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A Systematic Review of the Trends Thin Film Characteristics Research as Electronic Device (2015-2024)

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Abstract: Thin film characteristics are the properties possessed by the thin film, both physical and chemical properties. The characteristics of this thin film are influenced by several factors, namely the material that makes up the thin film, the thin film deposition method, and the conditions of the thin film deposition process. This research aims to identify and analyze research trends in the characteristics of thin films as electronic devices. This research method is descriptive and analytical. The data used in this research was obtained from documents indexed by Google Scholar from 2015-2024 using Publish or Perish and Dimension.ai. Research procedures use PRISMA guidelines. The data identified and analyzed are the type of publication, publication source, and the title of research on thin film synthesis that is widely cited. The data analysis method uses bibliometric analysis assisted by VOSviewer software. The results of the analysis show that the trend of research on the characteristics of thin films as electronic devices indexed by Google Scholar from 2015 to 2024 experienced a fluctuating increase, however, in 2023 there was a decline in the trend of research on the characteristics of thin films as electronic devices. There are many documents in the form of articles, proceedings, book chapters, preprints, and edited books that discuss research into the characteristics of thin films as electronic devices. Key words that are often used in research on the characteristics of thin films as electronic devices are thin film coating, heat transfer characteristic, film characteristic, and photovoltaic characteristic.

Keywords: Characteristic; Electronic device; Thin film; Review

Introduction

Technological advances in the field of electronics have brought major changes in almost all aspects of our lives. Consumer electronic devices such as smartphones, tablets, and televisions have become more sophisticated with better screen displays, more powerful cameras, and higher computing capabilities. Innovation continues to change the way we interact with the world around us and open new opportunities for the future (Coll et al., 2019; Khan et al., 2020).

The development of new and innovative materials, including two-dimensional materials such as graphene and nanoscale structured materials, has opened the door to more advanced uses in electronic devices (Sengupta et al., 2018). Sustainability of technologies, such as optical and photovoltaic devices, requires a deep understanding of the characteristics of thin films. This

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involves developing thin films that are efficient in generating, converting, or detecting light (Gupta et al., 2018; Sang et al., 2019).

A thin film is a material structure that has a very thin thickness compared to its other dimensions (Liang et al., 2021; Mercaldo et al., 2018). In a scientific and technological context, a thin film often refers to a film of material that has a thickness in the range from a few nanometers (nm) to a few micrometers (µm) (Qin et al., 2020). This thinness allows thin films to have special properties that are often used in a variety of applications, including in the fields of semiconductors, optoelectronics, nanotechnology, and more (Doyan, Susilawati, & Muliyadi, 2022; Hao et al., 2018; X. Li et al., 2019).

The basic principle of thin coating is to create a very thin film of material on a substrate or surface for a specific purpose (Wei et al., 2019). The thin film principle also involves controlling the structure and composition of the deposited material. This includes selecting appropriate materials, controlling the crystal structure if relevant, and mixing materials if necessary to achieve the desired properties. Thin films are often used to impart special properties to a substrate or surface, such as electrical conductivity, optical reflection, semiconductor properties, hydrophobic or hydrophilic properties, and more. The principle is to achieve the desired properties by changing the structure, composition or thickness of the film (Imawanti et al., 2017; Yang et al., 2020).

The main process in making thin films is depositing or transferring material onto the desired substrate or surface (Wan et al., 2018). Thin films can be applied or produced by various techniques, such as physical vapor deposition, chemical vapor deposition, atom-by-atom deposition, or other techniques (Zhu et al., 2021). They are used for a variety of purposes, including protective coatings, regulation of surface properties, semiconductor devices, sensors, optoelectronics, and more, depending on the application and desired characteristics (An-Nufuus et al., 2023; Fei et al., 2018). The technique used depends on the type of material to be deposited and the desired application.

One of the main characteristics of thin films is their thinness. Controlling film thickness is very important and is usually done by adjusting parameters such as deposition time or deposition rate (Chung et al., 2019; Munandar et al., 2020). The main characteristic of thin films is their thinness, which gives them special properties that are often used in various technologies (Muliyadi et al., 2019; Park et al., 2018). Some examples of uses for thin films include protective coatings to reduce corrosion on metals, optical coatings on glass and lenses to control light reflection, and semiconductor films in electronic devices (Dong et al., 2018).

