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Science mapping of catalyst support for gas adsorption applications

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Abstract. Science mapping is a visual representation of the structure and dynamics of scholarly knowledge. Gas adsorption on catalyst supports is a crucial process in many catalytic reactions. The R package "Bibliometrix" and VosViewer software were employed for science mapping analysis. The results show that the upward trend but fluctuates from year to year for both annual scientific production and average article citations per year. Co-occurrence of the keywords were used to identify the primary fields of study and to map the existing state of research. Trending topics reveal some interesting features that support the growth of research in this field and are associated with emerging disciplines or areas of study that have not been extensively explored.

Keywords: catalyst supports; gas adsorption; keywords; science mapping

1. Introduction

Catalyst support plays a crucial role in gas adsorption processes, particularly in the field of chemical and petroleum engineering. Catalyst support refers to the material that provides a framework or structure for the active catalyst material. Catalyst support materials are typically porous solids with a high surface area, allowing for increased gas adsorption capacity. Catalyst support materials are crucial for enhancing the performance and stability of catalysts in gas adsorption processes. Gas adsorption refers to the process of molecules adhering to the surface of a solid material, known as the adsorbent.

In chemistry, a catalyst support is the material, usually a solid with a high surface area, to which a catalyst is affixed (IUPAC 1997). The incredible potential of heterogeneous catalysts is derived from their porous nature, which can be optimized to meet reaction conditions including high temperature, high pressure, and corrosive environments.

Consequently, the share of solid catalysts in the chemical industry will continue to rise because of the growth in world population and the escalation of global energy demand, which was forecast to double from 2000 to 2035 (Boffito and Van Gerven 2019).

The porous catalyst support of clay-fly ash composite and their reticulated structures are shown

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Fig. 1 A porous composite support catalyst made from clay and fly ash

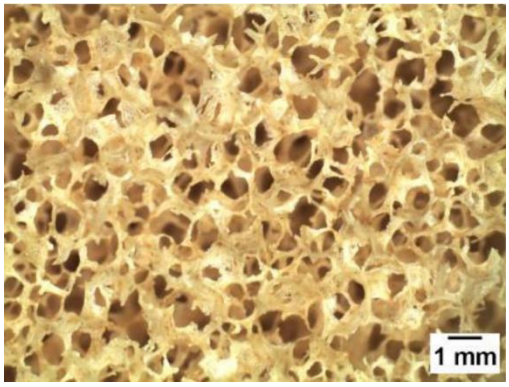

Fig. 2 Reticulated structures of porous clay-fly ash composites

in Figs. 1 and 2 respectively have the potential to be used in many fields, such as catalyst supports (Chan *et al*. 2016) and gas adsorbents (Chan *et al*. 2013). Science mapping is a technique used to analyze and visualize the research landscape of a particular field. In this study, science mapping is used to identify the key research areas, gaps, and trends in the field of catalyst support for gas adsorption applications.

2. Methodology

The raw numbers of publications and citations deriving from the timespan between 1970 and 2022 include 18760 documents via Web of Science (WoS) database. The R package "Bibliometrix", an open-source software for automating data analysis and visualization was used to analyse data manually retrieved from WoS.

In this study, Bibliometrix is used to identify and analyze the scientific performance of authors, articles, journals, and institutions through the analysis of keywords and the number of citations. VOSviewer, which is a software tool was used for constructing and visualizing bibliometric networks for keyword analysis (van Eck and Waltman 2010).

