5 Analysis of Publications by Document Type
Source: http://www.scopus .com (assessed on 2nd September 20

3.1.5 Publications Analysis by Country or Territory
Based on the countries or territories, the publication was examined using the Scopus database. It demonstrates that China released the most documents within the chosen era, followed by India.
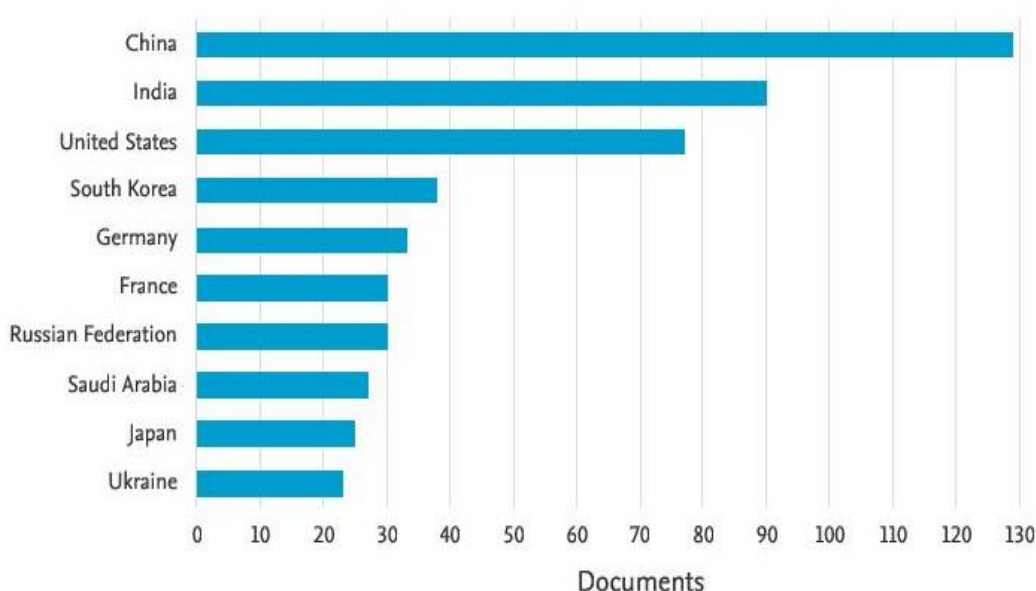
Fig. 6. Information by Country
Source: http://www.scopus .com (assessed on 2nd September 2022**)**

3.1.6 Documents authored by
Fig 7 shows the analysis of documents by authors.

It is observed that Chattopadhyaya S was having 14 publications and Bhattacharjee R published 13 articles in this area. This analysis, confirm that the average publication for the elected timeline is 7-8.

Documents by author
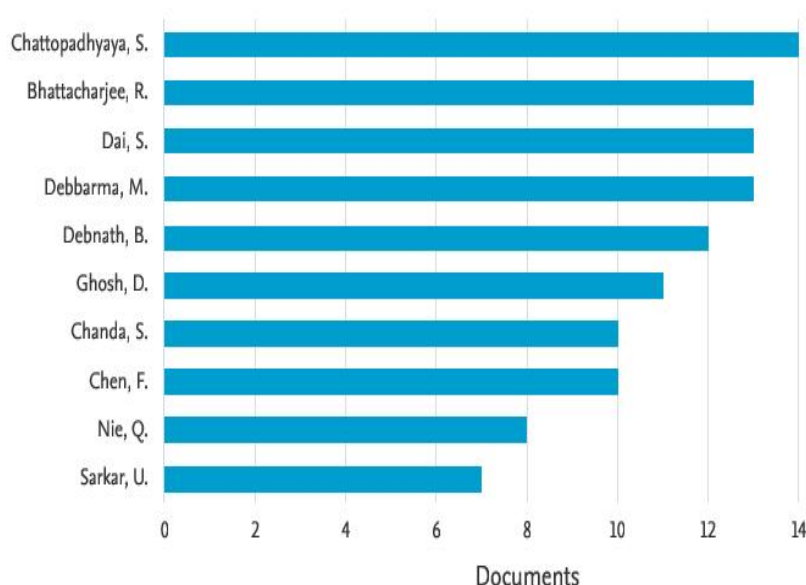
Compare the document counts for up to 15 authors.

Fig. 7. Subject-specific documents and documents by affiliation Source http://www.scopus .com (assessed on 2nd September 2022)

3.1.7 Records of Affiliations

In this case, affiliation documents are used to analyze metal chalcogenide materials. The top 10 affiliations are taken into account in this study. for evaluation of the results. From these results noticed that the majority of the articles (34) are published by the Chinese Academy of Sciences and followed by   Ningbo University (17).

