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A BIBLIOMETRIC ANALYSIS OF CARBON NANOTUBES SYNTHESIS RESEARCH USING VOSVIEWER

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Abstract. Carbon nanotubes (CNTs) have been rigorously studied during the past decade due to their extraordinary physical, chemical, mechanical, electrical and optical properties. The purpose of this research is to conduct bibliometric analysis in carbon nanotubes synthesis by combining mapping analysis using VOSviewer software. Application reference manager used to obtain research data, namely Mendeley. The data obtained is the result of a search based on the keyword " Synthesis Method of Carbon Nanotubes ". From the search results, 247 relevant published articles were found in the range of 2018-2022. The results showed that the number of articles researching carbon nanotubes synthesis has been increasing since 2018 until 2021. However, there have been 8 articles that published in the early of 2022, this number could be increased by the time. Research that is being popularly studied by researchers until today is about review due to the COVID-19 pandemic situation that forced the researchers to decrease experiment activity and physical interations. This research is expected to help and become a reference for researchers in conducting and determining the research themes to be taken.

1. Introduction

VOSviewer is a software tool for creating maps based on network data and for visualizing and exploring these maps. Although VOSviewer is intended primarily for analyzing bibliometric networks, it can in fact be used to create, visualize, and explore maps based on any type of network data [1]. The bibliography itself means that a list of book or magazine articles of a certain topic or subject. VOSviewer usually used for exploring references from any topics that most widely used so that we could found a certain topic that still have chance to be researched [2].

Carbon nanotubes (CNTs) have been rigorously studied during the past decade due to their extraordinary physical, chemical, mechanical, electrical and optical properties [3]. Carbon nanotubes (CNTs) are tube-like materials that are made up of carbon with a diameter

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calculating on a nanometer scale. They are originated from graphite sheet and these graphite layers seems similar to a rolled up non-stop unbreakable hexagonal like mesh structure and the carbon molecules appears at the apexes of the hexagonal structures. Depending upon the number of carbon layers, carbon nanotubes can be single-walled carbon nanotubes (SWCNTs), double-walled carbon nanotubes (DWCNTs) and multi-walled carbon nanotubes (MWCNTs). Carbon nanotubes exhibit various characteristic properties such as high elasticity, high thermal conductivity, low density and they are chemically more inert etc. Due to these interesting properties, carbon nanotubes have played a significant role in the field of nanotechnology, electronics, optics and other fields of materials science. Carbon nanotubes (CNTs) can be fabricated by three main methods i.e., chemical vapor deposition, electric arc method and laser deposition method [4].

There are several research about carbon nanotubes synthesis conducted by many researchers, namely by Anggoro and Saraswati [5] in synthesis of carbon nanotubes using plant based materials, research conducted by Arunkumar *et al*. [6] in synthesis and characterisation of MWCNT, research conducted by Awais *et al*. [7] in synthesis and purifications of carbon nanotubes, research by Anazawa *et al*. [8] in synthesis of high-purity carbon nanotubes by an arc discharging in magnetic field, and even an article review that conducted by Anzar *et al*. [4]. However, there has been less research on bibliometric analysis in the field of carbon nanotubes synthesis research, specifically by utilizing VOSviewer software as a tool in conducting mapping analysis. This analysis is important to determine the quantity and up-to-date of a term.

Thus, aim of this paper is to conduct bibliometric research in carbon nanotubes synthesis by combining mapping analysis using VOSviewer software. This research is expected to help and become a reference for researchers in conducting and determining the research topic to be taken, especially those related to the field of carbon nanotubes synthesis.

2. Method

The article data used in this research is research data from articles that have been published in journals that have been indexed by Science Direct. Reference managers' application was used to obtain research data. The reference managers application used in this research is Mendeley. Mendeley was used in conducting a literature review of the theme that we would take. Every article data must be indexed by Science Direct and in the type of journal articles and having conformity with the search for the themes needed in this study are backed up into a file that is used in the use of VOSviewer.

