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# Bibliometric Computational Mapping Analysis of Graphene-Based Surfaced – Enhanced Raman Scattering Spectroscopy (SERS) During 2012 – 2022

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**Abstract** This study aims to examine the development of research related to Graphene-Based Surfaced-Enhanced Raman Scattering (SERS) through a bibliometric approach to computational mapping analysis using VOSviewer. The acquisition of article data was obtained from the Google Scholar database using the publish or perish reference manager application. The keywords used to guide the process of searching for the title and abstract of the article were "Graphene, SER, surface enhanced Raman scattering, nanoparticle". A total of 920 articles were obtained which were considered related to the topic of this research. The study period used as study material is Google Scholar indexed articles for the last 10 years (2012 to 2022). The results showed that the Graphene-Based Surfaced-Enhanced Raman Scattering (SERS) research can be separated into 4 terms:Raman Spectroscopy, Graphene, Nanoparticle and Surface. The term "Raman Spectroscopy" is associated with 189 links with total link strength 1539 The term "Graphene" has 198 links with total link strength 2036 the term "Nanoparticle" has 199 links with total link strength in 2739 and the term "Surface" has 189 links with total link strength 1651. The results of the analysis of the development of Graphene-Based Surfaced-Enhanced Raman Scattering (SERS) in the last 10 years show an increase. However, in 2020-2021, there was a slight decrease from 136 in 2020 to 135 in 2021. The increase in research occurred from 2014 - 2020 (49, 63, 80, 99, 105,116 and 136 publications per year respectively). While the popular Graphene-Based Surfaced-Enhanced Raman Scattering (SERS) research was carried out in 2020, there were 136 studies. From the results of research on article data using VOS viewer on Graphene-Based Surfaced-Enhanced Raman Scattering (SERS) and its relationship to the problem area, the results show that there has been an increase over the last 10 years. This study can be an initial consideration for future researchers who will conduct research related to this research topic.
**Keywords**: Bibliometric Analysis, Graphene-Based Surface-Enhanced Raman Scattering (SERS), Publish of Perish, VOS viewer

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## 1. Introduction

Since its inception, Surfaced-Enhanced Raman Scattering Spectroscopy (SERS) has been used for a variety of purposes, including structural analysis of materials, bimolecular analysis, and detection of chemicals and hazardous substances. A single component Graphene is one of the nanoparticle substrates that can be used to develop Surface-enhanced Raman Spectroscopy (SERS). Noble metals such as Au and Ag, which can produce strong electromagnetic enhancement and generate strong SERS signals from molecules adsorbed on the surface, are common SERS substrates. However, this substrate has the disadvantage of being less stable, and it is difficult to use in the long term. The modification of noble metal and graphene with the goal of achieving a composite structure is an effective solution to the problem of instability and poor sensitivity of SERS substrates. As a result, graphene-based SERS has become a popular research topic in recent decades.

After decades of continuous efforts and exploration by researchers, SERS has been developed as a new technique which has the advantages of non-destructive, fast, and highly sensitive detection of structural information of chemical and biological molecules with increasing factors up to 1014~1017 [1-5]. Therefore, SERS can be applied in ultra-trace detection of harmful substances, quantitative detection of molecular concentrations, and flow cytometry, which are beyond the reach of conventional Raman spectroscopy. The most common metallic materials used in SERS substrates are Au, Ag, and Cu, with Ag being the most effective enhancement. However, Ag substrates are susceptible to oxidation by oxygen in the air during preparation and storage. Therefore, most researchers currently use Au nanoparticles to prepare various SERS substrates. In addition, many transition metals can be used to make SERS substrates, such as cobalt, iron, nickel, platinum, and lead [6,7], but their enhancing effects are weak and have not been widely studied.