Documents by affiliation ⓘ

Compare the document counts for up to 15 affiliations.
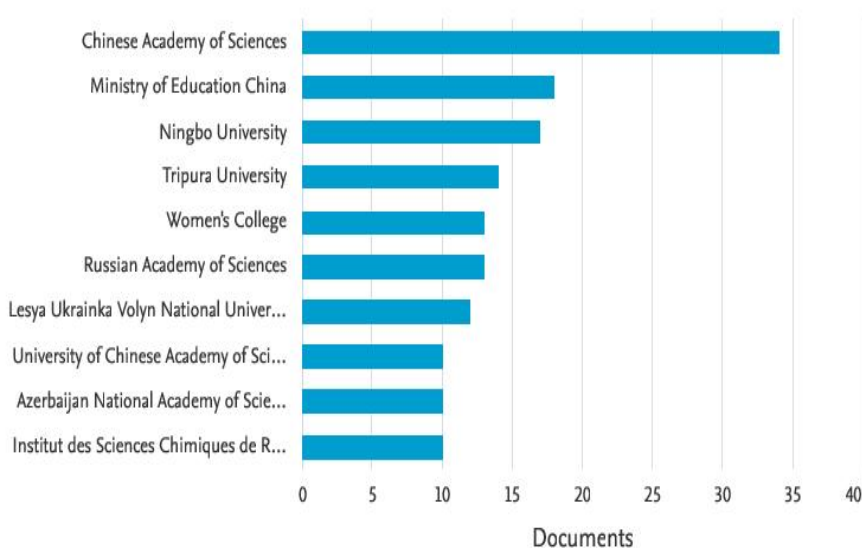
Fig. 8. Records of Affiliations-analysis
Source: http://www.scopus .com (assessed on 2nd September 2022)

3.1.8 Sponsors of funding analyze

Fig 9 depicts the analysis of documents by affiliation of the top 15 countries. It is found that China was sanctioned by the National Nature Science Foundation receives the most funding compared to other countries. In this analysis, noticed that The majority of the financing organizations are in the sphere of science and research.

Documents by funding sponsor
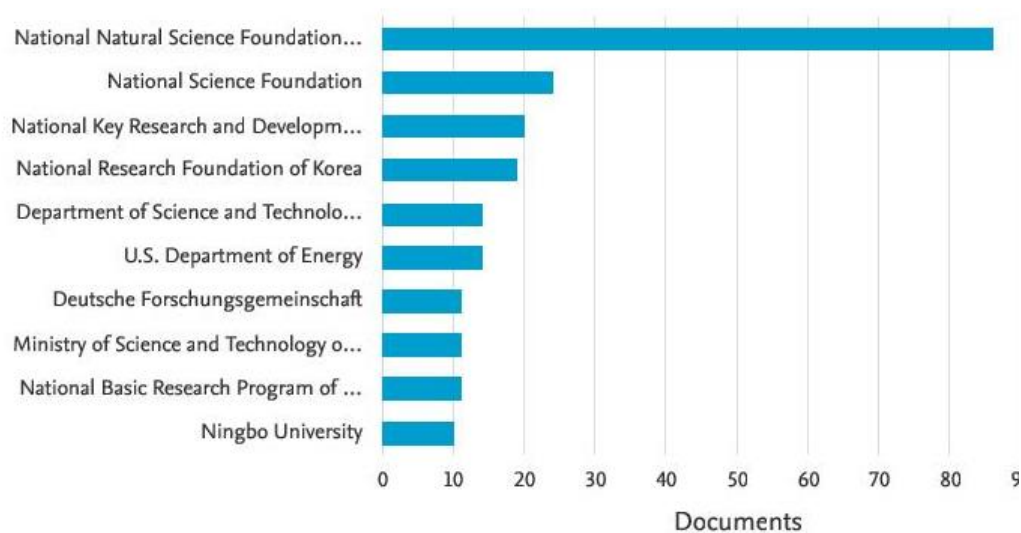
Compare the document counts for up to 15 funding sponsors.

Fig. 9 Sponsors of funding analysis.
Source: http://www.scopus .com (assessed on 2nd September 2022)

3.2 Network Evaluation
3.2.1 Collaboration Analysis
3.2.1.1 In terms of Authors, co-authorship

Regarding this investigation, the co-authorship of the documents is examined using three separate factors, including writers, organizations, and nations.

In this analysis, documents with an extremely high author count are disregarded.
This quantity is regarded as 25. The threshold is five documents, which is the required minimum for an author. 46 authors out of 2048 met the criterion. The link strengths are obtained using this method. 54 citations and 64 maximum links were collected. These results were depicted in Fig.

