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The Trend Synthesis Thin Film Research as Electronic Device (A Review)

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Abstract: A thin film is a material with optical properties highly dependent on the dielectric constant, refractive index, and gap energy. This research aims to identify and analyze research trends in thin-layer synthesis as electronic devices. This research is qualitative. The data used in this research was obtained from documents indexed by Google Scholar from 2014-2023 using Publish or Perish and Dimension.ai. Research procedures use PRISMA guidelines. The data identified and analyzed included the type of publication, author on thin layer synthesis, source of publication, and the title of research on thin layer synthesis that was widely cited. The data analysis method uses bibliometric analysis assisted by VOSviewer software. The results of the study show that the research trend in thin-layer synthesis has experienced a fluctuating increase from 2014 to 2020. The journal containing the most thin-layer synthesis articles is ECS Meeting Abstracts with 676. The results of the density mapping analysis show that the theme that is rarely researched is organic semiconductors, organic thin film transistors, and green synthesis.

Keywords: Electronic Device; Review; Synthesis; Thin Film

Introduction

Thin films are one aspect that has received much attention, especially in the field of materials, because thin films are exciting materials that have optical properties that are highly dependent on the dielectric constant, refractive index, and gap energy (Beygisangchin et al., 2021; Liu & Wöll, 2017; Ramanujam et al., 2020). The thin film also really depends on the properties of the thin layer material to be deposited (Bittau et al., 2018; Fu et al., 2017; Jilani et al., 2017). With thin film technology, it is hoped that a good quality material can be obtained to be applied to a material (Giraldo et al., 2019; Ludwig, 2019). Nowadays, the development of research on the growth of thin films is increasingly advanced, which can be applied to the fields of communications, engineering, and other technologies, including applications in physics, which are used in the electronics industry, microelectronics for semiconductor material devices (Cao et al., 2017; Deng et al., 2018; Xue et al., 2017).

A thin film is a layer of organic, inorganic, metal, or metal-organic mixtures that can have properties as a conductor, semiconductor, superconductor, or insulator (Liu et al., 2022; Lo Presti et al., 2022). Light layer technology has undergone many developments in manufacturing methods, materials used, and applications. Thin films are usually made by depositing a compound on a medium called a substrate (Bretos et al., 2018; Jangid et al., 2020). The characteristics of a thin film are that it has a uniform surface, that is, it coats the surface of the substrate evenly with minimal defects, has a stable surface temperature and high accuracy, has strong adhesion between molecules, and has a

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crystalline structure. Thin layers generally range from 10^{-6} – 10^{-9} meters (Bush et al., 2018; Lin et al., 2017; Son et al., 2019; Yoon et al., 2021).

In materials engineering, fragile layers commonly used are In2O3, WO3, SnO2, TiO2, ZnO, ITO, and many other materials. In terms of general applications, thin coatings have reached various fields of science. In the construction sector, especially those related to metal materials, a thin layer increases the material's resistance to corrosion.

The manufacture of thin films can be done on various substrates, broadly divided into conductive and non-conductive substrates. Conductive substrates include indium tin oxide (ITO) glass, Ti, and precious metals. Meanwhile, non-conductive substrates such as glass and silica. Choosing a conductive substrate is a way to modify metal attachment to a semiconductor surface using electrolysis.

In electronics, thin films are used to make capacitors, semiconductors, and sensors. In the decoration field, thin layers are used to make the appearance more attractive and are also used in home decoration, jewelry, and other accessories (Hossain et al., 2021; Huang et al., 2020). Another essential aspect of thin film manufacturing technology is the preparation method. Until now, various forms have been known and have been applied widely. Several ways used to grow thin layers include physical vapor deposition (PVD), such as evaporation and condensation, chemical vapor deposition (CVD), and chemical bath deposition (CBD) (Chaudhari et al., 2021; Liao et al., 2017; Obodo et al., 2023). These methods have the same goal: to produce thin layers of good quality at low production costs (Aboulkhair et al., 2019; Scopigno et al., 2017).

Synthesis of thin film, as explained above, provides benefits for technological development. Therefore, researchers are interested in researching the Trend Synthesis of Thin Film Research as an Electronic Device (a Review). Hopefully, this research can contribute to researchers researching thin film synthesis in literature reviews.

