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Development Analysis on BiFeO3 Nanoparticle as Material Research in Laboratorium Area through Bibliometric using Vosviewer

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Abstract
Purpose: This research aimed to conduct analysis in the research of BiFeO3 nanoparticles through bibliometric analysis techniques with computational mapping used VOSviewer application.
Methodology/approach: By using the publish or perish reference management tool and the Google Scholar database's collection of research article data to obtain research data article. The search was focused on the article's title and abstract with "BiFeO3 nanoparticles" was used as the search term, and literature review method was used according to related topics. This study's research era covers the most recent 10 years (2012 to 2022) from publications in both national and international journals that Google Scholar has indexed.
Results/findings: From the search result, there were 996 journal articles related to keywords. The range of journal articles searched from the Google Scholar database is the last decade (from 2012 to 2022).
Limitations: This limitations of this research was focused on the development trend of BiFeO3 nanoparticle research in the last decade shows a slight fluctuation but still an uptrend from time to time.
Contribution: This research is expected to provide information on research development trends during the last decade for researchers who want to conduct research, especially related to the topic of BiFeO3 nanoparticle.
Keywords: *Bibliometric, $BiFeO_3$ nanoparticle, Publish or Perish, Vosviewer.*
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1. Introduction

Bismuth ferrite (BiFeO3, BFO) has been intensively studied over the last decade to have ferroelectric and antiferromagnetic properties. By using BifeO3 nanoparticles as nanofillers with magnetic moments as a magnetic source in composites for future uses in medicine, environmental protection, the electronic industry, electromagnetic interference shielding, etc (Bangruwa et al., 2019). Particularly, composites made of polymers electronic devices with the benefits of miniaturization, lightweight, and low cost can be created using materials having both dielectric and magnetic capabilities, which has become a hot topic in business and academia (Li et al., 2019). Therefore, it has become an exciting area of research to create relevant preparatory technologies and unique processing techniques.

Given the promising potential of these nanoparticle materials, it would be excellent if academics could do a variety of studies employing BifeO3 nanoparticles on a laboratory scale so that they could serve as a sustainable reference. According to the pertinent issue, a literature evaluation is required prior to doing the research; thus, the bibliometric technique is employed. Bibliometric analysis can be

used as an analytical technique to find out the developing trends in research in the field of nanoparticles. In addition, the technique is a statistical evaluation of scientific articles published in the Google Scholar database and can be used as an effective way to measure the effect of publications in the scientific community (Iftikhar et al., 2019).

There are several research using material BiFeO3 nanoparticle conducted by many researchers, research conducted by Irfan et al. in Band-Gap Engineering and Enhanced Photocatalytic Activity of Sm and Mn Doped BiFeO3 Nanoparticles (Irfan et al., 2017), research by Annapu Reddy et al. in Particle size dependent magnetic properties and phase transitions in multiferroic BiFeO3 nano-particles: elucidating the photocatalytic mechanism under different light sources (Annapu Reddy et al., 2012), and research by Bai et al. in Size Effect on Optical and Photocatalytic Properties in BiFeO3 Nanoparticles (Bai et al., 2016). There is still little research on computational bibliometric analysis related to the field of BiFeO3 nanoparticle research, especially by using the Publish or Perish application as a tool in obtaining journal data and VOSviewer application as a tool for computational mapping in bibliometric analysis. This research is used to obtain update of term and quantity of term.

Therefore, the aim of this research is to conducting research and development analysis on BiFeO3 nanoparticles bibliometrically with computational mapping using VOSviewer application. This research provides information in the form of research studies for researchers in conducting research on relevant topics in the field of BiFeO3 nanoparticle.

2. Literature review

2.1 Membrane Technology

Membrane technology has evolved and is now widely used in the separation and purification of water. The membrane is generally defined as a porous medium in the form of a thin layer with semipermeable properties that allow certain species to pass through (Rahmaniyan et al., 2021). The particle size of the compound and the pore size of the membrane are used to separate species through the membrane, with particles larger than the membrane pores being retained on the membrane surface. The retentate, or part of the mixture that does not pass through the membrane, and the permeate, or part of the mixture that does pass through the membrane, are the results of the separation. The driving force for mass transfer on the membrane can be differences in concentration (C), pressure (P), temperature (T), or electric potential (E) (Zahirifar et al., 2018).