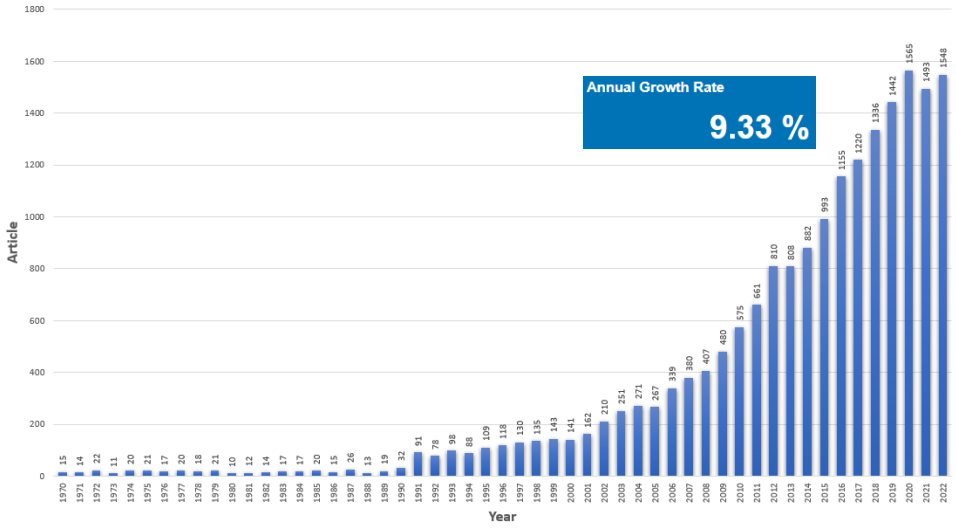

Fig. 3 Annual scientific production

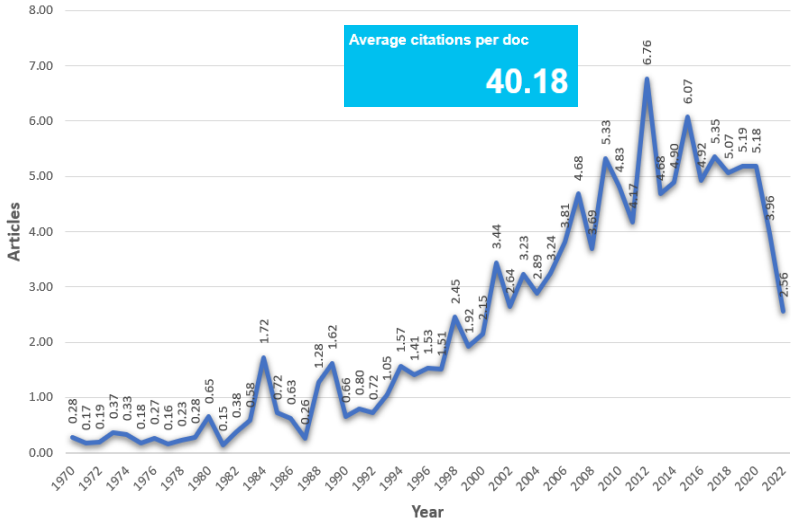

Fig. 4 Average article citations per year

3. Results and discussion

According to the data in the WoS database, the annual publication from 1970 to 2022 with 9.33% annual growth rate is illustrated in Fig. 3. Since 2005, the number of publications exceeded 90 for the first time and has been fluctuating increase and decrease until 2022. Several possible reasons for the unsteady increasing and decreasing trend in annual scientific production of catalysts supports research have been identified.

The advent of technological advancements in the new generation of supported metal catalysts and flow chemistry (Ciriminna *et al.* 2021) and research on nano catalysts (Thangaraj *et al.* 2018) could be leading to fluctuations in research output as researchers explore new avenues of research.