Therefore, this research wants to know the research trend of the characteristics of the typhoid film as an electronic device. It is hoped that this research can become a reference in developing further research related to thin films.

Method

This research method is descriptive and analytical, which aims to understand and describe research trends in the characteristics of thin films as electronic devices. In addition, this method also provides insight into the development and evolution of the practice of thin film characterization as an electronic device. The data used in this study was obtained from information sources indexed by Google Scholar using analytical tools such as Publish or Perish and Dimension.ai. To carry out a search on Google Scholar, keywords related to research trends on the characteristics of thin films as electronic devices are used.

In this research, an analysis was carried out on 1,000 documents that had been indexed by Google Scholar between 2015 and 2024. The reason for choosing Google Scholar as a document search source is because Google Scholar applies consistent standards in selecting documents to be included in its index and also because Google Scholar has more documents than any other major database, especially in the context of research in education and social sciences. To filter data that has been collected via Publish or Perish, researchers used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Result and Discussion

This research aims to analyze research trends regarding the characteristics of thin films as electronic devices. Research documents on research trends regarding the characteristics of thin films as electronic devices are taken from documents from 2015 to 2024. Figure 1 is presented below regarding research trends on the characteristics of thin films as electronic devices.

Figure 1 shows that the trend in research on the characteristics of thin films as electronic devices from 2015 to 2024 has increased. Where the research trend is with an increase in the number of publications every year, namely from 2015 to 2022. However, in 2023 the research trend on the characteristics of thin films as electronic devices has decreased. The increasing trend in research on the characteristics of thin films as electronic devices is due to research on the characteristics of thin films has much importance and relevance in various fields of science and technological applications. Thin films are used in various modern technologies, such as

electronics, optoelectronics, solar energy, and others (Romeo et al., 2021; Vyas, 2020). Understanding the characteristics of thin films allows the development and improvement of this technology (Zhao et al., 2018).

In 2015 there were 100,000 publications related to the characteristics of thin films, then this will continue to increase to 160,000 publications in 2022. This increasing research trend provides a deeper understanding of the basic properties of materials, such as electronic and mechanical properties on a very small scale. Research can help optimize thin film materials to achieve higher efficiency. Below are also presented research trends characteristics of thin films as electronic devices based on the type of publication.