2.2 Desalination

Water desalination is the separation of dissolved minerals (including salt) from seawater, brackish water, or treated wastewater (Saleem & Zaidi, 2020). Distillation, ion exchange, freeze desalination, and membranes are some of the basic techniques for separating salt and other dissolved solids (Subramani & Jacangelo, 2015). Membrane desalination technology is the use of a semipermeable membrane to isolate salt and achieve salt-water separation. Water desalination technologies that use membranes, such as reverse osmosis and nanofiltration, can be used (Anis et al., 2019). According to the driving force, pressure membrane water desalination technology (RO and NF) has the advantages of relatively high energy efficiency, low operating pressure, a high rejection rate for divalent salts, and is environmentally friendly when compared to other salt separation technologies (Homaeigohar & Elbahri, 2017). Reverse osmosis is the most effective technology for producing drinking water from seawater at the moment. Water is pressed against a semipermeable membrane during reverse osmosis desalination, allowing water to pass through while salt is retained. A high-pressure pump will press the feed water into the membrane to supply it. A high-pressure pump will press the feed water into the membrane to supply pressure and push the water through the membrane, so a higher pressure is required to treat water with a higher salt concentration (Okamoto & Lienhard, 2019).

2.3 Bibliometric

Bibliometrics is a tool for determining objective publication data, which is frequently used as performance data and can assist in completing the tasks mentioned. Its basic features can be considered highly mathematically and statistically, or they can be rendered understandable and

transparent to nonmathematicians. Opposition to and reservations about gathering data on research performance stem primarily from people who do not understand the method and fear it as manipulation. As a result, it is critical not only to make bibliometrics understandable and transparent, but also to reveal its limitations and identify alternatives (Husaeni & Nandiyanto, 2022). Cole and Eales developed the first bibliometric analysis. The authors investigated which books on human anatomy were published between 1550 and 1860 in 1917 (Ball, 2018).

On the other hand, Bibliometrics is a set of quantitative methods for analyzing academic literature and patents. Meanwhile, using keywords, the bibliometric method can describe distribution patterns within a given topic, field, institute, or country, as well as assess development trends or future research orientations. The basic idea behind bibliometrics is to quantify people's and institutions' academic output. A second step involves drawing qualitative conclusions from the figures and values. Bibliometrics is one method for accomplishing this (Hassan et al., 2020). The bibliometric method is an indirect approach that deduces academic quality from quantification of academic output and publications (Al Husaeni & Nandiyanto, 2021). Aside from traditional publications, there are a slew of other quantifiable factors that can be used to assess academic performance and quality, such as the number of final projects supervised (doctoral theses, postdocs, etc.), the amount of external funding raised, the number of pending patents, the number of exhibitions and visitors, appointments on relevant national and international committees, the number of students enrolled per chair or professor, and the extent and number of publications (Ball, 2018).

3. Experimental Procedure

In this study, journal publications indexed by Google Scholar were used as a data collection of research articles. We use the Google Scholar database in this study because it is an open source program. the manager's reference application, namely Publish or Perish, is used as a tool to obtain research data. Publish or Perish application is used to collect data for the research articles that we want with the specified time period.

The research was conducted through several steps:

(i) Collecting data on articles that have been published using the publish or perish application,
(ii) Microsoft Excel application is used to process bibliometric data on articles that have been obtained,
(iii) Using the VOSviewer application which publishes data through analysis bibliometric approach with computational mapping, and
(iv) Conduct a review of the results of computational mapping analysis.

Article data collection is searched by filtering publications using the keyword "$BiFeO_3$ nanoparticles" based on the relevant research title in the Publish or Perish application. Papers published between 2012 and 2022 were used as the data collection period for articles. The articles that have been obtained must be relevant according to the analysis of this research and then converted into two different file types, namely the research information system (.ris) and the comma-separated value format (*.csv).