Graphene as a monolayer carbon film of $sp^2$ hybridized carbon atoms has been considered in scientific studies since the 1940s [8], but the available preparations are unstable. Novoselov et al. [9,10] have obtained the first stable graphene preparation on film support using mechanical exfoliation of high-oriented pyrolytic graphite bands. Since then, graphene has attracted the attention of researchers and industrial manufacturers in fundamental physics research and advanced functional composites and devices for applications such as biological and chemical sensors, flexible displays, new energy batteries, and seawater desalination. It was found that the Raman signal of the molecule can be significantly enhanced when certain molecules are adsorbed on the graphene surface using graphene as a substrate [11]. By comparing the Raman signal intensity of phthalocyanine molecules on graphene and SiO2/Si substrates, it was found that the Raman signal intensities of phthalocyanine molecules adsorbed on the monolayer graphene surface were much stronger than on $SiO_2$/Si substrates, indicating that monolayer graphene has a significant Raman enhancing effect. Despite the many advantages of graphene in SERS applications, its CM effect is weak, with increasing factors (EFs) usually only in the range of 0.3-100 [12-15], much lower than that of metal SERS substrates.

In recent years, several scholars have reviewed work on graphene-based SERS. For example, Cao et al. [16] and Kang et al. [17] have summarized the sensing and catalytic applications of graphene-based SERS. The analytical applications of graphene-based SERS are summarized by Zhang et al. [18]. SERS properties of graphene/silver nanocomposite are summarized by Sharma et al. [19]. A series of reviews summarize important work on this topic in recent years, ranging from the material properties of graphene and conventional SERS. In this review, we try to analyze and summarize this topic using bibliometric analysis. Bibliometric analysis is a form of meta-analysis of research data that can assist researchers in studying bibliographic content and analysis of citations from articles published in journals and other scientific works.

However, research on computational mapping of bibliometric analysis of published data in the field of surface-based Graphene-Enhanced Raman Scattering (SERS) that has been carried out specifically to determine research development has not been carried out. Especially bibliometric analysis for research in the last 10 years in the period 2012 to 2022 through Publish of Perish and the VOSviewer application.

Therefore, this study was conducted to conduct computational research on mapping bibliometric analysis of articles indexed by Google Scholar using Public of Perish and VOSviewer software. This research was conducted with the hope that it can be a reference for researchers to conduct and determine the research themes to be taken, especially those related to the Graphene-based Surface-Enhanced Raman Scattering (SERS) field.

## 2. Methods

The article data used in this study is based on research from publications that have been published in Google Scholar indexed journals. We chose Google Scholar in this study because the Google Scholar database is open source. To obtain research data, a reference manager application, namely Publish or Perish, is used. Publish or Perish software was used to conduct a literature review on our chosen topic. Detailed information for using and installing the software and a step-by-step process for obtaining data are described in the study [20] and detailed information on library search in searching for data in Google Scholar is described in a previous study conducted by Azizah et al. [21]

The research was conducted through several stages:
(i) Collection of publication data using the publish or perish application,
(ii) Processing of bibliometric data for articles that have been obtained using Microsoft Excel applications,
(iii) Computational mapping analysis of bibliometric published data using the VOSviewer application, and
(iv) Analysis of computational mapping analysis results

An article data search in Publish or Perish is used to filter publications using the keywords "Nanoparticle, SERS, Graphene, Graphene Surface-Enhanced Raman Scattering" based on the title requirements of the publication. The papers used were published between 2012 and 2022. All data were obtained in September 2022. The collected articles that met the research analysis criteria were then exported into two types of files: research information system (.ris) and comma separated values format (. *.csv). VOSviewer is also used to visualize and evaluate trends using bibliometric maps. The article data from the source database is then mapped. VOSviewer is used to create 3 variations of mapping publications, namely network visualization, density visualization, and network-based overlay visualization (co-citation) between existing items. When creating a bibliometric map, the keyword frequency is set to be found at least 3 times. Therefore, 271 terms and keywords that were less relevant were omitted.

## 3. Results and Discussion

This chapter lays out specific instructions for writing the full text, including the article section, the systematic chapter and its contents. These specific instructions will guide the entire editorial process of the article as shown in Figure 2.

