Visualization Analysis of Nano-Flame Retardant Materials Based on Citespace

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**Abstract.** Based on 3083 articles in the research field of nano-flame retardant materials collected from The Web of Science database from January 1, 2000, to December 31, 2019, the author, institution analysis, keyword analysis and journal co-citation analysis were carried out with Citespace software and bibliometrics method, and the relevant visual knowledge atlas was drawn. The results show that the development of nano-flame retardant materials can be roughly divided into three stages: exploration stage (2000-2005), steady development stage (2006-2013), and rapid growth stage (2014-2019). Yuan Hu, a professor at the State Key Laboratory of Fire Science at the University of Science and Technology of China, and his team published the most articles. The Nanocomposite is the most representative research topic. Keywords zirconium phosphate has the highest frequency of occurrence. The periodical DEGRADATION AND STABILITY has been cited the most. Above all, nano flame retardant materials is a young but the heat of the research subject, this paper reveals the authors and institutions of cooperation relations, the Subject of co-occurrence relations, the relationship between journals were cited in the field of knowledge base, hotspot and development trend of the series of research, in order to provide a valuable reference for the development of its.

**Keywords:** Nano flame retardant materials, Citespace. Knowledge map, Visual analysis.

1. **Introduction**

Flame retardation is a protective measure used against polymer materials that is intended to prevent the material from burning and to delay the spread of the flame, thus to some extent controlling the fire. Nanotechnology refers to the interdisciplinary science and technology that studies the properties and interactions of substances at the nanoscale (between 1 and 100nm) and utilizes these properties. When a substance is as small as 1~100nm, due to its quantum effect, the local property of the substance and huge surface and interface effect, many properties of the substance undergo qualitative changes, presenting many strange phenomena that are different from both macroscopic objects and single isolated atoms. Nano-flame retardant material is a new kind of material which is synthesized by various ways using various nanometer units and organic polymer materials. Due to its ideal effect in flame retardant, nano-flame retardant material has been leading the development direction in the field of flame retardant materials in recent years [1-2]. Citespace software is a beauty, professor Chen
Drexel university research and development of a visual data analysis software, based on the analysis of samples of literature data, such as authors, institutions, keywords and common network, can research present development situation, the trend of a particular field, is now widely used in areas such as intelligence, medicine, information science [3-5].

In this article, with the help of Citespace software and combined with the method of literature metrology theory, 2000-2019 in a web of science, included 3083 paper (article, review) as a sample source, knowledge of its foundation, the research hotspot and development trend of knowledge map visualization analysis, in order to in the field can provide a valuable reference to the research of scholars in the future.

2. Research methods and data sources
In this paper, Web of Science, a large citation index database platform provided by Thomson Reuters, is used as the data source, and the data collection and retrieval strategy are "Subject = ((Nanocomposite*) and (Flame Retardan *)); Warehousing time =2000-2019; Database = core collection of Web of Science, obtaining the relevant research literature included in Web of Science from 2000 to 2019, and retrieving 3083 kinds of literature (including articles and reviews). In this paper, the visualization software CiteSpace developed by Dr Chaomei Chen was selected to analyze, mine and visualize the literature data of scientific research, so as to reveal the potential knowledge contained in scientific analysis. WOS data analysis is used for data processing in this paper.

3. Results and analysis
By using Citespace software and bibliometrics research methods, the knowledge map visualization was carried out from six aspects, namely, literature publication volume, main authors and institutions, core research areas and journals, to study the development status, hotspots and trends in the field of nano-flame retardant materials.

3.1. Literature publication volume analysis
It is of great significance to count the number of published papers and draw the corresponding distribution map by means of metrology, so as to evaluate the stage of this field and predict the development trend and dynamics. The number of samples from 2002 to 2019 in the research field of nano-flame retardant materials was counted at an interval of one year, and the interval histogram was drawn, as shown in Figure 1. According to the number variation law with time, it is not hard to see literature in the field of nano flame retardant materials was steadily rising trend, basic present explosive growth in 2018, did not appear and the rise and fall repeatedly, the 2018-2019 literature output has more than the ten years from 2000 to 2009 in the field of literature, shows the subject research has experienced from steady growth to the fast breakthrough development.

According to the growth rate, the development stage can be roughly divided into three stages: the first stage is the stage of gradual exploration (2000-2005), which is in the early accumulation stage due to the small amount of literature. The second stage is the stage of steady development (2006-2013). A total of 1026 papers were published in this stage, which is a transitional stage with certain basic skills and high output, accounting for 33.28% of the total volume in the past 20 years. The third stage is the rapid growth stage (2014-2019), which shows a high-quality growth. It is not difficult to see that with the increase of fire hazards and other hazards in recent years, the world's demand for flame retardant materials and flame retardant technology increases, and the field of nano-flame retardant materials have been highly valued. At the same time, the literature output in this stage was the largest, with 1948 kinds of literature accounting for 63.19% of all literature. Therefore, nano-flame retardant materials will still be a research hotspot in the future, and the global research literature on nano-flame retardant materials will show a trend of rapid growth.
3.2. Visualization of author cooperation

The co-occurrence map analysis of the authors can identify the core authors of the research field of nano-flame retardant materials and their cooperative network, thus understanding the general trend of the research field.

