Optical Properties of Erbium-Doped Tellurite Glasses: A Review and Bibliometric Study

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Abstract. The aim of this paper is to review the optical properties of tellurite glasses doped by erbium and describe their bibliometric study about it. The research documents on of optical properties of tellurite glasses doped by erbium in the Scopus database are 115, start from 1999 until now. The visualization of the research assisted by VOSviewer software. There are three clusters: (1) red cluster for the optical properties begin from the fabrication process until the characterization of glasses based on the geometrical optics phenomena, (2) green cluster for the emission spectra until the analysis using McCumbers Theory, and (3) erbium-doped tellurite glasses optical properties based on energy transfer and XRD analysis on the blue cluster. Based on the Scopus documents, not too many researchers are concerned with researching erbium-doped tellurite glasses, never more than 12 documents per year. However, the researchers are consistent to explore further exploring the characteristics of the optical properties of glass exposed to erbium ion for laser applications. The research funding shows that the tellurite glasses doped by erbium are being developed for laser applications.

Keywords. Optical properties, Tellurite glasses doped by erbium, Bibliometric Study.

1 Introduction

Tellurite glass research is fairly developed research in the field of optical materials. The forming glass needs combined by the element of network modifying [1-2], such as heavy metals, alkali metals, metals transition, alkali earth, or oxides [3]. Some types of optical materials use tellurite glass doped with rare earth ions for certain purposes. Materials doped with the rare earth elements have a wide applications spectrum since they provide potential photonic implementations such as fluorescence imaging for determination of biomolecules, display units, LCD background light, optical data storage, solid compact lasers, etc. [4]. One type of rare earth ion that has recently become a concern for tellurite glass optical materials for laser applications is the addition of erbium ions. Another implementation of tellurite glasses is the application in optical, electrical, and other industries resulting from their good properties of semiconductor [5-6].

Erbium is one of the rare earth ions [3] that has ability to up conversion so that it can increase the absorbance and excitation ability of electrons in the host material [7-9]. It is believed increasing the light optical absorption. Therefore, tellurite glasses doped by erbium were developed for application as an optical amplifier, a potential high-energy capacitor, a laser host, and the others [10-13]. There are various types of glass material compositions with a host of tellurium dioxide which is then doped with erbium ions. These variations are carried out to determine the composition that has the optimum capability for optical applications using glass material.

The fabrication of tellurite glass mostly uses the quenching melt technique with a certain temperature so that an amorphous arrangement is obtained in the developed material [7-14]. The process of making tellurite glass with this technique is not easy, so not many researchers are concerned about the development of tellurite glass material. However, research on erbium-doped tellurite glass continues to be developed by researchers in the field of optical materials.

Based on Scopus data on the previous research, information has been obtained that *"erbium-doped tellurite glasses"* research has as many as 695 documents until 2021. The trend of erbium-doped tellurite glass research until 2021 is presented in Fig. 1 [12].

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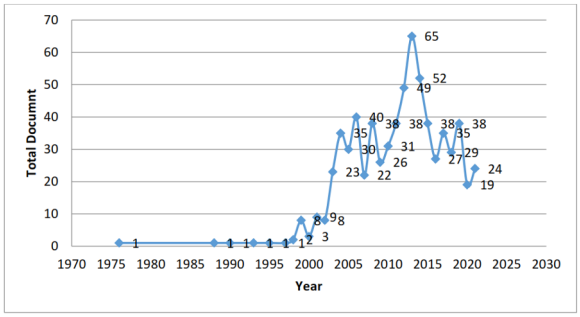

Fig. 1. The erbium-doped tellurite glasses research trend (1999-2021) [12].

Based on Fig.1, there are 4 clusters, one of which is the optical material characterization of erbium tellurite glasses which was developed [12]. Meanwhile, one of the characteristics studied in the study of optical materials is the optical properties of the material. In this paper, the research are explored by bibliometric analysis to get the map or report research trends [15-17].