Next, we use VOSviewer to visualize the data and select developing trends using bibliometric techniques. The collected article data is mapped by making 3 types of publication mapping visualizations, namely overlay visualization, density visualization, and network visualization between existing items. as a result we get 8 clusters with 255 terms and filter keywords as desired.

4. Results and Discussion

4.1 Development trend of research in the Field of $BiFeO_3$ nanoparticle

The outcomes of bibliometric analysis using Perish software and the keywords "$BifeO_3$ nanoparticle." can be seen in Table 1 and Figure 1. The number of publications between 2012 and 2022, 996 publications on $BifeO_3$ nanoparticles were published; these publications were chosen based on their

relevance to the issue. Every year, the amount of study on $BifeO_3$ nanoparticles advances, with the peak number of publications or research on this topic occurring in 2018.

Table 1. Development of $BiFeO_3$ nanoparticles research

Year of Publications	Total of Publications
2012	41
2013	62
2014	73
2015	89
2016	85
2017	89
2018	119
2019	108
2020	115
2021	115
2022	100
Total	996
Average	90,5

According to Table 1, it is shows that the development trend of research published in Google Scholar indexed journals in the field of $BiFeO_3$ nanoparticles. in Table 1, it is known that from 2012 to 2022 the number of research articles on $BiFeO_3$ nanoparticles was 996 articles. The details are 41 articles in 2012, 62 articles in 2013, 73 articles in 2014, 89 articles in 2015, 85 articles in 2016, 89 articles in 2017, 119 articles in 2018, 108 articles in 2019, 115 articles in 2020, 115 articles in 2021, and 100 articles in 2022. Based on the total publications, it shows that research on $BiFeO_3$ nanoparticles is relatively increasing every year.

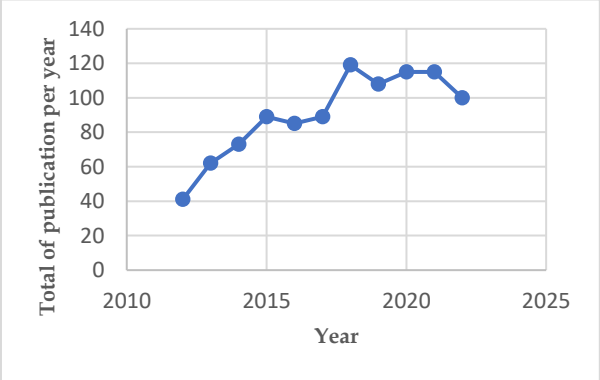

Figure 1. Trend of development in $BiFeO_3$ nanoparticles research

According to Figure 1, it is shows that the development of research on $BiFeO_3$ nanoparticles during the last decade in the range from 2012 to 2022. In Fig.1, it is known that research developments related to $BiFeO_3$ nanoparticles have increased from 2012-2018. This increase can be seen from the total publications in 2012 of 41 publications to 2018 of 119 publications. the development of research on $BiFeO_3$ nanoparticles in 2018-2022 has slightly fluctuated. however, the research development of $BiFeO_3$ nanoparticles has increased in the last decade. These data indicate that the popularity of research on $BiFeO_3$ nanoparticles is relatively stable and interest in $BiFeO_3$ nanoparticles can continue to increase.

4.2 Visualization $BiFeO_3$ nanoparticle Research Area Using VOSviewer

Article data were collected and treated with computational mapping using VOSviewer application. Based on the results of computational mapping found 255 items and the analysis is divided into 8 clusters, namely:

1) Cluster 1 has 63 items, and marked in red, the 63 items are adsorption, advantage, ag nanoparticle, application, au nanoparticle, bifeo, bismuth, catalyst, characterization, comparison, composite, degradation, development, diameter, efficient degradation, efficient photocatalyst, electron, enhanced photocatalytic acitvity, enhanced visible light property, fabrication, facile synthesis, graphene oxide, growth, high purity, hydrothermal method, hydrothermal synthesis, insight, magnetic nanoparticle, mechanism, metal, metal nanoparticle, methyl orange, microwave, morphology, nanocomposite, nanofiber, nanoparticle, nanowire, novel, organic pollutant, particle, performance, perovskite, photocatalysis, photocatalyst, photocatalytic activity, photocatalytic degradation, photocatalytic performing, photodegradation, preparation, process, rhodamine b, solution combustion nm, surface, synthesis, time, tio, visible light, visible light irradiation, visible light photocataly, water, work.
2) Cluster 2 has 51 items, and marked in green, the 51 items are article, bi0, bife, bife03 ceramic, bife03 sample, bismuth ferrite, bulk, ceramic, change, comparative study, composition, compound, conventional solid state, correlation, crystal structure, effect, electrical property, feo, ferroelectric property, ferroelectricity, ferromagnetism, improvement, Ion, magnetic behavior, magnetic property, magnetoelectric coupling, mol, multiferroic, multiferroic bifeo, multiferroic ceramic, multiferroic property, pattern, phase, polycrystalline sample, powder, pure bife03, rare earth, senes, site, sol gel, solgel method, solid solution, solid state reaction, solid state reaction method, spark plasma, structural property, structural transition, structure, substitution, ti co, undoped bifeo.
3) Cluster 3 has 39 items, and marked in blue, the 39 items are antibacterial activity, band gap, behavior, bfo, bife03 film, bife03 phase, bife03 thin film, cofe204, defect, dielectric property, electric property, electronic structure, enhancement, exchange bias, film, impact, impurity phase, matrix, multiferroic bife03, multiferroic material, nanocrystalline, observation, order, oxygen vacancy, photovoltaic effect, physical property, polarization, polycrystalline, polycrystalline bifeo, potential application, pulsed laser deposition, raman spectroscopy, role, strain, study, substrate, system, thin film, variation.
4) Cluster 4 has 36 items, and marked in yellow, the 36 items are ba x feo, bife03 material, bife03 nanopowder, case, co doped bife03, co precipitation method, concentration, dielectric, dielectric properties, doping, formation, low temperature, magnetic, magnetic properties, microstructure, microwave absorption V:, multiferroic nanoparticle, nano, nanopowder, optical, optical property, paper, presence, present work, pure phase, raman, rhombohedral structure, route, sample, shape, single phase bifeo, sol, sol gel method, structural, x ray diffraction study, x rd.
5) Cluster 5 has 34 items, and marked in purple, the 34 items are addition, analysis, average Elze, bfo nanoparticle, bife03, bife03 perovskite, bismuth ferrite nanoparticle, co doping, doped bfo nanoparticle, enhanced multiferroic property, example, exchange bias effect, ferroelectric, fig, figure, function, lanthanum, magnetic field, nanocrystal, nanocrystalline bife03, nanomaterial, origin, phase transition, possibility, prepared nanoparticle, pure bifeo, room temperature, solgel technique, structural study, temperature, x ray, x ray diffraction, xrd pattern, yftrium.
6) Cluster 6 has 17 items, and marked in light blue, the 17 items are enhanced magnetization, evidence, ferrite nanoparticle, magnetism, magnetization, magnetodielectric property, magnetoelectric property, particle size, present study, report, single phase, size, solgel, structural analysis, structural transformation, value, weak ferromagnetism.
7) Cluster 7 has 14 items, and marked in orange, the 14 items are bife03 nanoparticle, co substitution, cofe, influence, investigation, journal, mn co, multiferroic bife03 nanoparticles, photocatalytic property, property, research, saturation magnetization, synthesized nanoparticle, tartaric acid.
8) Cluster 8 has 1 items, and marked in brown, the 1 items are size effect.

4.3 Visualization Mapping of $BiFeO_3$ Nanoparticle Keyword

In each group, it shows that there is an interaction between one term and another, with each term found being labeled in the form of a colored circle. Each term varies has a circle size depending on the frequency of occurrence of the term (Hamidah, et al., 2020). Relationship that relates to finding the term in the article is referred to as the circle size on the label (Nandiyanto. et al., 2021). The bigger the size of the label, the more often the term is found (Al Husaeni & Nandiyanto, 2021). The

computational mapping visualization reviewed in this study consists of 3 parts: network visualization (see Figure 2), density visualization (see Figure 3), and overlay visualization (see Figure 4).