Fig. 10. Co-authorship Network Analysis in Terms of Authors

B) Organizations' definition of co-authorship

In this criterion, a minimum of five documents are considered to explore collaboration in the unit of organizations. In this analysis, we neglected the citations of the publications. In this work, VOS viewer was used for the analysis of 1276 organizations. Among these organizations, nine are in the range of threshold criteria.   Here 25 organizations were selected. Two organizations have the highest link strengths at 16.
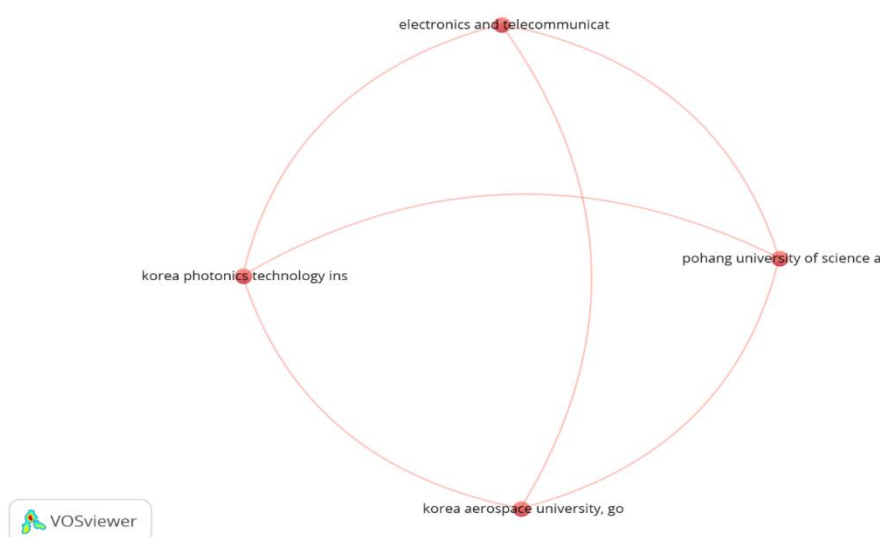

Fig. 11 Co-authorship analysis in terms of Organizations

C) Co-authorship according to Country

Co-authorship can be correlated in terms of country. The database observed that 62 countries are published articles on ternary metal chalcogenide materials. In this analysis, a need for at least 5 papers is considered per country to discuss the details of co-authorship. From these results noticed that 27 countries are in the range

of threshold criteria. However, the strongest citations and links (2472 and 57) of the documents belong to China and followed by United States (2165) citations. Romania has the fewest documents overall, according to the number of documents.
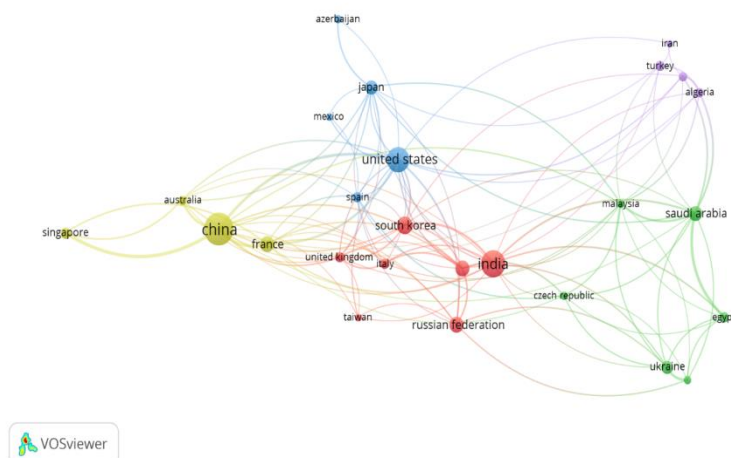

Fig . 12. Analysis of co-authorship by Country (Scale is with number of documents)