In order to analyze the author distribution, Li divided the data from 2000 to 2019 according to each year and set the node type as Authors. Each cluster in the graph network represents a research team, and each node represents an author. The node number is denoted by N, the number of connections is denoted by E, and the cooperative Density is denoted by Density. The cooperative network was shown in Figure 2 (N = 778, E = 1322, d = 0.0044). The 3,083 papers selected in the sample were contributed by 778 authors, with a total of 1322 pair cooperation times, and the Density of the cooperative network was 0.0044, which reflected that the cooperative Density in the field of a building fire was low and the cooperation was relatively dispersed.

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**Figure 1.** Number of published literature on nano-flame retardant materials from 2000 to 2019.

**Figure 2.** Distribution of main authors in the research field of nano-flame retardant materials from 2000 to 2019.
The top five authors with the most publications (≥50) were selected and ranked by their publications in the order of high to low: YUAN HU, LEI SONG, DEYI WANG, ZHENGPING FANG, and XIN WANG. These high-yielding authors jointly constituted the core research force for the study of nano-flame retardant materials. In the cooperative network, Professor Hu Yuan from the State Key Laboratory of Fire Science of The University of Science and Technology of China published 217 papers, ranking the first and having the strongest influence, representing the international research strength and level in the field of nano-flame retardant materials research. LEI SONG came in second with 132 publications. To sum up, the development of nano-flame retardant materials has attracted the attention of more and more scholars, but the research teams are scattered. Therefore, the development of this field still needs to be further strengthened by various teams, in-depth academic exchanges, and enhanced technology sharing, so as to better promote the development of global research on nano-flame retardant materials.

3.3. Visualization of institutional research

The mapping analysis of the core author institution can also determine the general trend of the research field of nano-flame retardant materials. Through the visualization analysis of the mapping of scientific knowledge, the pioneering force of the discipline and the close contact between institutions can be mined. To explore the distribution of research institutions, set up network nodes as "institutions" and then run Citespace. Thus, the distribution diagram of the mechanism in the research field of nano-flame retardant materials is obtained (As shown in Figure 3). The size of the nodes in the figure represents the output of the paper of the institution, the connection in the network represents the cooperative relationship between the institutions, and the intermediary centrality is an index reflecting the bridge role of a node in the network. The sample included 3,083 papers from 515 institutions, but there were only 611 collaborations between units. Among them, the team of state Key Laboratory of Fire Science of University of Science and Technology of China has the largest number of node networks and the largest nodes, indicating that it has a high establishment in this field. Although 515 institutions have made some achievements in this field, the distribution of research institutions is very scattered, and there is little cooperation between them. In the knowledge atlas, there are few nodes among research institutions, most of which exist in isolation, and the degree of cooperation still needs to be improved, which is consistent with the analysis results of the author's cooperation atlas.

![Figure 3. Diagram of core institutions in the research field of nano-flame retardant materials from 2000 to 2019.](image-url)
The number of publications can, to a certain extent, represent the research strength of institutions in this field. The top 10 research institutions with publications (≥50 publications) are shown in Table 2. As can be seen from Table 1, the University of Science and Technology of China has published 282 papers, ranking as the institution with the highest publication volume. Sichuan University ranked second with 126 papers, while the Chinese Academy of Sciences ranked third with 116. According to the nature of these units, the research of nano-flame retardant materials in China is mainly concentrated in universities, and relatively remarkable achievements have been made initially.

Table 1. Top 10 institutions in the research field of nano flame retardant materials from 2000 to 2019.

| Ranking | Institution                  | Number of papers |
|---------|------------------------------|------------------|
| 1       | Univ Sci & Technol China     | 282              |
| 2       | Sichuan Univ                 | 126              |
| 3       | Chinese Acad Sci             | 116              |
| 4       | Qingdao Univ Sci & Technol   | 74               |
| 5       | City Univ Hong Kong          | 74               |
| 6       | Islamic Azad Univ            | 72               |
| 7       | Beijing Univ Chem Technol    | 71               |
| 8       | Beijing Inst Technol         | 70               |
| 9       | Zhejiang Univ                | 64               |
| 10      | Politecn Torino              | 51               |

3.4. Visualization of keyword research

Keywords are the core content of the article is highly summarized and refined; it can often reflect a hot issue in the research field. Keywords with high frequency can usually be used to determine the research heat of a stage. Visual analysis of knowledge map of keywords is also of great significance.