The trends analysis frequently uses indicators such as the distribution of countries, the distribution of institutions, document sources, author keywords, the number of citations, and top authors [15-19]. The aims of this study to find and describe the trend of research that can help the researchers get comprehend landscape of research on the properties of tellurite glass doped by erbium.

2 Method

The method is descriptive research. It used analysis of bibliometric based on Scopus data [12,20-22]. The procedure of the research as shown in Fig. 2 [21-24].

Fig. 2. The research procedure [24].

2.1 Defining search keyword

The keyword used to define the document research on Scopus is" TITLE-ABS-KEY (optical AND properties AND of AND erbium-doped AND tellurite AND glasses)" for all years.

2.2 Initial Search Result

Data mining was conducted from June to August 2022. Based on the result, there are 114 documents on June 2022 and an increase to 115 documents on 22 August 2022.

2.3 Refinement of the Search

All of the 115 documents were extracted. It extracted into (.ris) and (.csv) extension file. The data in the form of (.ris) was processed with the VOSviewer software. Whereas the Microsoft Excel used to process data in the form of (.csv).

2.4 Compiling Data

The compiling data in the form of (.ris) was processed on the VOSviewer application [22-23]. To make the data more detailed, Microsoft Excel is supported for further analysis.

2.5 Data Analysis

Based on the 115 related documents that process with VOSviewer, the authors looking forward on the node's size and the link's strength. In the last of the result and discussion, there are also review the top 5 cited articles.

3 Results and Discussion

3.1 Bibliometric Information

The distribution of total research documents each year on this topic shown in Fig. 3. It shows that this research topic is volatile and have the most documents in 2019, that is 12 documents.

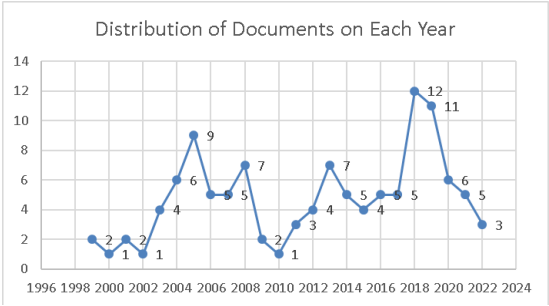

Fig. 3. The distribution of documents each year.

The type of documents for the research on this topic is shown in Fig. 4. There are 115 documents from journal articles (82), conference papers (22), conference reviews (7), and reviews (4) for all of the Scopus documents. Whereas the source type of the documents is from journals (90), conference proceedings (16), and book series (9) which can be seen in Fig. 5.

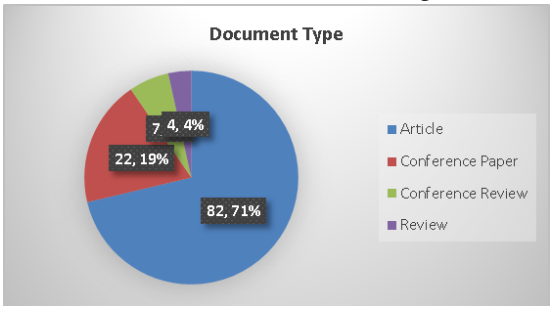

Fig. 4. The research document type.

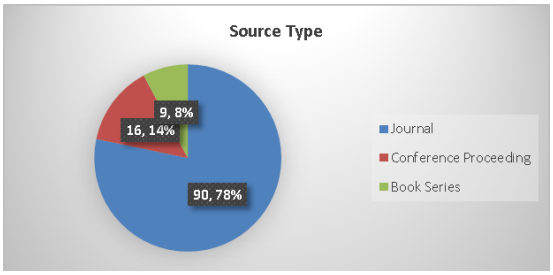

Fig. 5. The source type.