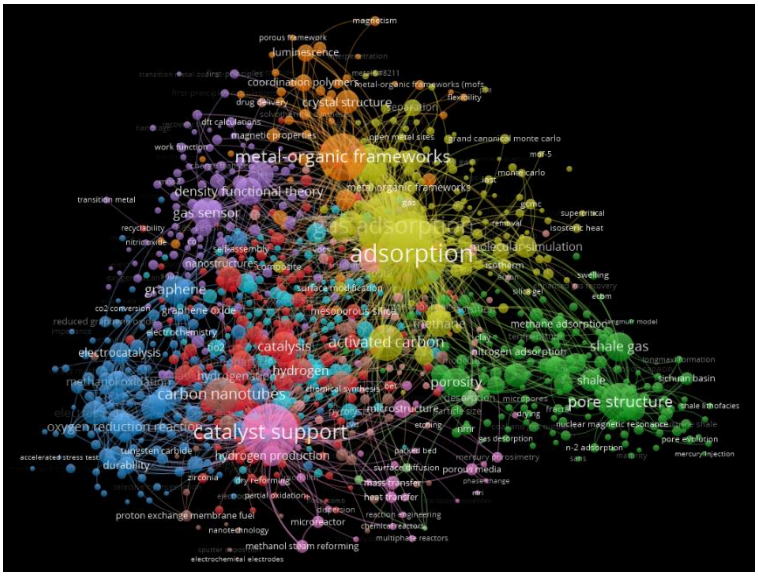

Fig. 5 Co-occurrence network of keywords

Changes in funding availability could lead to fluctuations in research output as researchers are able to pursue different avenues of research depending on funding availability. Increased competition in the field could lead to fluctuations in research output as researchers compete for funding and publication opportunities.

The average citations per document of catalyst support is 40.18 which is considered a relatively moderate level. However, the average article citations per year shows an upward trend but fluctuates from year to year as shown in Fig. 4. The research focus in support catalysts may be shifting towards topics that are less frequently cited, leading to a decrease in average article citations per year.

In order to have more insights on the correlation between the scientific content and the bibliometric trends, a co-occurrence of keywords was carried out in Fig. 5. The most frequent keywords were divided into 5 clusters with five different colors. Keywords that were similar in content were grouped in a cluster. The main keyword clusters of catalyst support research, which are adsorption, gas adsorption, catalyst support, metal-organic frameworks, and pore structure. By analyzing the co-occurrence of these keywords in publications related to catalyst supports research, researchers can identify the most popular research topics, the most influential authors, institutions, and journals in the field, and emerging research topics and areas where more research is needed.

The size of the circle represents the frequency of the keyword. The size of the line represents the links between the keyword to the other. The thicker the line between two keywords, the more frequently that the two keywords appear together (Li 2020). The analysis of high-frequency keywords is key to investigating hot topics in a field. A total of 50 keywords were obtained from the 18760 articles analyzed as shown in Fig. 6.

Fig. 7 demonstrates the most productive of the 10 authors. A count of an author's distributions is one of the foremost essential and critical insights. Productivity as well as impact are measured to understand scientific productivity patterns in each research area. From the data, it shows that all the 10 productive authors are from China.

In bibliographic research, another common unit of analysis is the sources (journals) in which