![Figure 4. Co-occurrence spectrum of high-frequency keywords.](image)

In Citespace, the node type was selected as Keywords, and the analyzed time interval was divided according to each year to analyze the Keywords' word frequency and co-word network. Finally, the keyword co-occurrence network containing 820 Keywords and 4192 co-occurrence relationships was obtained, as shown in Figure 4. In the network, the larger the tags of keywords are, the more attention will be paid to the keyword in the whole research field of nano-flame retardant materials. The links
between keywords reflect the co-occurrence relationship between keywords; that is, these keywords are selected in pairs as the keywords in the paper. The number of keywords with a frequency over 255 was 21 in total, among which Nanocomposite ranked first (the occurrence frequency was), mechanical Property and Composite ranked second and third with 815 and 753 times respectively. From the perspective of keyword co-occurrence network, in the field of nano-flame retardant materials worldwide at present, nano-coefficiency system and its physical properties are the hot topics in the whole time range.

3.5. Keywords dynamic frontier evolution map

The dynamic frontier map of keywords usually reflects the research hotspots in a certain field in a certain period of time. By dividing the time series, the keywords are presented in different periods of time. In Citeseer, the node type was selected as Keywords, and the analyzed time interval was also segmented according to each year for the dynamic frontier evolution analysis of Keywords. The year of literature publication was used as the X-axis, and the cluster number was used as the Y-axis. Finally, the keyword timeline network was obtained, as shown in Figure 5.

![Dynamic frontier evolution map](image)

Figure 5. Dynamic frontier evolution map.

3.6. Literature publication volume analysis

Journal co-citation analysis can classify and locate journals, identify core journals and marginal journals in a certain field, and provide strong support for researchers in data collection.

In Citeseer, the node type is Cited Journal. Also, the analyzed time interval is divided according to the year to be Cited, and co-cited analysis of the Journal is conducted based on the number of nodes obtained, as shown in Figure 6. Based on the co-citation analysis of journals, the top 5 listed are POLYMER DEGRADATION AND STABILITY, POLYMER, JOURNAL OF APPLIED POLYMERS FOR ADVANCED TECHNOLOGIES, AND CHEMISTRY OF MATERIALS. Among them, the publication of periodical DEGRADATION AND STABILITY is the most frequently cited, showing a relatively high authority in this field, AND providing more academic value for scholars. It can be seen that in the research field of nano-flame retardant materials, the articles published in the above five journals represent the highest level in this field and serve as an important window for scholars to learn and communicate.
4. Conclusions
In this paper, the development status, research hotspots and sources of core journals in the research field of nano-flame retardant materials from 2000 to 2019 are visualized by bibliographic measurement method and knowledge map visualization analysis combined with specific literature. It is found that the current academic research in the field of nano-flame retardant materials has the following characteristics: First, from the perspective of time, authors and organization distribution, the development of nano-flame retardant materials can be roughly divided into three development stages: exploration stage (2000-2005), steady development stage (2006-2013), and rapid growth stage (2014-2019). The academic circles pay more and more attention to nano-flame retardant materials, and the number of research literature has maintained a high growth trend since 2014. From the perspective of growth rate, professor Hu Yuan and his team from the State Key Laboratory of Fire Science of The University of Science and Technology of China ranked the first in terms of publication volume, indicating that China has a relatively solid academic foundation and scientific research strength in the field of nano-flame retardant materials. However, at present, the research institutions in this field are relatively scattered, with less cooperation and exchange among them. Most of the research institutions exist in isolation, and the degree of cooperation needs to be improved.

Second, through keyword co-occurrence analysis shows that the research hotspot in the field of vocabulary mainly for zirconium, DOPO, intumescent flame retardant, rubber, phosphate and Nanocomposite. As Graphene's applications become more and more mature, the research focus mainly focuses on nanotechnologies represented by Graphene and others and focuses more on the Synthesis and evaluation of synergistic properties of flame-retardant polymer/inorganic nanocomposites. It is not difficult to see that in the future, the research on nano-flame retardant materials will focus on new flame-retardant nanocomposites with lower smoke toxicity, higher efficiency and better other properties (thermal stability, mechanical properties, etc.).

Thirdly, based on the analysis of co-citation of journals, it can be seen that the most cited quantity AND STABILITY of journals are more authoritative in this field, offering more academic value for scholars.

To sum up, this paper employs Citespace software intuitive shows the nano flame retardant materials research in the field of the knowledge base, research focus and development trend, at the same time, we combine the map to determine the core journals and the domain edge of journals and predict the future research direction, provides the relevant scholars to conduct research in the field of work.
Acknowledgements
This work was financially supported by Synthesis of a novel phosphorus nitrogen intumescent flame retardant based on "three sources" and its flame-retardant polystyrene (16211248) fund.

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