In this study, each article was filtered, and we took only articles relating to Synthesis, Production, or Fabrication. We search for data on Mendeley by entering the keyword "Synthesis Method of Carbon Nanotubes" according to the title, keyword, and abstract criteria. Thus, 247 articles were obtained which were assessed according to the chosen topic. The articles used in this study were articles published in the 2018-2022 range. The collected articles were then saved in *.ris format. Next, we used the VOSviewer application to visualize and analyse trends in the form of bibliometric maps. We did data mapping articles from database sources that have been prepared. Data mapping consists of three types, namely network, density, and overlay visualization. In addition, we also filtered the terms that would be included in the VOSviewer network mapping visualization.

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3. Results and Discussion

3.1 Research Developments in the Field of Carbon Nanotubes Synthesis

Figure 1 shows a curve of the growth or development of research on carbon nanotubes synthesis from 2018 to 2022. Based on Fig. 1, the development of research on carbon nanotubes synthesis over the last 5 years, namely from 2018-2022, has increased until 2021. The number of articles in 2018 was 31 articles, where in 2019, the number of articles increased to 41 and continue to increased to 70 and 97 articles in 2020 and 2021, respectively. However, there have been 8 articles that published in the early of 2022, this number could be increased by the time.

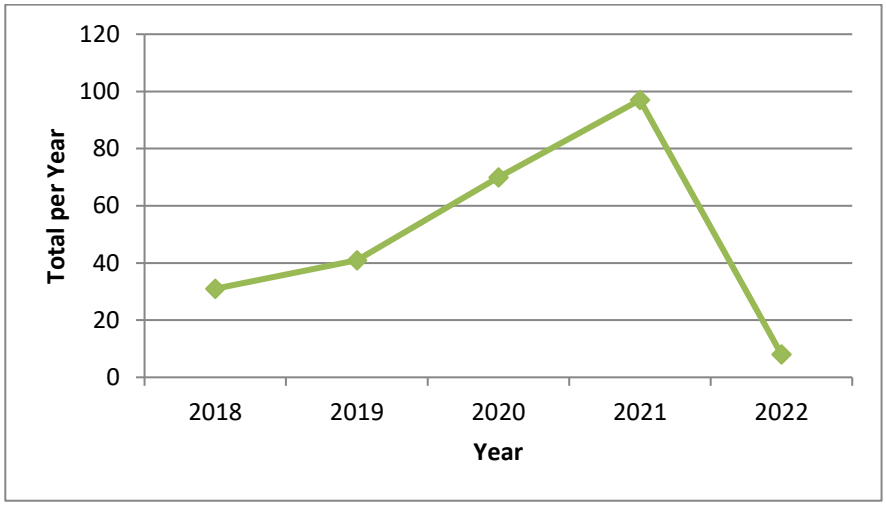

Figure 1. Level of development of research on carbon nanotubes synthesis

3.2 Visualization Carbon Nanotubes Synthesis Topic Area Using VOSviewer

According to Al Husaeni and Nandiyanto [2], the minimum number of relationships between terms in the VOSviewer is regulated by 2 terms. Research related to carbon nanotubes synthesis based on analysis mapping visualization is divided into 7 clusters, namely:

a) Cluster 1 has 69 items, namely advance, amorphous carbon, application field, array, attention, carbon fiber, carbon material, catalyst design, catalyst support, catalytic chemical vapour deposition, characterization method, chirality, cnt formation, controlled synthesis, copper, decade, depth, detail, difficulty, direction, drawback, example, flexibility, fuel cell, function, future, future development, high density, high purity, history, industrial scale production, industrialization, intrinsic property, large scale synthesis, laser, laser ablation, latest development, latter, lifetime, low cost, low temperature, microwave plasma, multi wall carbon nanotube, mxenes, nanotechnology, overview, past decade, pecvd, physical property, potential application, principle, progress, promissing candidate, properties, recent advance, recent progress, recent study, review, significant attention, simple method, specific application, state, swnt, ton, understanding, unique property, vacnt, view, and wall number.