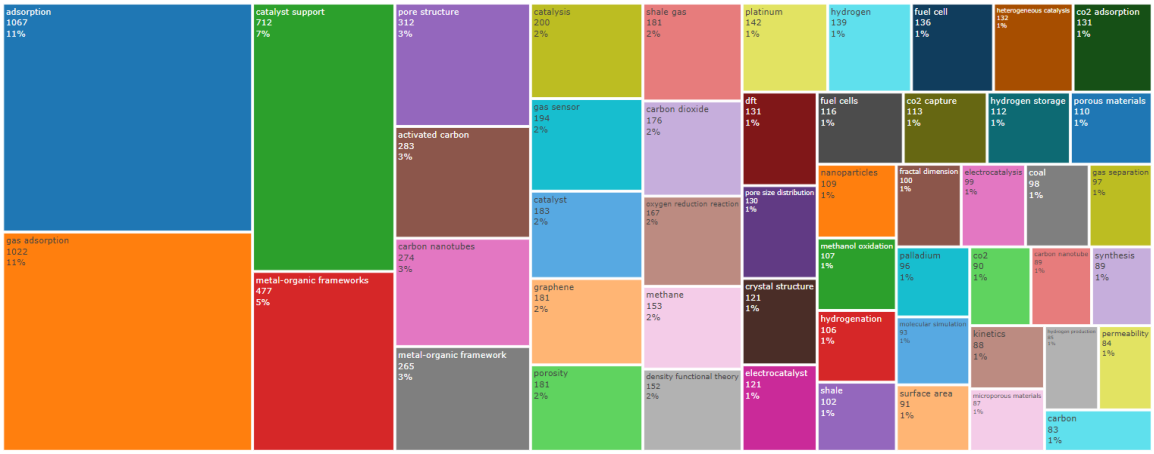

Fig. 6 Word tree-map of keywords

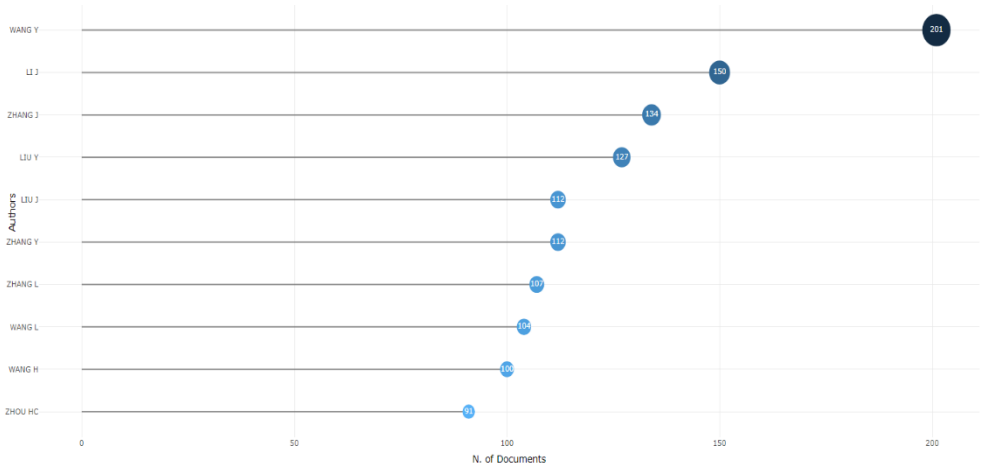

Fig. 7 Most relevant authors

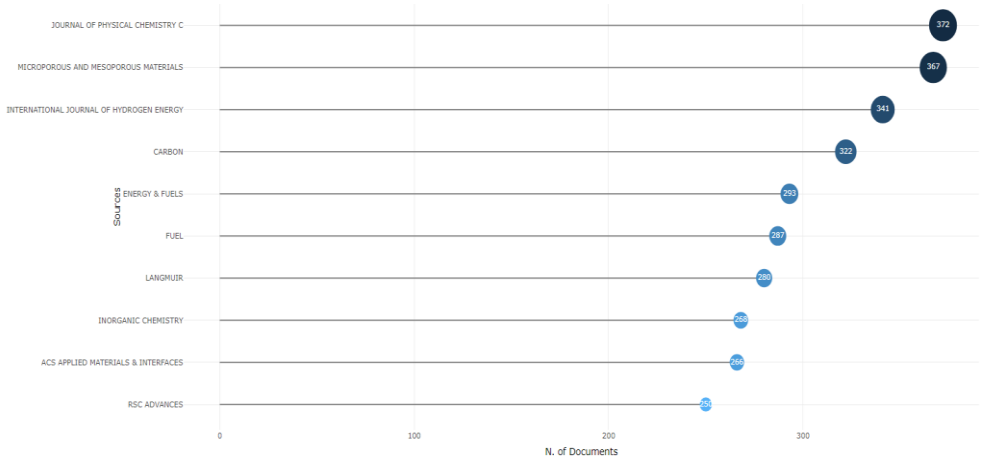

Fig. 8 Most relevant sources

Fig. 9 Most relevant affiliations

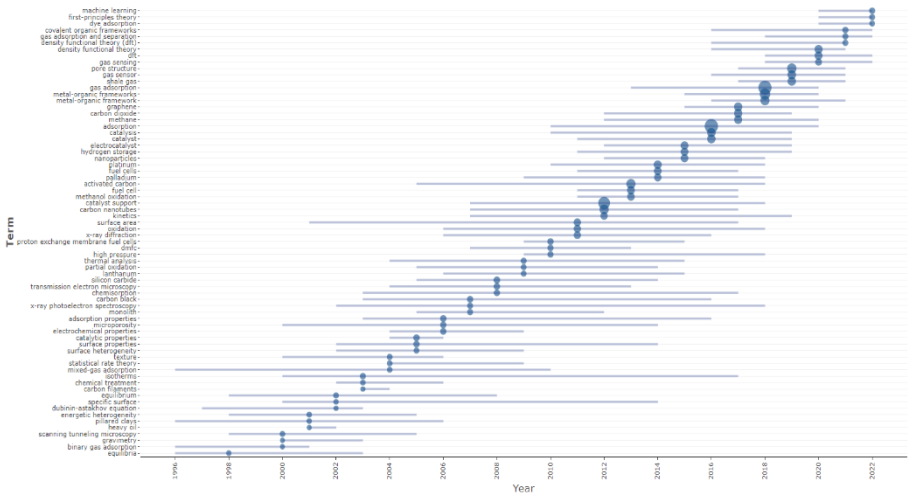

Fig. 10 Trend topics

articles are published. A descriptive analysis of the most active publications, similar to the work of the authors, was performed and reported in Fig. 8. The raw data demonstrate that Journal of Physical Chemistry C, Microporous and Mesoporous Materials and International Journal of Hydrogen Energy are the top publishing journals.

The most relevant affiliations among the scholars working on catalyst support are reported in Fig. 9. Six Chinese institutions and four US institutions dominate the 10 largest allies in this field.

Trends topic in catalyst support research is shown in Fig. 10. The integration of machine learning techniques, such as natural language processing and topic modeling, are being used to analyze large volumes of literature and identify key research areas and trends in the field. The use of advanced characterization techniques such as in situ spectroscopy and microscopy has proven to be a growing trend in this area and are being used to gain a deeper understanding of the properties and behavior of catalyst support materials. Another emerging trend is the integration of catalyst support materials with other technologies such as membrane separation and electrochemical processes. There is an

increasing focus on the development of sustainable and environmentally friendly catalyst support materials, such as biomass-derived carbon materials and organometallic frameworks.