3.2.2. Network Analysis of Co-occurrences
A) Co-occurrence analysis in terms of all keywords
In this network analysis of co-occurrences, various keywords are used. Five minimal keyword occurrences are taken into consideration in this work. Fig, observed that 383 documents are existing in the threshold condition out of 4651 documents. "Chalcogenides" is the most occurring keyword in fig 1.3. It has the occurrence 278 times and 2837 link strength with various documents.
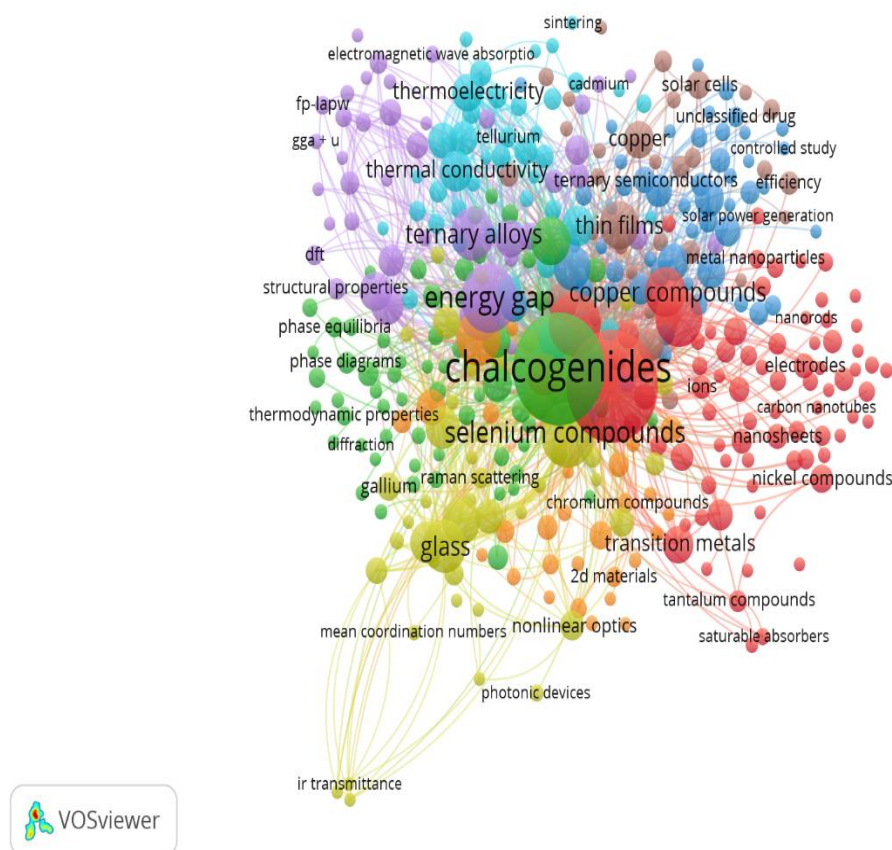

Fig . 13. Analysis of Co-Occurrence Considering All Keywords

B) Keyword co-occurrence analysis for the author
The co-occurrence analysis in terms of Author keywords used a minimum threshold of 5 papers per author.

Out of 1165 keywords, 43 co-occurrence author keywords fall within the range of the threshold requirement. However, the keyword "wearable antennas" is mentioned 21 times with 35 link strengths.
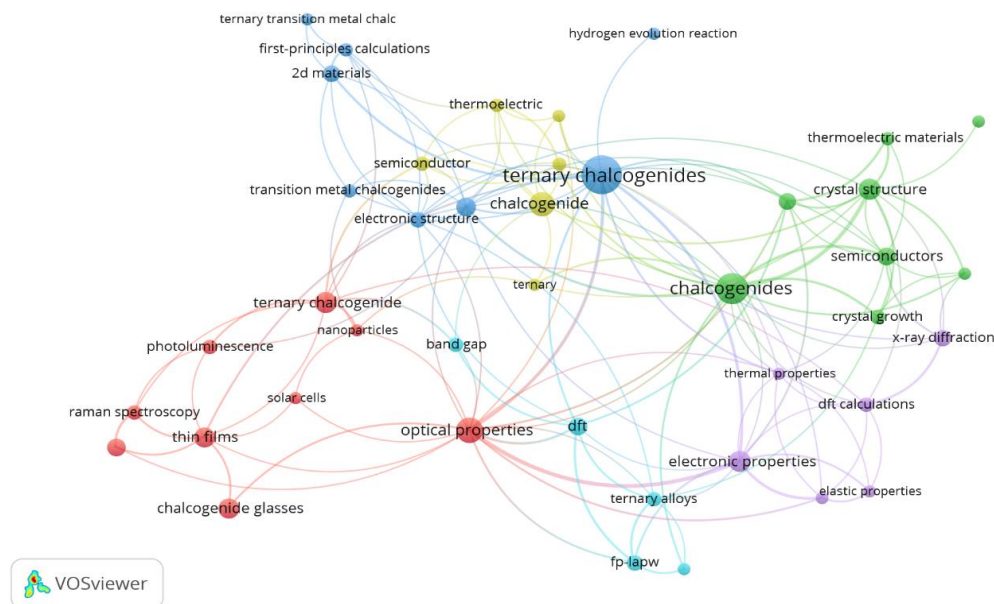

Fig. 14. Coincident events Network Analysis (Author Keywords)