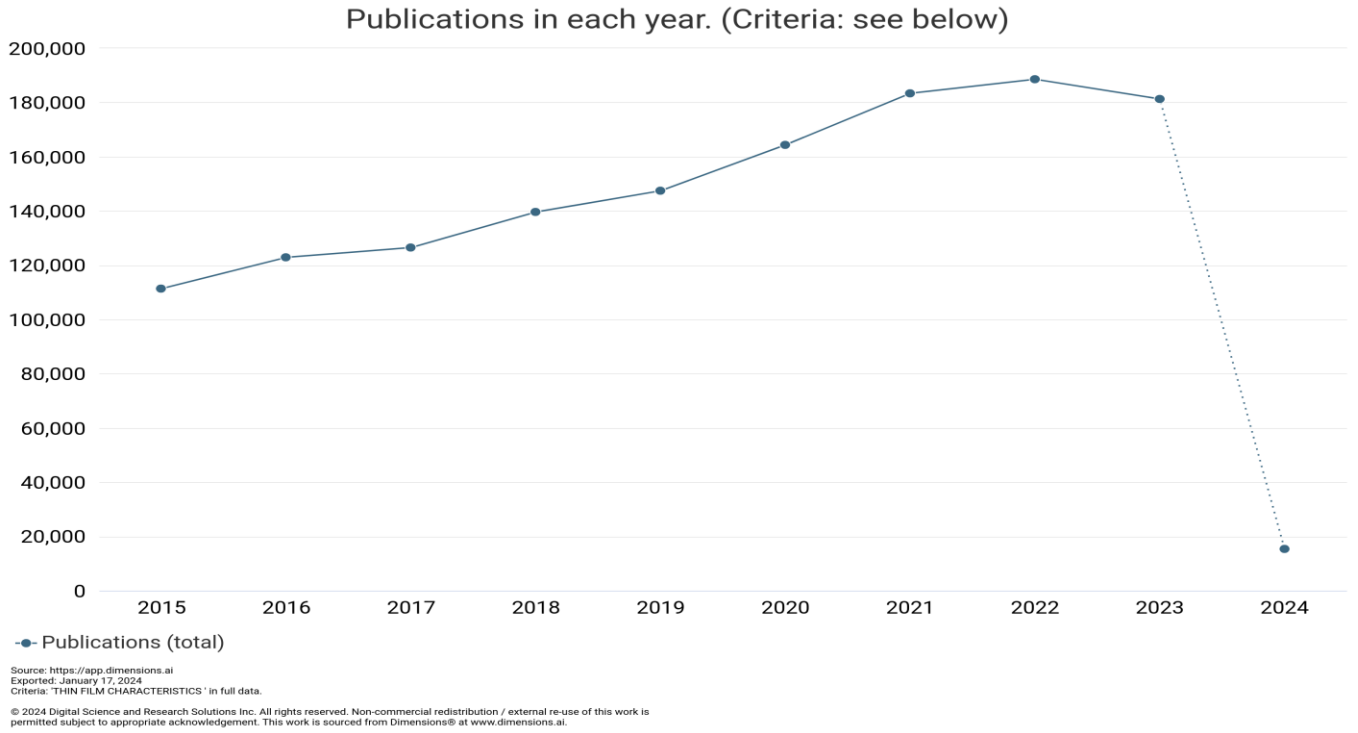

Figure 1. Research trends in thin film characteristics

Table 1. Trends in Thin Film Characteristics Research Based on Publication Types

Publication Type	Publications
Article	2,149,652
Chapter	508,927
Proceeding	144,312
Edited Book	94,663
Monograph	73,809
Preprint	68,259

Based on Table 1, it is known that research characteristics of thin films as electronic devices from 2015 to 2024 contained in 6 types of publications. In the form of articles there were 2,149,652 documents, chapters as many as 508,927 documents, proceedings as many as 144,312 documents, edited books as many as 94,663 documents, monographs as many as 73,809 documents, and preprints as many as 68,259 documents. Research trends characteristics of thin films as electronic devices in article form is the type of publication that contains the most research about characteristics of thin films as electronic devices compared to other types of publications. Meanwhile, the type of publication contains the least amount of research results characteristics of thin films as electronic devices is a preprint. Research conducted by Oltarzhevskyi (2019) states that an article is a complete factual essay of a certain length created for publication in online or print media (via newspapers, magazines or bulletins) and aims to convey ideas and facts that can convince and educate. These articles are usually published in scientific journals both in print and online (Suseno et al., 2020). Below are also presented the top ten (10) sources of research trends on the characteristics of thin films as electronic devices.

Table 2 shows that the most widely published source of research trends on the characteristics of thin films as electronic devices is the proceedings of SPIE, namely 36,353 publications with 123,589 citations and an average citation of 3.40.The proceedings of SPIE is the conference record of the society of Photo-Optical Instrumentation Engineers (SPIE) (Loew, 2022). The first proceedings were published in 1963. All proceedings in this series are open access, i.e. the articles published in them are immediately and permanently free to read,

download, copy & distribute (Lozi et al., 2022). Below are also presented ten (10) top trends in research on the characteristics of thin films as electronic devices which are often cited by other researchers related to this matter.

Table 2. Top 10 Sources Title Trend of Thin Film Characteristics Research in 2015-2024

Name	Publications	Citations	Citations Mean
Proceedings of SPIE	36,353	123,589	3.40
Thin Solid Films	25,626	575,827	22.47
Applied Surface Science	23,418	593,256	25.33
ACS Applied Materials & Interfaces	23,360	957,618	40.99
Physical Review B	23,188	1,080,588	46.60
Journal of Applied Physics	21,962	719,237	32.75
Applied Physics Letters	21,334	902,568	42.31
Journal of Alloys and Compounds	17,481	392,775	22.47
The Journal of Physical Chemistry C	15,598	563,489	36.13
MRS Advances	14,969	49,038	3.28

Table 3 shows that research on the characteristics of thin films as an electronic device that is widely cited by other researchers is about "Characteristics of a Pt/NiO thin film-based ammonia gas sensor" which is 18.83 (Chen et al., 2018). Then the research entitled "Effects of the support on the characteristics and perm selectivity of thin film composite membranes" was cited 18.40 times (Z. Li et al., 2019). Research by Ng et al. (2021) also entitled "Thin film nano composite RO membranes: Review on fabrication techniques and impacts of nano filler characteristics on membrane properties" is widely cited by other researchers, namely 16.67 per year. Qasem et al. (2022) in their research entitled "Determination of optical band gap energy and optical characteristics of Cd30Se50S20 thin film at various thicknesses" was cited 14.00 per year.