27 countries contributed to this research topic. Fig.6 show the information for the top ten countries that contributed to this research topic. China is the most contributed research on this topic (42 documents), followed by Malaysia (17 documents). The next contributed countries are India (14), Italy (8), Tunisia (7), Brazil (7), the United Kingdom (6), Japan (5), Saudi Arabia (4), and Portugal (3).

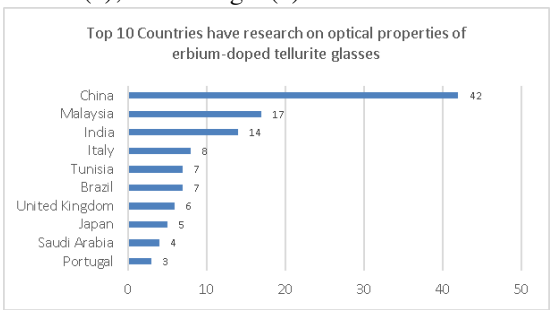

Fig. 6. The top ten countries.

3.2 Top Affiliation

The top ten affiliations that contributed to this topic of research are shown in Fig. 7. The first position is the Chinese Academy of Sciences (17), the second one by Ningbo University (14). The next affiliations are the Shanghai Institute of Optics and Fine Mechanics Chinese Academy of Sciences (112), Universiti Teknologi Malaysia (11), University of Chinese Academy of Science (7), South China University of Technology (7), University of Leeds (6), Institute for Photonics and Nanotechnologies, Rome (4), Universiti Putra Malaysia (4), and Sri Venkateswara University (4).

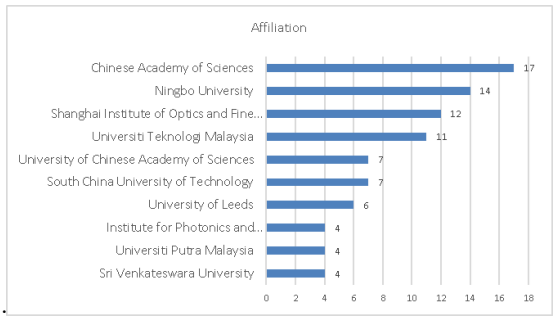

Fig. 7. The top ten affiliations.

3.3 Top source title and authors

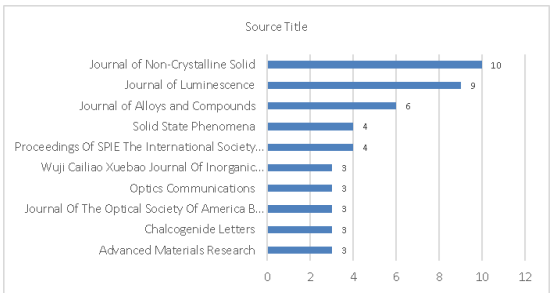

Fig. 8. The top ten source title

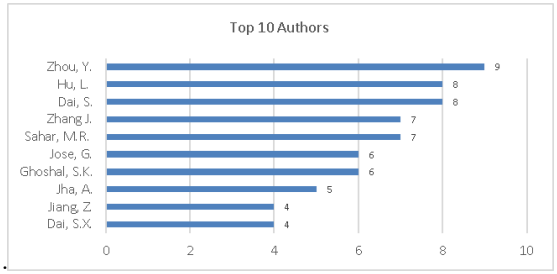

Fig. 9. The authors on the top ten data

The top ten data for authors of the research on this topic shown in Fig. 9. The most contributed author with 9 documents is Zhou, Y., followed by Hu, L. and Dai, S. with 8 documents. Zahar, J. and Sahar, M.R. as the authors with 7 documents. Jose, G. and Goshal, S.K. have 6 documents. Jha, A. has 5 documents and 4 documents from Jiang, Z. and Dai, S.X.

3.4 Research trends mapping visualization

Based on the data in the form of (.ris) documents, the analysis of the VOSviewer is based on authors and texts shown in Fig. 10 and Fig. 11. Based on the authors' mapping, there are 7 items with 2 clusters, 11 links, and 41 total link strength. On the red clusters, there are Dai, S., Hu, L., Xu, S., and Zhang, J. Whereas on the green cluster are Li, J., Shen, X, and Zhou, Y.