b) Cluster 2 has 68 items, namely absence, active site, aerogel, aggregation, aqueos solution, ball, bamboo, bed reactor, carbon nanomaterial, carbon nanotubes synthesis, catalyst preparation method, catalytic activity, catalytic material, cenosphere, chemical method, cnts production, coating, cobalt, combination, current density, cycle, decoration,

electrocatalysis, electrocatalyst, electrochemical performance, ethylene, experimental condition, fact, good stability, heating, high activity, hybrid, hydrogen evolution reaction, hydrothermal method, impregnation, large number, large surface area, lithium ion battery, manufacturing, methodology, microstructure, minute, multi walled cnt, nano, nanofiber, nickel, nitric acid, nitrogen atom, optical property, polyethylene waste, polypropylene, porous structure, practical application, prepared catalyst, prepared cnt, promising method, removal, series, single wall carbon nanotube, sodium ion battery, sol gel, synergistic effect, synthesis procedure, thermal decomposition, urea, waste plactic, zinc oxide, and zno.

c) Cluster 3 has 63 items, namely acetylene, additive, aerosol, amorphous carbon layer, average diameter, benzene, bottom, carbon nanotube forest, carbon naotube growth, carbon nanotube synthesis, catalyst nanoparticle, catalyst precursor, catalytic chemical vapour deposition, catalytic growth, ccvd, change, chemical composition, cnt forest, cnt growth, comparison, conventional method, crystallinity, defectiveness, diameter distribution, dimension, drop, environment, fe3o4, ferrocene, flame, flame synthesis, flow rate, fuel, graphitization degree, growth condition, growth parameter, growth rate, growth region, growth temperature, height, ink, lack, large scale, low cost method, methane, nucleation, present review, pyrolysis temperature, reduction, scalability, scanning, selectivity, signal, simple, single walled carbon nanotube, sol gel method, structural characteristic, synthesized carbon naotube, template, thickness, top, transmittance, and water vapor.

d) Cluster 4 has 59 items, namely average, calculation, camphor, catalyst chemical vapor deposition, cathode, cathode material, cnt bundle, cntfs, critical role, crystal structure, decrease, double, eds, electrical property, electrochemical property, electron microscope, elemental analysis, ethanol, fccvd, fiber, first time, functionalized carbon nanotube, goal, graphite, graphitization, heat treatment, high value, hrtem impurity, insight, key factor, mean, measurement, multiwall carbon nanotube, new method, optimal condition, optimization, outer diameter, peak, pore, presence, present paper, present study, promising material, reactant, reaction temperature, reaction time, response surface method, room temperature, rsm, solvent, strength, synthesis condition, synthesis parameter, synthesis cnt, synthesis mwcnts, thermal stability, and xps.

e) Cluster 5 has 54 items, namely adsorbent, adsorption, adsorption capacity, agglomeration, arc discharge, assessment, catalysis, chemical, chemical functionalization, cnts synthesis, composite material, data, detection, disadvantage, drug, drug delivery, electronic, energy saving, environmental impact, final product, fossil fuel, functional group, functionalization, functionalization cnts, green chemistry, high surface area, high temperature, isotherm, laser vaporization, limit, manufacture, mechanical strength, medicine, metal ion, modification, nanocomposite, need, physicochemical property, plant, polymerization, promising nanomaterial, recent development, respect, review paper, sensor, significant improvement, single walled cnts, storage, swcnts, synthesis time, synthesis material, toxicity, and water purification.

f) Cluster 6 has 27 items, namely active material, artificial neural network, catalyst system, conductivity, cost, dispersion, efficient method, electrode material, energy density, enhancement, high degree, high electrical conductivity, high thermal conductivity, improvement, mechanical property, modulus, nanofluid, nanoscale, oxygen, process parameter, small amount, step method, supercapacitor, temperature range, thermal conducticity, thin film, and, wide variety.

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g) Cluster 7 has 25 items, namely anode, arc discharge method, carbon precursor, case, cathode deposit, ccvd method, electrode, fraction, graphite rod, hydrogen, important role, incorporation, liquid, mixture, mwnt, mwnts, nm diameter, oil, present work, purification, single, spray pyrolysis, spray pyrolysis method, swnts, and synthesis technique.

Cluster 1 is marked in red, cluster 2 is marked in green, cluster 3 is marked in dark blue, cluster 4 is marked in yellow, cluster 5 is marked in purple, cluster 6 is marked in light blue, and cluster 7 is marked in orange.