In terms of economic demands, there is no specific data on the expected volume and growth rate for support catalysts used in gas adsorption and only mentioned specifically about catalyst. The demand for catalysts from manufacturers worldwide is increasing due to the escalating demand from applications such as petroleum refining, chemical synthesis, polymers and petrochemicals, and environmental (Pulidindi and Ahuja 2023). The global demand for refining catalysts was 831 kt/year in 2018 and is expected to grow by 1.1% through 2040 (Alabdullah *et al.* 2020). The global catalyst market size was valued at USD 29.7 billion in 2022 and is anticipated to grow at a compound annual growth rate (CAGR) of 4.6% from 2023 to 2030 (Pulidindi and Ahuja 2023).

4. Conclusions

Based on the results, several conclusions can be withdrawn from this study:

• Both annual scientific production and average article citations per year display an upward trend but fluctuates from year to year. The new generation of supported metal catalysts and flow chemistry, research on nano, changes in funding availability and increased competition in the field could lead to fluctuations in research output as researchers compete for funding and publication opportunities. The research focus in support catalysts may be shifting towards topics that are less frequently cited, leading to a decrease in average article citations per year.

• The main keywords in catalyst support for gas adsorption are adsorption, gas adsorption, catalyst support, metal-organic frameworks, and pore structure.

• Trend topics reveal some interesting features that support the growth of research in this field such as the integration of machine learning techniques, the use of advanced characterization techniques, is the integration of catalyst support materials with other advanced technologies and the development of sustainable and environmentally friendly catalyst support materials.

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