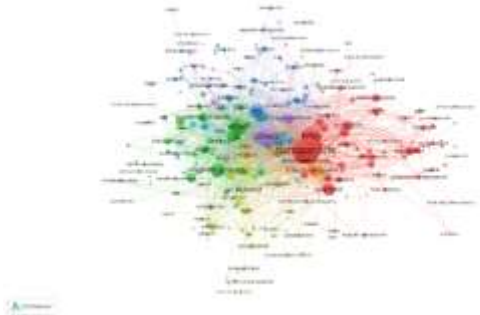

Figure 2. Network visualization of $BiFeO_3$ nanoparticle keyword

According to Figure 2, it is shows that the correlation between terms. The correlation between terms is described in an interrelated network. In Fig.2, it is found that there are groups of terms that are often studied and according to the research topic of $BiFeO_3$ nanoparticles.

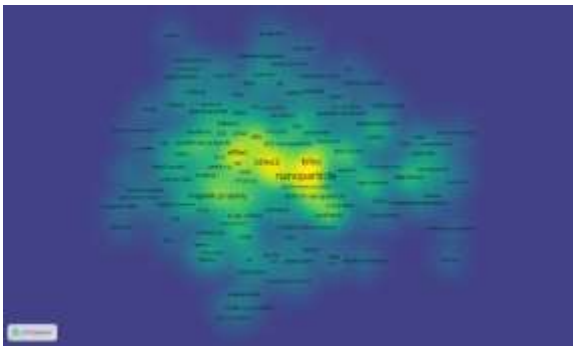

Figure 3. Density visualization of $BiFeO_3$ nanoparticle keyword

According to Figure 3, shows that the density visualization. Density visualization indicates that the larger the diameter of a circle and the brighter the yellow color of the keyword term, the more frequent the term will appear (Hamidah, et al., 2020). This shows that a lot of research has been done on related terms. On the other hand, if the color of the term fades close to the background color, then the number of studies on the term is small. In Fig.3, it can be seen that research related to the terms, bfo, bifeo3, bifeo, and nanoparticle have a high number of studies.

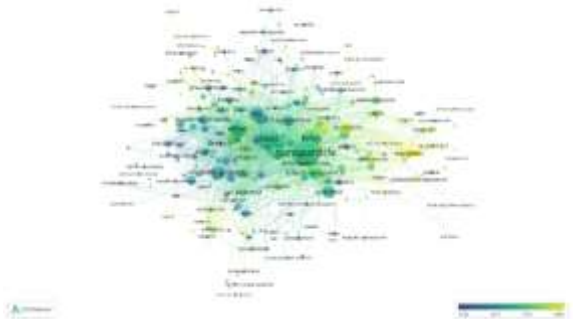

Figure 4. Overlay visualization of $BiFeO_3$ nanoparticle keyword

According to Figure 4, shows that the overlay visualization. This visualization overlay shows the update of research on related terms. In Fig. 4, Most research on $BiFeO_3$ nanoparticles was found in 2017 to 2018 so that we can find inspiration for the latest research on $BiFeO_3$ nanoparticles.

5. Conclusion

The purpose of this study is to analyze computational mapping on bibliometric data of research articles using VOSviewer application. Google Scholar database is used as a place to get article data using Publish or Perish. The library data used in this research concerns titles, keywords, and abstracts. The data obtained by searching using the keyword "$BiFeO_3$ nanoparticles" resulted in 8 clusters with a different number of terms in each cluster and each color represented its own cluster. Based on the search results, in the range of 2012 to 2022, as many as 996 articles have been found as research article data. In 2012 – 2018 there was an increase in the number of studies from 41 to 119 (78 studies). However, in 2018 – 2022 it decreased from 119 to 100 (19 studies). Results of this research indicate that there is a high enough opportunity for further research on $BiFeO_3$ nanoparticles to be developed and related to other terms.

Limitation and suggestion

This research is limited to the analysis of research developments related to $BiFeO_3$ nanoparticles as a research material in general in the last decade using bibliometric methods so that deeper study is needed. For further research, this bibliometric analysis can be carried out more specifically regarding the various applications of using $BiFeO_3$ nanoparticles, as well as research mapping related to each keyword that needs to be studied further.

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