This research data is comparable to data on the increasing trend of research on the characteristics of thin films as electronic devices from 2015 to 2024. This means that in that year, research related to the characteristics of thin films as electronic devices was continuously cited by other researchers. In the articles researched and written by these researchers, there are many terms/keywords related to ethno pedagogy. Below are presented eleven (11) popular keywords related to ethno pedagogy.

Table 3. Top 10 Citations on Trend of Thin Film Characteristics Research in 2015-2024

Cites/year	Year	Author	Title
18.83	2018	HI Chen, CY Hsiao, WC Chen, CH Chang	Characteristics of a Pt/NiO thin film-based ammonia gas sensor
18.40	2019	X Li, Q Li, W Fang, R Wang, WB Krantz	Effects of the support on the characteristics and perm selectivity of thin film composite membranes
16.67	2021	ZC Ng, WJ Lau, T Matsuura, AF Ismail	Thin film nanocomposite RO membranes: Review on fabrication techniques and impacts of Nano filler characteristics on membrane properties
14.00	2022	A Qasem, MS Mostafa, HA Yakout, M Mahmoud	Determination of optical band gap energy and optical characteristics of Cd30Se50S20 thin film at various thicknesses
14.00	2019	Z Zhang, C Yin, L Yang, J Jiang, Y Guo	Optimizing the gas sensing characteristics of Co-doped SnO2 thin film based hydrogen sensor
12.25	2016	B Rahmati, AAD Sarhan, WJ Basirun, W Abas	Ceramic tantalum oxide thin film coating to enhance the corrosion and wear characteristics of Ti6Al4V alloy
11.45	2015	RP Yadav, M Kumar, AK Mittal	Fractal and multiracial characteristics of swift heavy ion induced self-affine nanostructured BaF2 thin film surfaces
10.67	2021	MF Iqbal, AKM Yousef, A Hassan, S Hussain	Significantly improved electrochemical characteristics of nickel sulfide Nano plates using graphene oxide thin film for super capacitor applications
10.60	2019	Z Liu, Y Zhi, S Li, Y Liu, X Tang, Z Yan	Comparison of optoelectrical characteristics between Schottky and Ohmic contacts to β-Ga2O3 thin film
10.26	2016	K Muthukrishnan, M Vanaraja and S Boomadevi	Studies on acetone sensing characteristics of ZnO thin film prepared by sol–gel dip coating

Table 4 shows that the keywords that often appear related to research on the characteristics of thin films as electronic devices are thermal characteristics 93 times with a level of 0.12. Thermal characteristic is specs related to the properties of a material related to heat, such as thermal conductivity, heat capacity, and thermal expansion (Jin et al., 2021; Liang et al., 2021). Materials with high thermal conductivity will conduct heat more easily, while materials with low thermal conductivity will have more difficulty conducting heat (Buyanova et al., 2019; Doyan, Susilawati, Mahardika, et al., 2022; Susilawati et al., 2019).

Table 4. Keywords on Trend of Thin Film Characteristics Research in 2015-2024

Terms	Occurrences	Relevance
Electrochemical characteristic	5	2.92
Dielectric characteristic	5	2.68
Thin film thickness	5	2.39
Electrode position	5	2.39
Wear characteristic	5	2.34
Photovoltaic characteristic	12	1.17
Thin film structure	22	0.94
Ferroelectric thin film	7	0.91
Thin film solar cell	41	0.86
Polycrystalline silicon thin film transistor	13	0.80
Thermal characteristic	93	0.12