C) Index Keyword Co-occurrence

Co-concurrence index keywords are also one of the important parameters to analyze the ternary materials. Fig 15 shows the Co-occurrence of index keywords. From this Fig noticed that the 349 index keywords are obtained in the range of threshold criteria out of 4032 index keywords. The occurrences range is 275 with total link strengths of 2663.
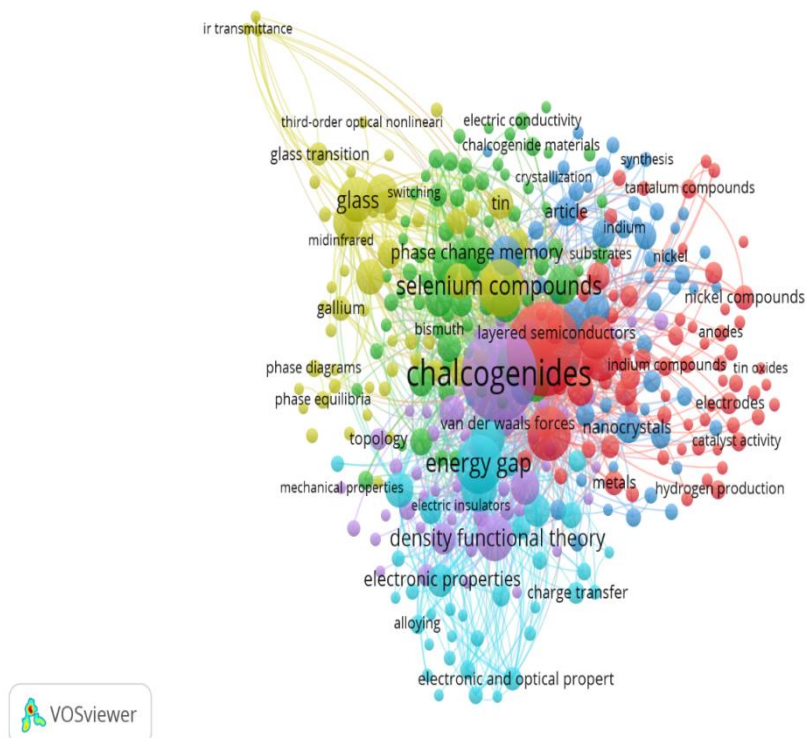

Fig . 15 Co-occurrence of Index Keywords 4.2.3. Citation Network Analysis

This examination plays an important role to get information on the ternary materials. In this case documents, sources, authors, country, and organization are used as units for analysis.

A) Citation Analysis of Documents

In this work, minimum no. of There is a threshold of five citations per document. using the VOS viewer analysis confirms that the 284 documents achieved the threshold range out of 511 documents. In the year 212, Cao Y has been published the highest number of citations 306 along with link sturdiness is 3.
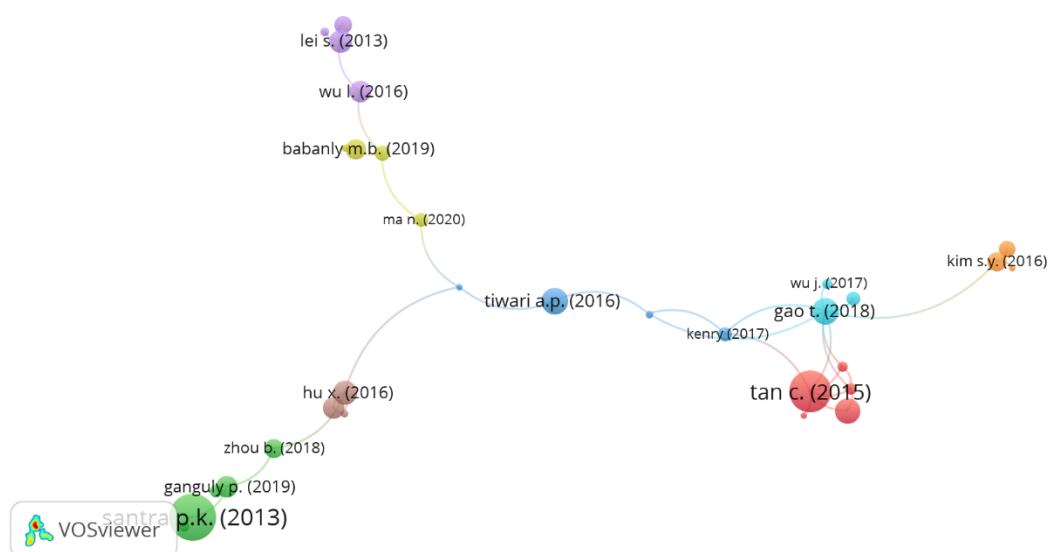