Method

This research is qualitative. Qualitative research is descriptive and tends to use analysis in which the researcher is the critical instrument (Farghaly, 2018). The data used in this study were obtained from documents indexed by Google Scholar using Publish or Perish and dimension.ai. The keywords used in the Google Scholar search are Synthesis Thin Film. The documents analyzed were 1,000 Google Scholar-indexed documents between 2012 and 2022.

The selection of the Google Scholar database as a place to search for documents is because Google Scholar applies consistent standards in selecting papers to be included in its index, and Google Scholar displays more documents than top databases. Others, especially research in the fields of education and social sciences (Hallinger & Chatpinyakoop, 2019; Hallinger & Nguyen, 2020). Researchers use the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) to filter the data collected through Publish or Perish.

Result and Discussion

This research aims to determine The Trend of Synthesis Thin Film Research as an Electronic Device (a Review). Thin film materials have been widely applied in various scientific disciplines, such as in the field of mechanics; thin-layer materials are used to increase corrosion resistance (Santinacci, 2022; Tajik et al., 2020). In the field of optics, it is used to make anti-reflection lenses, reflector mirrors, light-shielding glass, camera equipment, and waveguides. Thin films range in thickness from the nanometer size of a single layer to a thickness of approximately micrometers. Compared to the substrate, this thickness is considered very thin (Güzelçimen et al., 2020). Many researchers have researched thin-layer synthesis. Below are presented trends in thin-layer synthesis research based on the publication type.

Table 1. Trend Synthesis Thin Film Research Based on Publication Types

Publication Type	Publications
Article	23,487
Chapter	1,056
Proceeding	977
Preprint	575
Edited Book	83
Monograph	27

Table 1 shows that the trend of thin layer synthesis research from 2014 to 2023 consists of six (6) types of publications. The research trend on thin layer synthesis in the form of articles is the largest type of research publication on thin layer synthesis compared to other types of publications, namely 23,487. There are 1,056 types of thin-layer synthesis research publications in chapters. The types of thin layer synthesis research publications are in the form of proceedings as many as 977. The types of thin layer synthesis research publications are in the form of preprints, as many as 575. The types of thin-layer synthesis research publications are edited books, as many as 83, and monographs, as many as 27. Research conducted by Basari (2020) states that articles have been published by many researchers

recently. Articles are a type of written work often found in academic and non-academic everyday life (Na & Ye, 2017). The general purpose of writing an article is to educate, inform, and entertain readers. Usually, articles are published via websites or other digital media (Ramos et al., 2019). Figure 1 is also presented below about the thin layer synthesis research trend from 2014 to 2023.