Table 4 also shows that thin film solar cell is also a keyword that appears frequently in research trends on the characteristics of thin films as electronic devices, namely 41 times with a relevance of 0.86. The research theme regarding thin film solar cells is a very relevant topic in research on the characteristics of thin films as electronic devices. Thin film solar cell is a solar cell technology that uses a thin film of semiconductor material to produce electricity from sunlight (Efaz et al., 2021). In contrast to more traditional crystalline silicon solar cells, thin film solar cells are made by depositing thin films of semiconductor material on a substrate that can be flexible or rigid (Mohammad et al., 2023). Some common materials used in thin film solar cells include amor silicon (a-Si), cadmium telluride (CdTe), and copper indium gallium selenide (CIGS) (Amalathas et al., 2019).

Examining thin film solar cells in research is an important step in understanding the characteristics of thin films (Nykyruy et al., 2019; Pant et al., 2020). The advantages of thin film solar cells include their flexibility, light weight, and potentially lower production costs compared to conventional solar cells. This technology can be used in various applications, such as the integration of solar cells in buildings (Building-Integrated Photovoltaic or BIPV), solar panels for portable devices, and applications in outer space (Rizaldi et al., 2021; Sinha et al., 2019). This visualization is accomplished by generating a landscape map, which offers a visual representation of subjects related to scientific studies. The outcomes of bibliometric mapping for the co-word network in articles related to the topic of thin film characteristic are illustrated in Figure 2.