Fig 16: Network Analysis of Citations

B) Source citation analysis

In this work, citation analysis of sources was performed by using a threshold of 5 citations per source. In this case, noticed that 26 sources are in the threshold criteria out of 225 sources. This analysis observed that the highest number of 848 citations was published by the Journal of the American Chemical Society.
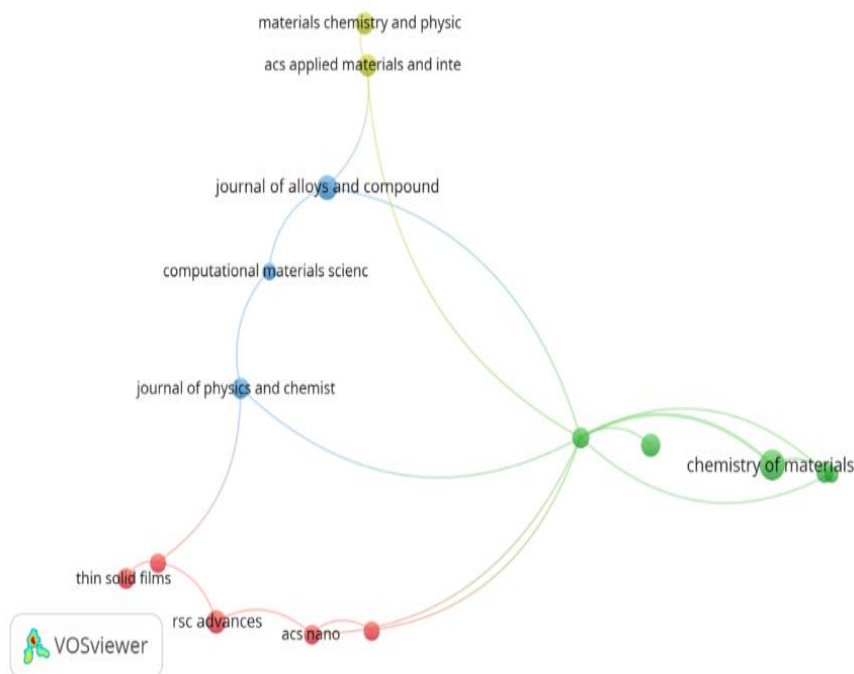

Fig. 17. A network analysis of source citations

B) Authors' examination of citations

In this analysis, 5 citations per author were considered as criteria for the threshold condition. From this results analysis, the total number of 40 authors is fall in the threshold region out of 2058 authors. The author Zhang has published with maximum citations of 397.
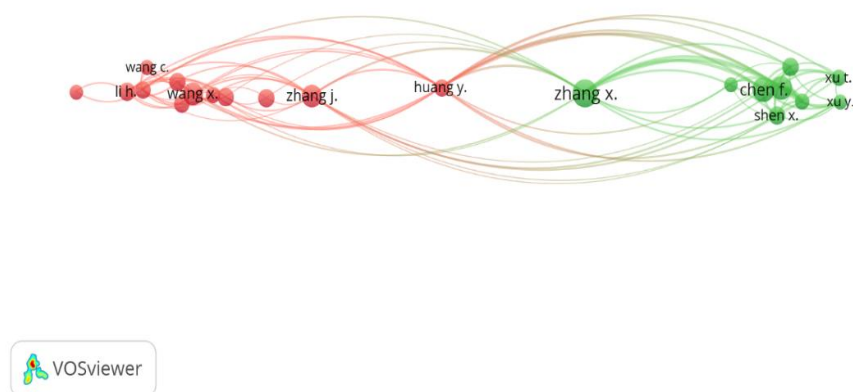
Fig 18: Authors' study of citations

B)   Citation analysis by the organization Citation analysis by the organization was performed by VOS viewer software. This analysis considered three documents per organization as the threshold condition**.** In this case, 1276 organizations were used for the analysis. Among these organizations, 25 are in the threshold area. It is found that the National renewable energy laboratory, golden co,80401, united states maximum citations 151.
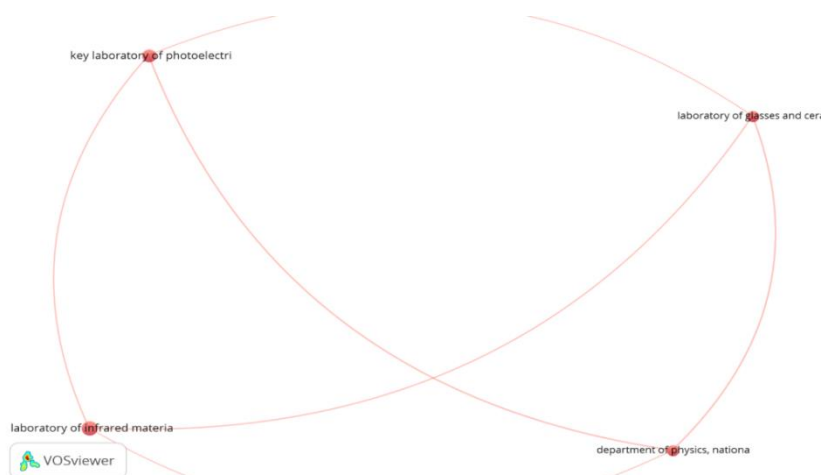
Fig. 19. Organizational Citations