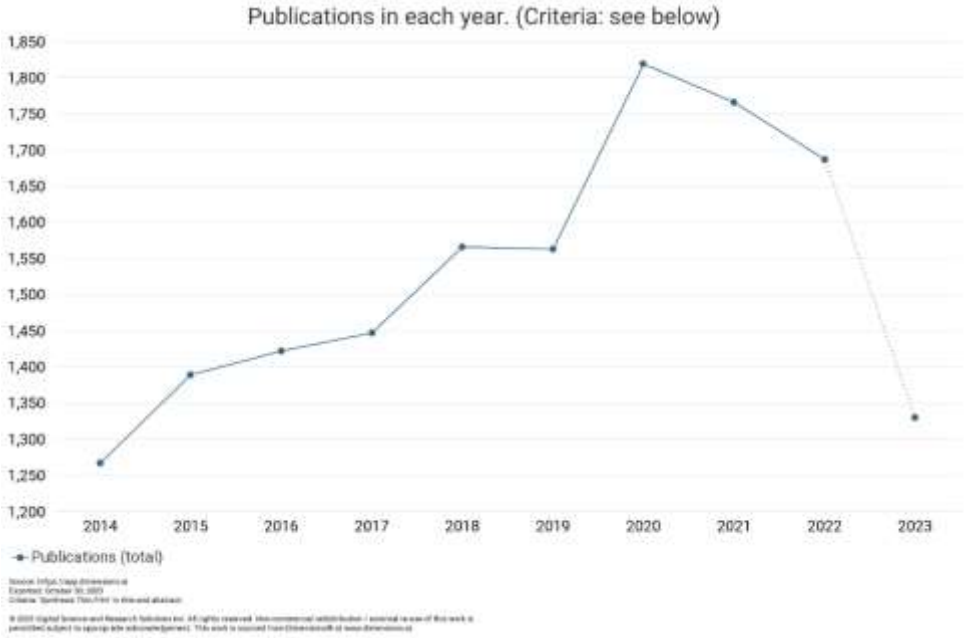

Figure 1. Trend Synthesis Thin Film Research on 2014 – 2023

Based on Figure 1, it is known that the research trend for thin layer synthesis was the highest in 2020, with 1,850 publications, while the least was in 2014, namely only around 1,260 publications. Figure 1 also shows that every year from 2014 to 2020, the trend of thin-layer synthesis research always increased, while in 2019, the trend of thin-layer synthesis research decreased slightly from 1,560 publications to 1,550 publications. However, the thin layer synthesis research trend in 2020 increased to 1,820 publications. The research trend in thin layer synthesis from 2019 to 2020 is a research trend that has increased the highest compared to other years. Different things will happen in 2021 to 2023, where the direction of thin layer synthesis research will experience a drastic decline. The decreasing trend in light layer synthesis research is because there has been too much previous research, so researchers have had difficulty determining the differentiating variables from previous research. Below are also presented the 10 top researchers who researched thin layer synthesis.

Table 2 shows the top ten (10) researchers who researched thin layer synthesis. As already explained, this thin layer is used to make capacitors, semiconductors and sensors. The characteristics of a thin layer are that it has a uniform surface, that is, it coats the surface of the substrate evenly with minimal defects, has a stable surface temperature and high accuracy, has strong adhesion between molecules, and has a crystalline structure. Table 2 above shows that Chandrakant Dnyandev Lokhande, from D.Y. Patil Education Society, India, has 109 publications on thin layer synthesis with 5,457 citations.

Some of his research titles related to thin film synthesis are "Reliable and reproducible colorimetric detection of mercury ions (Hg 2+) using green synthesized optically active silver nanoparticles containing thin film on flexible plastic substrate" (A. C. Lokhande et al., 2017), "Nanostructured metal chalcogenide/oxide films based supercapacitors" (V. C. Lokhande et al., 2020); "Facile synthesis of hierarchical mesoporous weirds-like morphological MnO2 thin films on carbon cloth for high-performance supercapacitor applications" (Shinde et al., 2017). Apart from Chandrakant Dnyandev Lokhande, Pramod Shankarrao Patil from Shivaji University, India, has 92 publications related to thin layer synthesis with 3,815 citations. Some of the research titles he conducted were "Study of solvent variation on the controlled synthesis of different nanostructured NiCo2O4 thin films for supercapacitive applications" (Dhavale et al., 2021); "Recent advances in the synthesis of Cu2FeSnS4 materials for solar cell applications" (Vanalakar et al., 2018). Below are also presented the top ten (10) sources of thin layer synthesis research trends.

Table 2. Top 10 Researchers on Trend Synthesis Thin Film Research in 2014-2023

Author	Organization	Country	Publications	Citations	Citations Mean
Chandrakant Dnyandev Lokhande	D.Y. Patil Education Society, India	India	109	5,457	50.06
Pramod Shankarrao Patil	Shivaji University, India	India	92	3,815	41.47
Jin-Hyeok Kim Jin-Hyeok Kim	Chonnam National University	South Korea	77	4,179	54.27
Tobin Jay Marks	Northwestern University	United States	67	5,973	89.15
Popatrao N Bhosale	Shivaji University	India	60	1,286	21.43
Andriy Zakutayev	National Renewable Energy Laboratory	United States	59	834	14.14
And Antonio Facchetti	Northwestern University	United States	57	6,087	106.79
Yun-Qi Liu	Fudan University	China	51	1,828	35.84
Shriram Ramanathan	Purdue University West Lafayette	United States	50	1,075	21.50
Ivan Paul Parkin	University College London	United States	49	1,606	32.78

Table 3 shows that the most widely published source for thin layer synthesis research trends is ECS Meeting Abstracts, namely 676 publications with 50 citations and an average citation of 0.07. ECS Meeting is the Electrochemical Society: Advancing solid state & electrochemical science & technology contains extended abstracts of the technical papers presented at ECS biannual and ECS-sponsored meetings. This publication offers a first look into current research in the field. ECS Meeting Abstracts are freely available to all visitors to the ECS Digital Library. ECS has been published continuously since 1902. Our portfolio contains works by renowned scientists, inventors, and Nobel Laureates. ECS currently publishes four peer-reviewed journals, with papers selected by a prestigious group of technical editors.