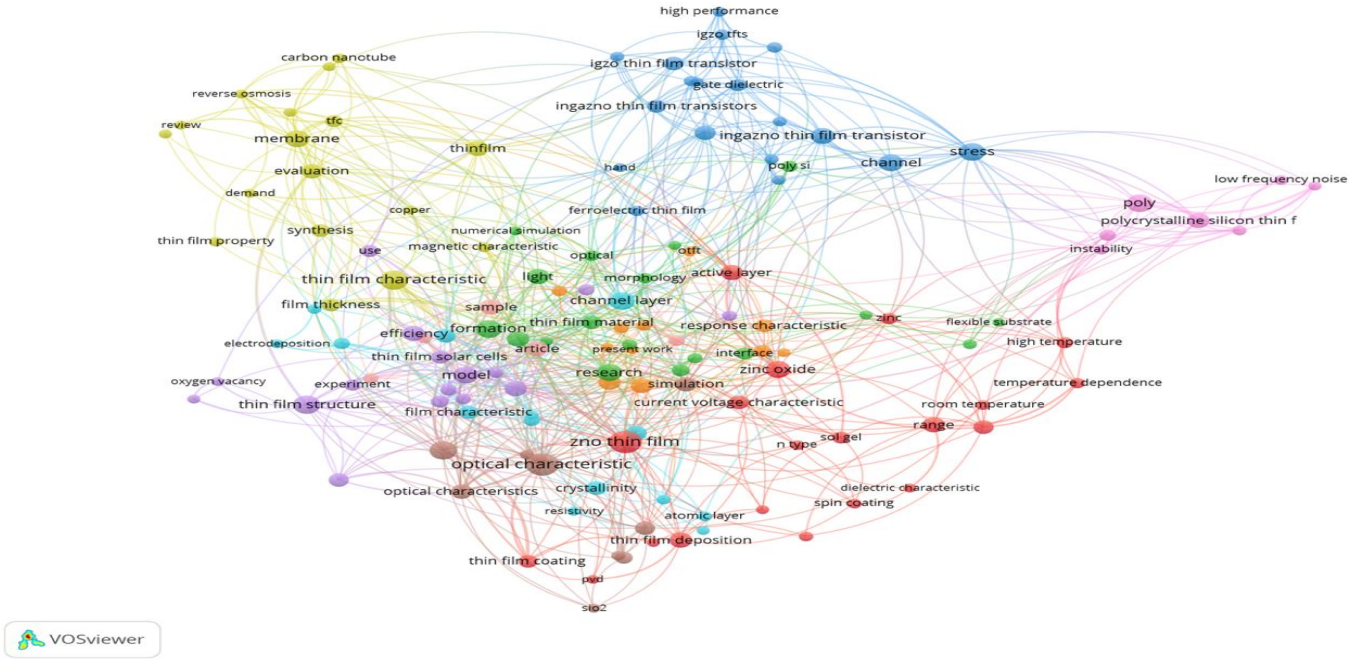

Figure 2. Network visualization on trend characteristics of thin films research

Figure 2 shows the results of bibliometric keyword mapping on research trends on the characteristics of thin films as electronic devices. In Figure 2 there are 136 keyword items that are often used in research on the characteristics of thin films as electronic devices from 2015 to 2024. Figure 2 also contains 720 links and 10 clusters, where the first cluster is colored red and consists of 136 keyword items, namely thin film deposition, thin film coating, spin coating, physical characteristics, etc. The second cluster in green consists of 18 keyword items, namely grain size, interface, silicon substrate, current voltage characteristic, etc. The third cluster in blue consists of 18 keyword items, namely ferroelectric thin film studies, dielectric gates, synaptic characteristics, etc. The fourth yellow cluster consists of 17 keyword items, namely carbon nanotubes,

electrochemical characteristics, film thickness, magnetic characteristics, etc. The fifth purple cluster consists of 16 keyword items, namely oxygen vacancy, optical property, thin film structure, etc. The sixth cluster, which is light blue, consists of 14 keyword items, namely atomic film, channel film, resistivity, electrode position, etc. Likewise, clusters seven to ten have keyword items related to the characteristics of thin films as electronic devices.

Figure 2 above also shows that network visualization shows the network between the terms being visualized. Keywords classified into ten clusters are arranged in a color chart showing the divisions/clusters that are connected to each other. 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 research on the characteristics of thin films as electronic devices. The more keywords that appear, the wider the visualization displayed. Below are also presented keywords regarding the characteristics of thin films as electronic devices based on overlay visualization.