C) Analysis of citations by the nation
It is also one of the important parameters in the VOSviewer software to study the ternary chalcogenide materials. From the database analysis, it is found that 27 countries out of 62 met the threshold criteria based on the minimum of 5 citations per country. This data confirms that China published with maximum citations of 2472 and India published with maximum documents 807.
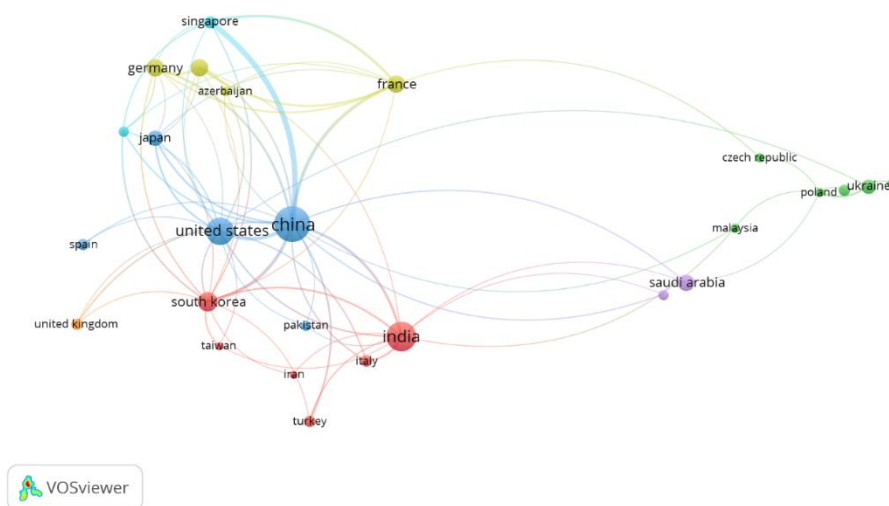
Fig .20 Citation Network Analysis of Bibliographic Coupling Bibliographic Coupling of Documents

A)   Citation Analysis of Country

Fig. 21 shows the bibliographic coupling of documents. In this survey, five documents are considered to analyze the coupling of documents. There are 284 documents are achieved for threshold criteria out of 511 documents. In the year 2018, Debbarmam has been published the highest number of total documents and link strengths on ternary chalcogenide materials are 13 and 230.
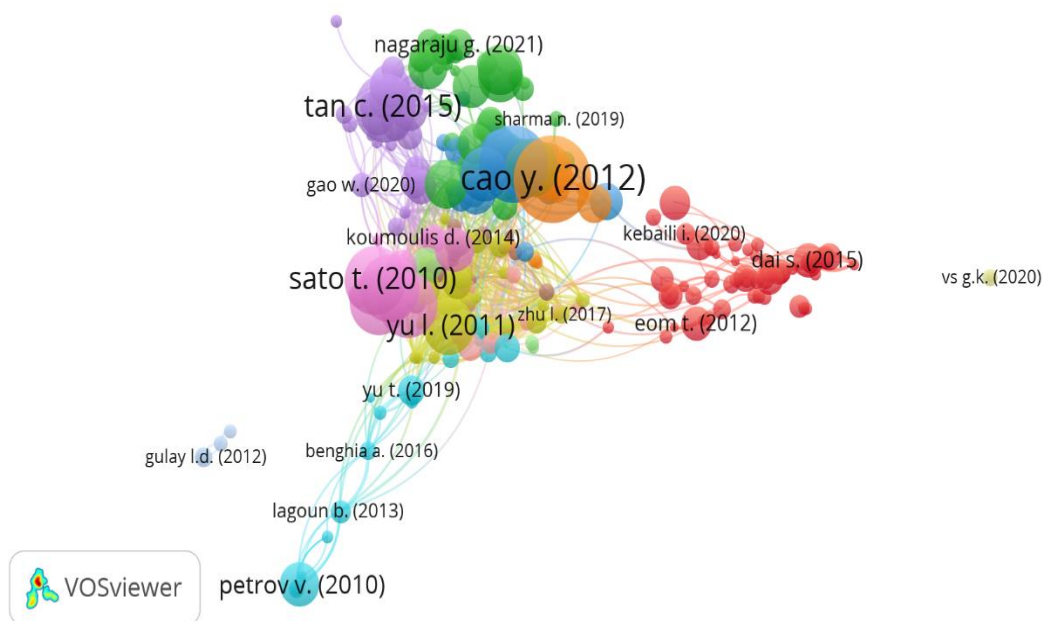
Fig. 21 Bibliographic coupling of documents