Table 3. Top 10 Sources Title Trend Synthesis Thin Film Research in 2014-2023

Name	Publications	Citations	Citations Mean
ECS Meeting Abstracts	676	50	0.07
Thin Solid Films	588	14,355	24.41
Chemistry of Materials	454	30,165	66.44
MRS Advances	444	1,255	2.83
Applied Surface Science	414	11,586	27.09
arXiv	357	7	0.02
Journal of Materials Science: Materials in Electronics	336	3,588	10.68
Journal of Alloys and Compounds	313	7,749	24.76
ACS Applied Materials & Interpaces	309	10,612	34.34
RSC Advances	298	6,668	22.38

Table 3 also shows that Thin Solid Films is a publication source that publishes many research trends on thin film synthesis, namely 588 publications with 14,355 citations and an average of 24.41 citations. Thin Solid Films is an international journal serving scientists and engineers in thin film synthesis, characterization, modelling, and applications. The topical scope of Thin Solid Films reflects a wide range of thin film-related themes: Thin film synthesis, with particular emphasis on the control of growth for desired physical properties; Surfaces and interfaces; Solar energy conversion; Catalysis; Batteries and other electrochemical devices; Metallurgical, protective, and hard coatings; Electronics, optics, and optoelectronics; Magnetics and magneto-optics; and Superconductivity. Below are also presented ten (10) top trends in thin layer synthesis research, often cited by other researchers related to this matter.

Table 4. Top 10 Citation on Trend Synthesis Thin Film Research in 2014-2023

Citation	Year	Author	Title
269	2014	D Emadzadeh, WJ Lau, T Matsuura, AF Ismail…	Synthesis and characterization of thin film nanocomposite forward osmosis membrane with hydrophilic nanocomposite support to reduce internal concentration …
245	2016	AS Pawbake, RG Waykar, DJ Late…	Highly Transparent Wafer-Scale Synthesis of Crystalline WS2 Nanoparticle Thin Film for Photodetector and Humidity-Sensing Applications
183	2019	A Ludwig	Discovery of new materials using combinatorial synthesis and high-throughput characterization of thin-film materials libraries combined with computational …
164	2015	B Khorshidi, T Thundat, BA Fleck, M Sadrzadeh	Thin film composite polyamide membranes: parametric study on the influence of synthesis conditions
161	2015	D Emadzadeh, WJ Lau, M Rahbari-Sisakht…	Synthesis, modification and optimization of titanate nanotubes-polyamide thin film nanocomposite (TFN) membrane for forward osmosis (FO) application
160	2015	M Ghanbari, D Emadzadeh, WJ Lau, SO Lai…	Synthesis and characterization of novel thin film nanocomposite (TFN) membranes embedded with halloysite nanotubes (HNTs) for water desalination
155	2014	C Lu, T Ben, S Xu, S Qiu	Electrochemical synthesis of a microporous conductive polymer based on a metal–organic framework thin film
150	2015	X Li, B Deng, X Wang, S Chen, M Vaisman…	Synthesis of thin-film black phosphorus on a flexible substrate
143	2015	C Hahn, DN Abram, HA Hansen…	Synthesis of thin film AuPd alloys and their investigation for electrocatalytic CO 2 reduction
143	2017	M Singh, BC Yadav, A Ranjan, M Kaur…	Synthesis and characterization of perovskite barium titanate thin film and its application as LPG sensor

Table 4 shows that other researchers have widely cited the research on thin film synthesis: "Synthesis and characterization of thin film nanocomposite forward osmosis membrane with hydrophilic nanocomposite support to reduce internal concentration...", 269 citations since 2014. Then, the research entitled "Highly Transparent Wafer-Scale Synthesis of Crystalline WS2 Nanoparticle Thin Film for Photodetector and Humidity-Sensing Applications" was cited 245 times since 2016. This data is comparable to the data on the increasing trend of thin film synthesis research from 2014 to 2020. This means that in this study, research related to thin films synthesis was continuously cited by other researchers.