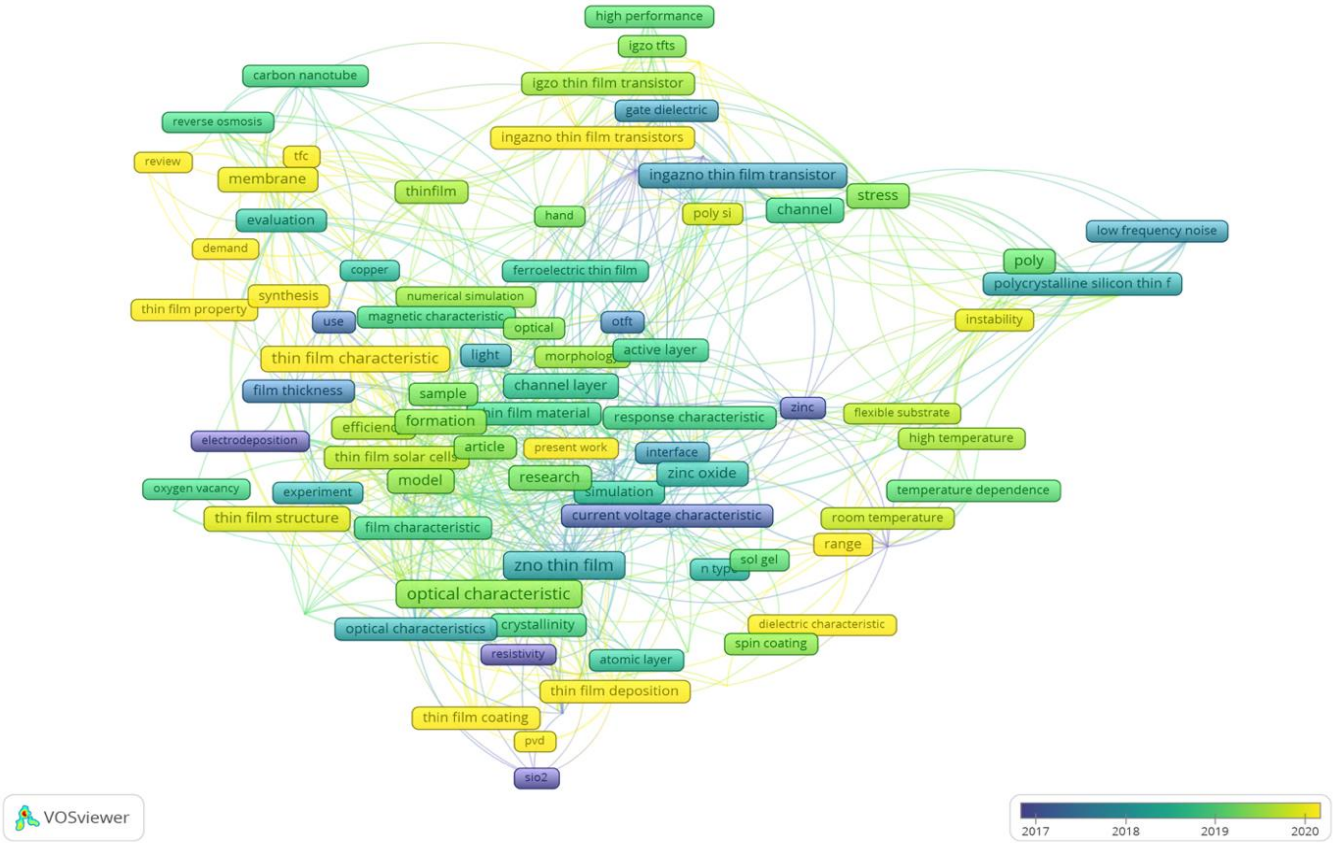

Figure 3. Overlay visualization on trend characteristics of research thin films

Figure 3 shows the trend of keywords related to research on the characteristics of thin films as electronic devices in Google Scholar indexed journals from 2015 to 2024. Trends in the themes of writing articles related to the characteristics of thin films as electronic devices from the oldest to the newest year are marked with purple, blue themes. , turquoise, dark green, light green and yellow. In the picture above you can see that the keywords thin film deposition, thin film coating, dielectric characteristic, etc. This shows that these keywords were widely used by researchers in 2020. In 2019, the keywords that frequently appeared were atomic film, n type, optical characteristic, film characteristic, etc.

Research on thin film characteristics is one area of research that has developed rapidly in recent years. This is due to the potential of thin films for various applications, such as solar cells, semiconductors and sensors. One of the most prominent research trends in thin film characteristics is the improvement of the efficiency of thin film solar cells. The efficiency of thin-film solar cells has increased significantly in recent years, from about 10% in 2010 to more than 20% in 2023. This increase in efficiency is driven by a variety of factors, including the development of new semiconductor materials, engineering of thin-film structures, and improved production methods.

The development of new semiconductor materials is one of the active research areas in the field of thin film

characteristics. The newly developed semiconductor materials have various advantages, such as higher efficiency, better stability and lower production costs. Several new semiconductor materials that have potential for thin film solar cell applications include perovskite, chalcogenide, and organic semiconductors. The following also presents keywords for ethno pedagogical research based on density visualization.