3.3 Network Visualization of Carbon Nanotubes Synthesis Keyword and Title

The visualization network will display the network between the visualized terms. In the network visualization, items are represented by their label and by default also by a circle. The size of the label and the circle of an item is determined by the weight of the item. The higher the weight of an item, the larger the label and the circle of the item [1]. Figure 2 shows the relationship between terms. The relationships in network visualization are depicted in a network or line that comes from one term to another. Figure 2 shows the clusters in each of the researched topic areas. In Fig. 2, carbon nanotubes synthesis itself is included in cluster 2 with a totalling strength of 42 and occurrence of 6.

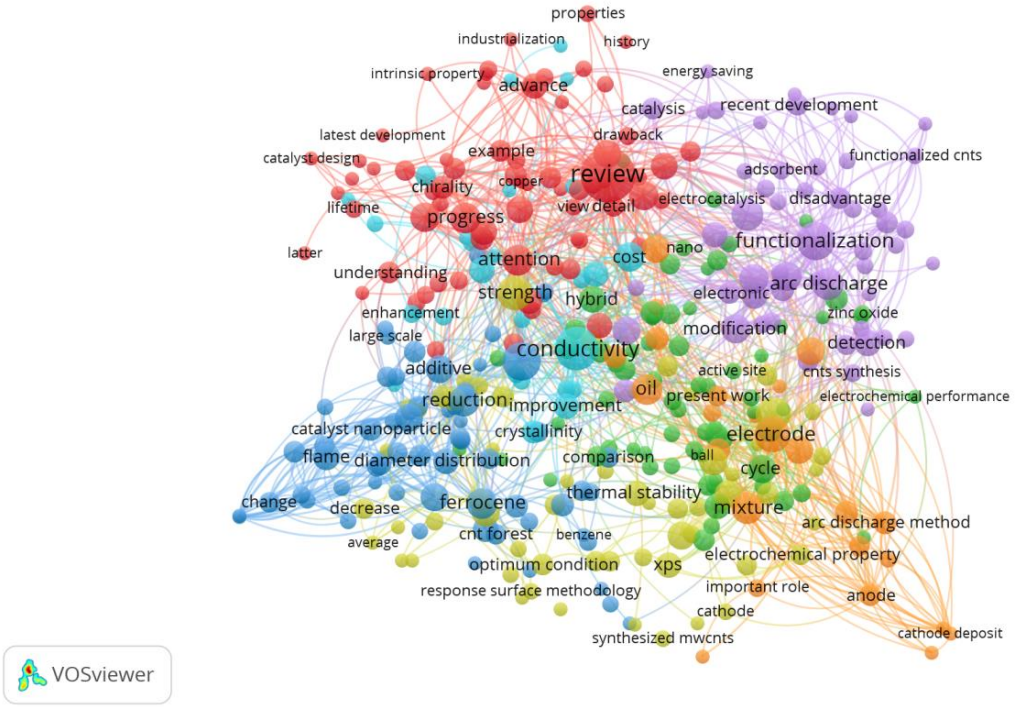

Figure 2. Network visualization of carbon nanotubes synthesis keyword and title

4. Conclusion

This study aims to conduct bibliometric research in carbon nanotubes synthesis by combining mapping analysis using VOSviewer software. Mendeley is a references manager application used to collect data in this research. The data obtained is the result of filtering

based on the keyword "Synthesis Method of Carbon Nanotubes ". The bibliographic data used in this study concerns the topic areas, titles, keywords, and abstracts. From the search results, we obtained 247 relevant articles published in the range of 2018-2022. In this study, it can be seen that the number of articles researching carbon nanotubes synthesis has been increasing since 2018 until 2021. However, there have been 8 articles that published in the early of 2022, this number could be increased by the time. Research that is being popularly studied by researchers until today is about review due to the COVID-19 pandemic situation that forced the researchers to decrease experiment activity and physical interactions. To search using the keyword " Synthesis Method of Carbon Nanotubes " produces 7 clusters that have a different number of items in each cluster.

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