Table 5. Keyword on Trend Synthesis Thin Film Research in 2014-2023

Terms	Occurences	Relevence
Organic Semiconductor	11	3.07
Thin film composite membrane	22	1.98
Thin film transistor	28	1.18
Solar cell application	17	1.14
Microsturcture	16	0.97
Thin film form	14	0.92
Electrical property	18	0.90
Thin film coating	22	0.88

In the articles researched and written by these researchers, there are many terms/keywords related to thin layer synthesis. There are presented eight (8) popular keywords pertaining to thin layer synthesis as seen in Table 5.

Table 5 shows that the keyword frequently appearing in relation to thin film synthesis research is thin film transistor 28 times with a level of 1.18. Thin film transistors or TFTs for short, are a special type of field effect transistor (FET) where the transistor is made by thin film deposition (Kim & Roth, 2018). The TFT is grown on a supporting (but non-conductive) substrate. A typical substrate is glass, as the traditional application of TFTs is in liquid crystal displays (LCDs). TFTs can be made with a variety of semiconductor materials. Because it is naturally abundant and well-understood, amorphous or polycrystalline silicon was (and still is) used as a semiconductor coating.

Table 5 also shows that thin film coating is also a keyword that appears frequently in thin film synthesis research trends, namely 22 times with a relevance of 0.88. Thin film coatings are part of our daily lives. Whether washing our hands, opening a door, or picking up a mobile phone, we touch them every day. Without these, our touchscreens would not function, and they also protect commodities from prematurely wearing out due to corrosion. As thin film coating technologies have

matured, they are now used in aerospace, energy, semiconductor, optoelectronics, and medical devices in medical fields. The basis of thin film coating technology involves either turning a solid into a gas and then condensing the gas onto a substrate or "cracking" a gas into radicals, which then concentrate on a substrate to form a coating.

This discussion will present a graphical visual mapping of published articles with the theme synthesis of thin film. The results of this analysis become the interpretation of article publications based on research objects that are often studied and analyzed. Related to bibliometrics, science mapping is a method for visualizing the object of study from a field of science (Chandra, 2018; Chen & Song, 2019). This visualization is carried out by creating a landscape map which can provide visual information on topics of study from science. The results of the bibliometric mapping of the co-word map network for the publication of articles with the synthesis of thin film can be seen in Figure 2.