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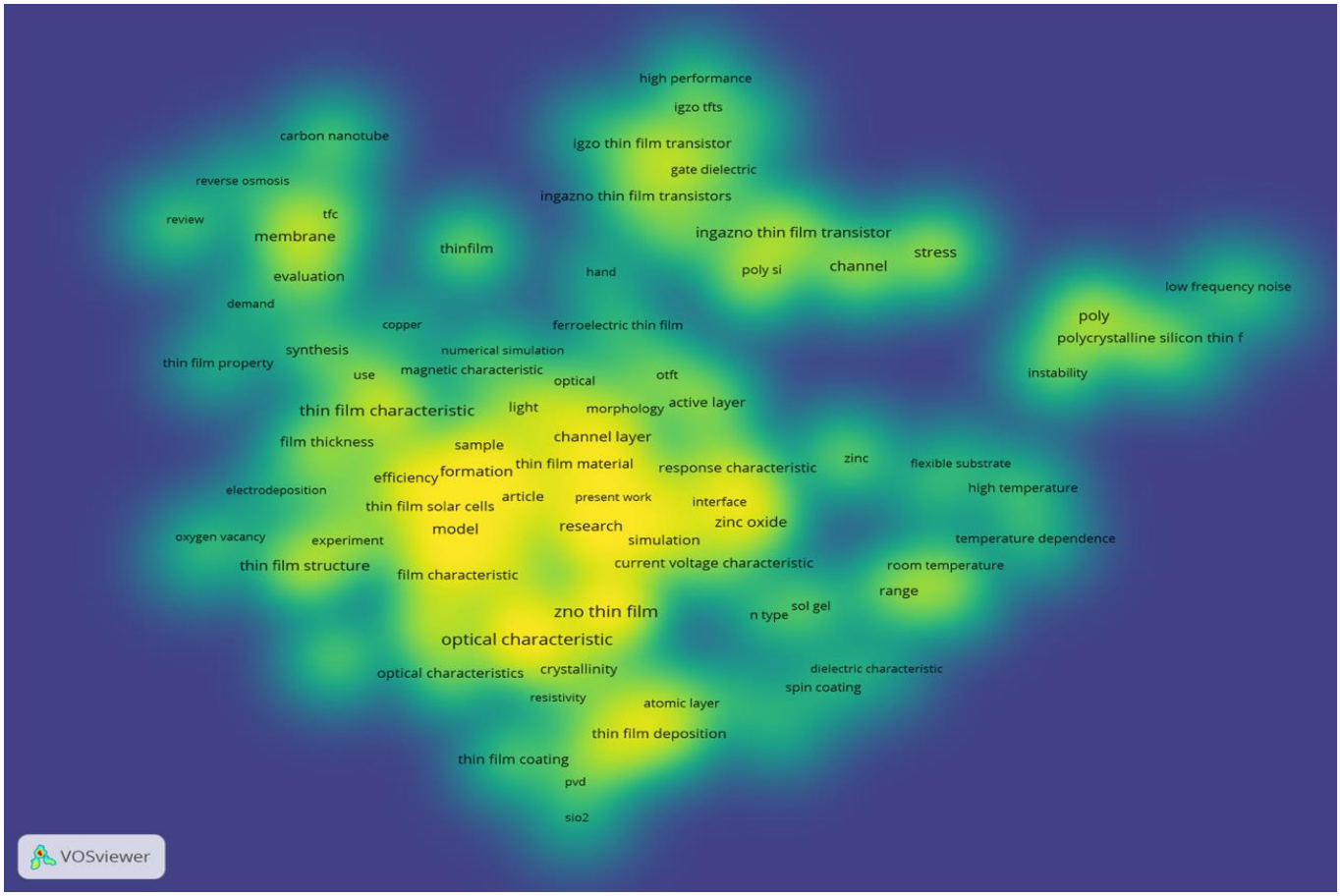

Figure 4. Density visualization on trend characteristics of research thin films

Figure 4 shows density visualization. The density of research themes is shown in bright yellow. The brighter the colors of a theme, the more research is done. The fainter the color means the theme is rarely researched. Faintly colored themes such as spin coating, oxygen vacancy, electrodepositing, and carbon nanotube are dimly colored keywords. This shows that these keywords can be used as a reference for further research. Doyan et al. (2023) and Bahtiar et al. (2023) stated that yellow indicates keywords that are currently and frequently used in research.

Overall, research on thin film characteristics is important because it makes significant contributions to the development of modern technology, improves energy efficiency, and helps understand material properties at the nanometer scale. It all has a positive impact on various aspects of our daily lives and the industry. Besides that, thin films can be used to increase the energy conversion efficiency of various electronic devices, such as solar cells, LED lights and heating systems. This can help reduce dependence on non-renewable energy resources and reduce greenhouse gas emissions.

The research trend in thin film characteristics is expected to continue to develop in the next few years. Increasing the efficiency of thin film solar cells, developing new semiconductor materials, engineering thin film structures, and improving production methods will be the focus of research in this field. Overall, research into thin film characteristics has the potential to provide various benefits to society. This research continues to develop and is expected to produce new, innovative technologies.

Conclusion

Research on trends in the characteristics of thin films as electronic devices has urgency high because of its potential to provide various benefits to society. The research trend on the characteristics of thin films as

electronic devices indexed by Google Scholar from 2015 to 2024 has experienced a fluctuating increase. However, in 2023 there will be a decline in the research trend on the characteristics of thin films as electronic devices. There are many documents in the form of articles, proceedings, book chapters, preprints, and edited books that discuss research into the characteristics of thin films as electronic devices. Key words that are often used in research on the characteristics of thin films as electronic devices are thin film coating, heat transfer characteristic, film characteristic, and photovoltaic characteristic.

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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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