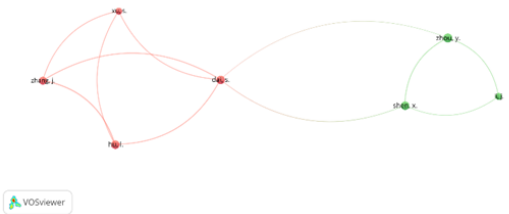

Fig. 10. The network visualization of authors' mapping based on VOSviewer analysis

Fig. 11 shows the visualization of networking for this research topic based on Scopus data using VOSviewer. Based on the visualization, there are three (3) clusters in the global research on this topic with 31 items, 378 links, and 1339 total link strengths. Based on Fig. 10, the size of the circle shows correlated with the appearance of the keywords, the line shows the networking and has the meaning that the shorter distance the stronger relationship [25].

The first cluster is the red cluster. The red cluster has 13 items of networking text, which are characterization, absorption, Er2O3, erbium-doped tellurite glass, fabrication, influence, optical absorption, optical property, order, paper, refractive index, room temperature, and series. The green cluster as the second cluster has 11 networking items of text. There are emission spectra, energy transfer, full width, fwhm, glass host, lifetime, m emission, melt quenching technique, nm laser diode, x-ray diffraction, and XRD. The last cluster is the blue cluster. There are 7 items on the blue cluster, which are cm2, emission cross-section, Er3+ ion, level, McCumbers theory, spectroscopic property, and TeO2.

Based on the analysis data using VOSviewer with the visualization (see Fig.10), one of the trends of this research topic is about the fabrication process until the optical characterization with direct measurements such as refractive index and optical absorption. On the green cluster, most of the researchers conducted advanced optical characterization and study its application in the field of optics. The last cluster study is about the analysis of the spectroscopic property of the erbium-doped tellurite glasses that have been developed.

Fig. 11. The network visualization of text mapping based on VOSviewer analysis.

Based on the previous research, other optical properties have been studied by researchers on other optical materials in the form of glasses, such as fluorescence intensity, fluorescence spectra, fluorescence branching ratio, up conversion, Judd-ofelt, etc. (See Fig. 12) [12]. It is a novelty for this research topic. The optical materials researchers can explore more with the advanced analysis of the same sample. For other kinds of glasses (such as Silica glass, Fluoride glass, etc.), there is also an analysis of the Raman spectra for the glass sample. So, it also can implement in the erbium-doped tellurite glasses for the deep analysis.

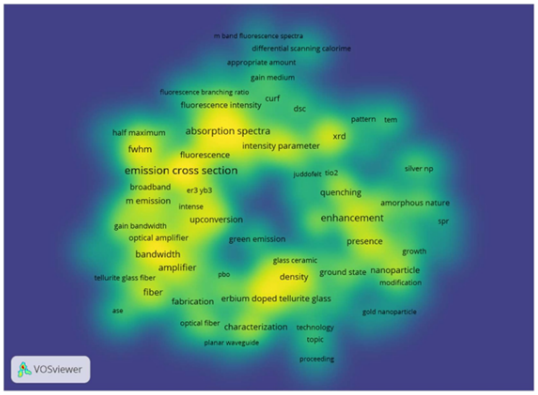

Fig. 12. Density visualization of text mapping based on VOSviewer analysis [12].

3.5 The top 5 cited publications review

The top 5 publication documents cited on this research topic can be seen on Table 1. Each document was reviewed based on the the document research.

Based on the review result, we know that the top 5 cited documents for the research of optical properties of erbium-doped tellurite glass have different material compositions with each characteristic. But, if we see it in more detail, all of the glass materials developed used in the optical application in the form of laser application [26-30]. So, for further research, the researchers can develop and analyse the optical characterization of the erbium-doped tellurite glasses based on the properties of the laser application.