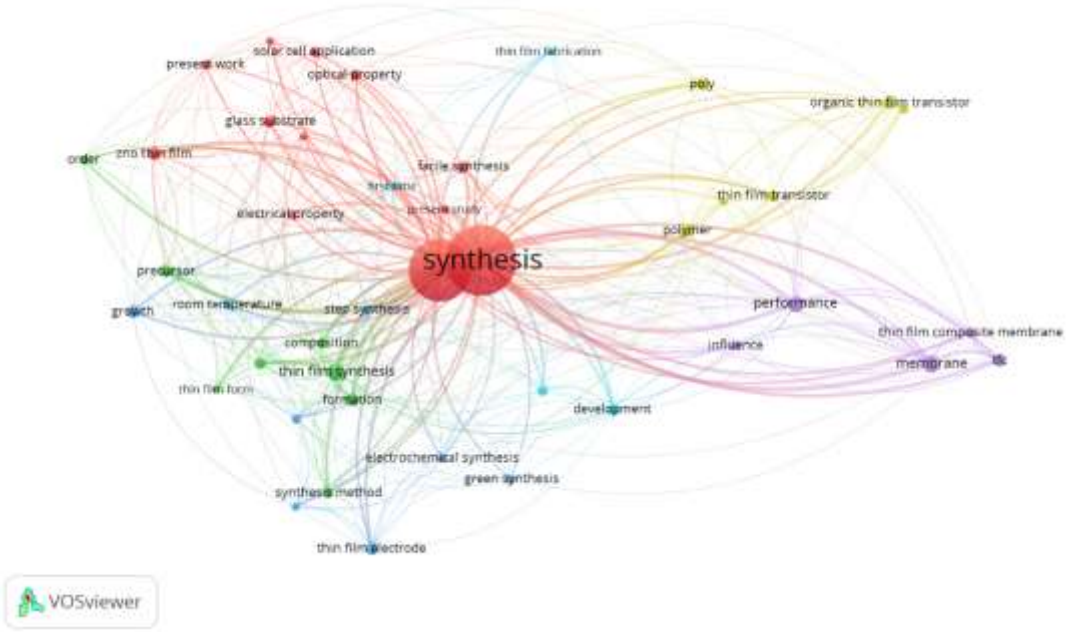

Figure 2. Network Visualization on Trend Synthesis Thin Film Research

Figure 2 shows the results of bibliometric keyword mapping on thin-layer synthesis research trends. In Figure 2, 43 keyword items are often used in research on thin layer synthesis from 2014 to 2023. The figure also contains 6 clusters, where the first cluster is coloured red and consists of 10 keyword items, namely Electrical property, facile thickness, glass substrate, optical property, the present study, present work, solar cell application, spin coating technique, synthesis, thin film, and ZnO thin film. The second cluster in green consists of 6 keyword items: Composition, formation, precursor, synthesis method, thin film deposition, thin film form, and thin film synthesis. The third blue cluster consists of 7 keyword items: Composite thin film, electrochemical synthesis, green synthesis, growth, room temperature, step synthesis, supercapacitor application, and thin film electrode. The fourth yellow cluster consists of 5 keywords: organic thin film transistor, otft, poly, polymer, and thin film transistor. The fifth purple cluster consists of 4 keyword items: Tfc, influence, performance, and thin film composite membrane. The sixth cluster, which is light blue, consists of 2 keyword items, namely Thin film fabrication and thin film material. The results of the cycles network visualization analysis show the same thing as the results of the study carried out by (Suprapto et al., 2021), where there are six clusters in the trend analysis of other research as well.

Figure 2 above also shows that network visualization shows the network between the visualized terms. Keywords classified into six clusters are arranged in a color chart showing the divisions/groups that are connected. The results of this analysis can be used to determine keyword research trends in the last year. This analysis shows several keywords that are often used in thin-layer synthesis research. The more keywords that appear, the wider the visualization displayed. Below we also present keywords regarding thin layer synthesis based on oerlay visualization.

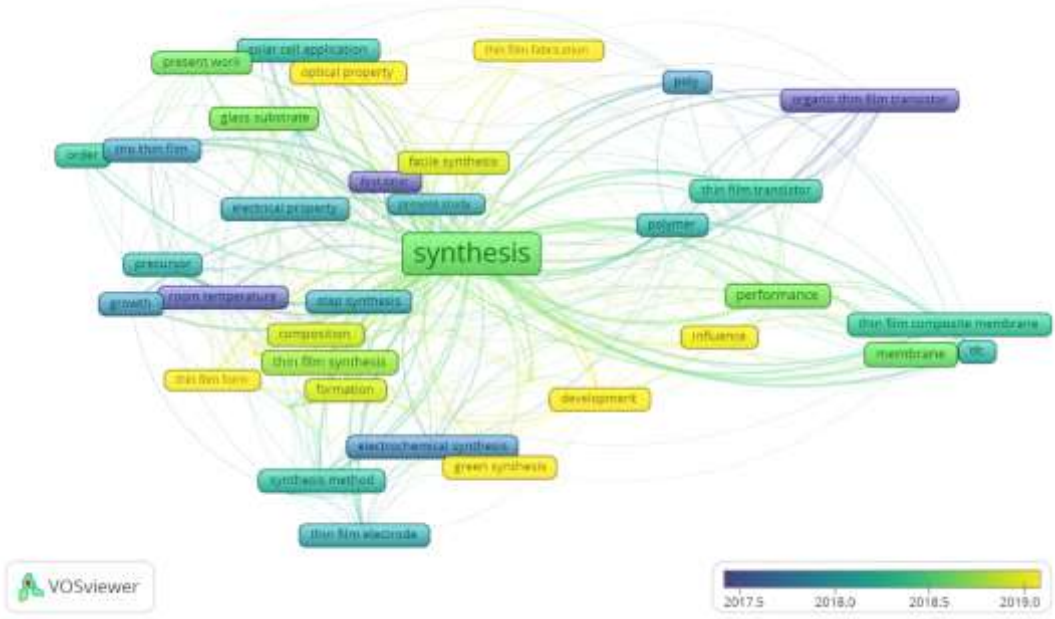

Figure 3. Overlay Visualization on Trend Synthesis Thin Film Research

Figure 3 shows the trend of keywords related to thin layer synthesis research in Google Scholar-indexed journals from 2014 to 2023. The movement in themes for writing articles related to thin layer synthesis from the oldest to the newest year is marked with purple, blue, turquoise, dark green, light green, and yellow. The image above shows that the keywords thin film fabrication, green synthesis, optical property, etc., are yellow clusters. This indicates that these keywords were widely used by researchers in 2019. In 2018, the keywords that often appeared were thin film composite membrane, thin film transistor, synthesis, synthesis method, thin film electrode, and others. The following also presents research keywords regarding thin layer synthesis based on density visualization.