B) Author coupling in the bibliography

In this analysis, two documents per author were considered the least valuable.   From this survey, it is found that 40 authors are in the range of threshold condition out of 2048 authors. From the Fig, noticed that the maximum citations of 250 for seven documents obtained by Haung Y.
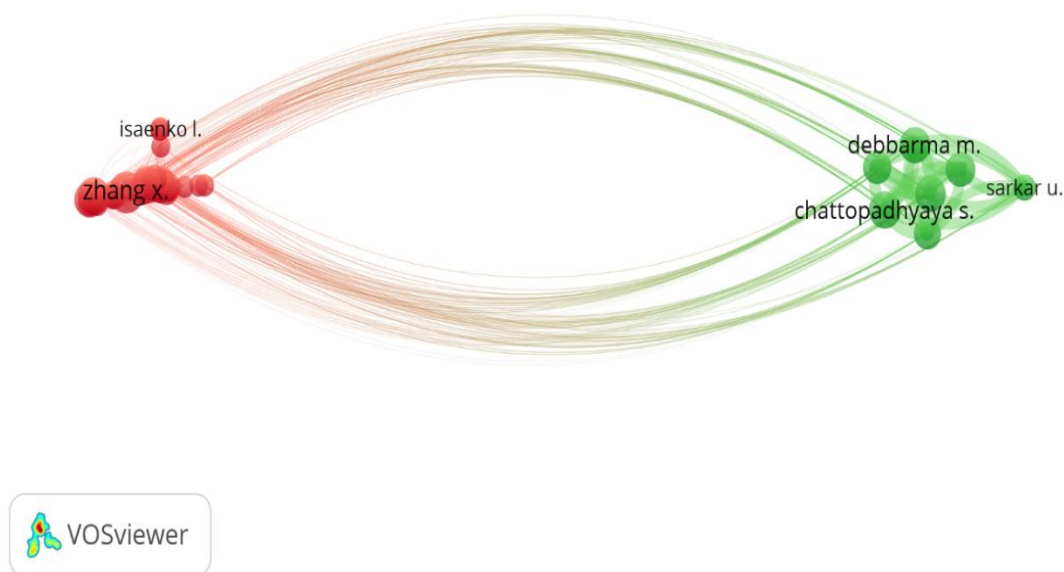
Fig. 22 Authors' bibliographic relationships

V. CONCLUSION

A bibliometric survey on ternary chalcogenide materials is completed by taking into account Scopus, the most widely utilized and largest database. The database is thought to date back from 2010 to 2022. VOS viewer Version 1.6.15 is used for the analysis of ternary chalcogenide materials with different parameters. In this work, Chalcogenides and Ternary chalcogenides are used as keywords to search for the ternary chalcogenide materials. A total of 511 documents were found after using the targeted keywords in the search. For the examination of this database, certain parameters are taken into consideration. It can be noticed that the majority of papers 505 reported by Chinese speakers are in English. According to the results of the keyword search, most publications were about "Ternary Chalcogenides." The year 2020 has the most document publication, followed by the year 2021. Material science was the subject matter of around 31.7% of the texts. Insofar as conference papers are concerned, the type of documents and journal articles are the main occupants. The examination of the various nations showed that China released the most documents between 2010 and 2022. documents with a variety of writers additionally From the affiliation documents analysis confirmed that the Chinese Academy of Sciences has the highest number of documents 34 and followed by Ningbo University has 17 affiliations. Funding analysis, China received the highest funding in the area of ternary chalcogenide materials for the period of 2010-2022. The network analysis is also used to analysis on the ternary chalcogenide materials by VOSVierer 1.65 version software. The different analysis types such as co-authorship analysis, co-occurrence analysis, citation analysis, and bibliographic coupling are done with the same database. From this different analysis, it is observed that quite significant information about ternary chalcogenide materials and reported. From this analysis, it was observed that the major work done in the area of chalcogenides from the period of 2020-2021. However, From this analysis, the authors confirm that there are a lot of scopes to develop ternary chalcogenide materials in terms of applications in the future.

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