4 Conclusion

Based on the data result and discussion, the research distribution on optical properties of erbium-doped tellurite glasses is volatile, not too many researchers are concerned with, never more than 12 documents per year. However, the researchers are consistent to explore further exploring the characteristics of the optical properties of glass exposed to erbium ion for laser applications.

The most Scopus document sources on this research topic are article journals. The most contributor country is China. The most institution contributor in this research topic is Chinese Academy of Science. Journal of Non-Crystalline Solids leads the source title. The most contributor author in this research topic is Zhou, Y.

The mapping of the authors and keywords show 2 clusters for the authors' mapping and 3 clusters for the keywords mapping. The red cluster shows the fabrication until the direct measurement. The analysis of the optical characterization until the analysis of parameters on the optical application for the material of tellurite glasses doped by erbium shown in green cluster. Whereas, the blue cluster is about the advanced optical properties analysis. The research findings is there are comprehend knowledge and needs to be more investigated for further research.

The review of the top 5 cited documents shows that the concentration of the analysis of optical properties of erbium-doped tellurite glasses is for laser application. So, for further research, this research topic can explore more to design, develop, and analyze the suitability of the material composition with the parameter of laser application.

Table 1. The top 5 cited publications review [26-30]

Author(s)	Citation	Findings	Recommendation
Jha, A., Richards, B., Jose, G., Teddy-Fernandez, T., Joshi, P., Jiang, X., Lousteaud, J.	325	The spectroscopic properties of tellurite and germanate glasses have been analysed with particular emphasis on oscillator strength and radiation rate characteristics for visible, near and middle IR emission. The review also compares the latest results of lasers and amplifiers. The achievements addresses the field of near-IR waveguide and bulk glass, fiber, and waveguide lasers.	The latest landmark results in mode-locked 2 μm bulk glass lasers set the precedence for engineering nonlinear and other laser devices for accessing the inaccessible parts of the mid-IR spectrum and discovering new applications for the future.
Babu, P., Seo, H.J., Kesavulu, C.R., Jang, K.H., Jayasankar, C.K.	138	The glasses may be suitable for use as a laser medium in manufacturing solid-state green lasers with a normal pumping route and as a laser medium and optical amplifier in the 1.5 μm region.	The results suggest that the glasses may be suitable for use as a laser medium in manufacturing solid-state green lasers with a normal pumping route and as a laser medium and optical amplifier in the 1.5 μm region.
Marjanovic, S., Toulouse, J., Jain, H., Sandmanna, C., Dierolfa, V., Kortan, A.R., Kopylov, N., Ahrens, R.G.	105	The emission results of newly fabricated double-clad Er3þ-doped tellurite single-mode fibers show their potential use for fiber lasers and optical amplifiers. Broad erbium emission spectra have been observed and a small signal net gain of ~30 dB was demonstrated in 1 m long fiber.	a strong local crystal field and effective re-emission and re-absorption processes are the reasons for more efficient tellurite glasses than other glasses used for optical applications.
Mori, A.	87	Tellurite-based glass in this research is capable of achieving a wider operating bandwidth, covering the 1600-nm region, than other glasses.	Because the transmission silica fiber has a minimum loss of around 1.58 m, the gain-flattened EDTFA is also an attractive device for application to long-haul transmission systems such as undersea transmission systems.
Mori, A., Sakamoto, T., Kobayashi, K., Shikano, K., Oikawa, K., Oikawa, K., Hoshino, K., Kanamori, T., Ohishi, Y., Shimizu, M.	85	By refining the raw material and adding a new PCF fabrication process, low background loss is achieved for Er^{3+}-doped, an undoped tellurite-based fiber and tellurite-based PCF. To overcome some of these problems, a tellurite and silica hybrid distributed/discrete fiber Raman amplifier (FRA) was constructed.	It is attractive functions for applications in the optical communication using these tellurite-based fibers with low background loss.

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