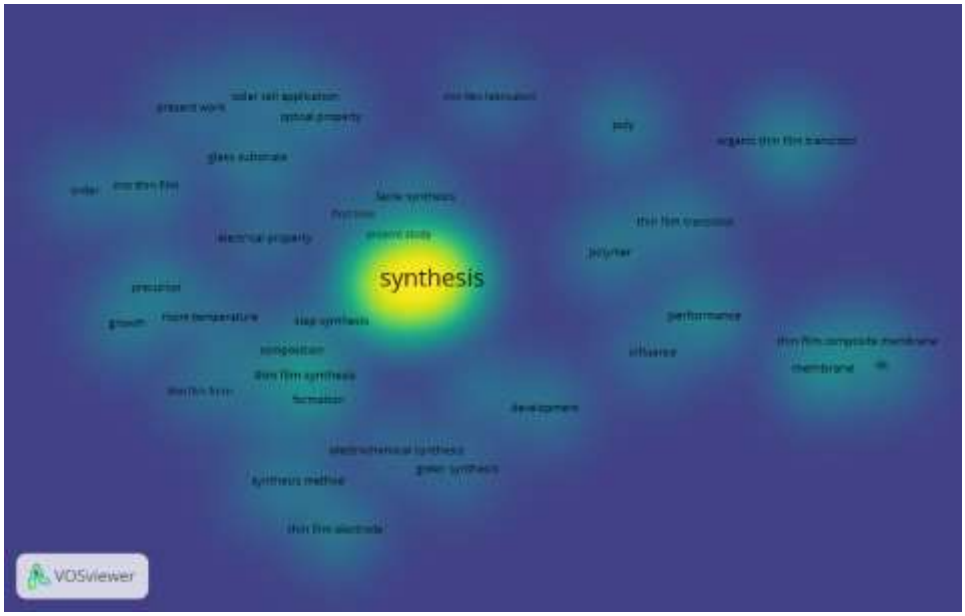

Figure 4. Density Visualization on Trend Synthesis Thin Film Research

Figure 4 shows density visualization. The density of research themes is shown in bright yellow. The brighter the colours of a theme, the more research is done. The fainter color means the theme is rarely researched (Bahtiar et al., 2023). Dimly coloured themes such as organic semiconductor, organic thin film transistor, and

green synthesis are dimly coloured keywords. This shows that these keywords can be used as a reference for further research. Kaur et al. (2022); Liao et al. (2017) stated that yellow indicates keywords currently and frequently used in study.

Conclusion

The trend in thin layer synthesis research indexed by Google Scholar from 2014 to 2023 has experienced a fluctuating increase. The most significant increase was from 2019 to 2020, then decreased from 2020 to 2023. Chandrakant Dnyandev Lokhande, who came from D.Y. Patil Education Society, India, is an author who has 109 publications on thin layer synthesis with 5,457 citations. The most widely published source of publications on thin layer synthesis research trends is ECS Meeting Abstracts, namely 676 publications with 50 citations and an average citation of 0.07. The research title "Synthesis and characterization of thin film nanocomposite forward osmosis membrane with hydrophilic nanocomposite support to reduce internal concentration ..." is thin film synthesis research with the most citations, namely 269 times cited since 2014. The results of the visualization analysis show that there are 43 items. and 12 clusters of keywords that are often used in research on thin film synthesis from 2014 to 2023. Based on density visualization, it is known that organic semiconductor, organic thin film transistor, and green synthesis are keywords that are dimly coloured, which means they are no longer researched by researchers in thin layer synthesis.

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Conflicts of Interest

As for the author's interest in publishing this article, namely for the needs of lecturer performance load and lecturer performance reporting for universities in the field of research.

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