### *3.1. Publication Data Search Results*

Based on the data search through application reference manager publish or perish from the Google Scholar database, 920 data articles were obtained that met the research criteria. The data was obtained in the form of article metadata consisting of the author's name, title, year, journal name, publisher, number of citations, article links, and related URLs. Table 1 shows some examples of published data used in the VOSviewer analysis of this study. The data samples taken were the 50 best articles that had the highest number of citations. The number of citations from all articles used in this study is 25568, the number of citations per year is 2556.80, the number of citations per paper is 25.59, the average author in the articles used is 4.62, all articles have an average h-index is 71, and the g-index is 129.

**Table.1** Articles about Graphene with H – Index Obtain from Bibiliometric Analysis with Poblish or Peries

| No | Authors | Title | Year | Number of Citation |
|---|---|---|---|---|
| 1. | X Ling et al | Charge-Transfer Mechanism in Graphene-Enhanced Raman Scattering | 2012 | 161 |
| 2. | Z Fan et al | Hybrid Graphene Oxide Based Ultrasensitive SERS Probe for Label-Free Biosensing | 2013 | 137 |
| 3. | Y Liu et al | Few-Layer Graphene-Encapsulated Metal Nanoparticles for Surface-Enhanced Raman Spectroscopy | 2014 | 117 |
| 4. | Q Hao et al | Surface-Enhanced Raman Scattering Study on Graphene-Coated Metallic Nanostructure Substrates | 2012 | 112 |
| 5. | M Iiut et al | A new green, ascorbic acid-assisted method for versatile synthesis of Au–graphene hybrids as efficient surface-enhanced Raman scattering platforms | 2013 | 109 |
| 6. | X Ling et al | Graphene-Thickness-Dependent Graphene-Enhanced Raman Scattering | 2012 | 97 |
| 7. | H Lai et al | Recent progress on graphene-based substrates for surface-enhanced Raman scattering applications | 2018 | 88 |
| 8. | H Kang et al | Recent progress in the applications of graphene in surface-enhanced Raman scattering and plasmon-induced catalytic reactions | 2018 | 88 |
| 9. | Y Li et al | A facile fabrication of large-scale reduced graphene oxide–silver nanoparticle hybrid film as a highly active surface-enhanced Raman scattering substrate | 2015 | 85 |
| 10. | J Liu et al | Fabrication of Graphene Nanomesh and Improved Chemical Enhancement for Raman Spectroscopy | 2012 | 82 |
| 11. | Y Du et al | Enhanced light–matter interaction of graphene–gold nanoparticle hybrid films for high-performance SERS detection | 2014 | 77 |
| 12. | F Yin et al | Self-assembly of mildly reduced graphene oxide monolayer for enhanced Raman scattering | 2016 | 75 |
| 13. | Y Zhao et al | Enhanced SERS Stability of R6G Molecules with Monolayer Graphene | 2014 | 69 |
| 14. | Y Guo et al | A dual colorimetric and SERS detection of $Hg^{2+}$ based on the stimulus of intrinsic oxidase-like catalytic activity of Ag-$CoFe_2O_4$/reduced graphene oxide nanocomposites | 2018 | 67 |

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| 15. | M Paillet et al | One-pot synthesis of multifunctional magnetic N-doped graphene composite for SERS detection, adsorption separation and photocatalytic degradation of Rhodamine 6G | 2018 | 59 |
| 16. | Balcioglu et al | Doxorubicin loading on graphene oxide, iron oxide and gold nanoparticle hybrid | 2013 | 58 |
| 17. | H Luo et al | Mechanical enhancement of copper matrix composites with homogeneously dispersed graphene modified by silver nanoparticles | 2017 | 58 |
| 18. | A Shiotari et al | Tip-enhanced Raman spectroscopy of graphene nanoribbons on Au (111) | 2014 | 58 |
| 19. | S Jiang et al | A novel U-bent plastic optical fibre local surface plasmon resonance sensor based on a graphene and silver nanoparticle hybrid structure | 2017 | 57 |
| 20. | H Lai et al | A review of the preparation and application of magnetic nanoparticles for surface-enhanced Raman scattering | 2018 | 57 |
| 21. | Y Lin et al | An electrochemical sensor for the determination of bisphenol A using glassy carbon electrode modified with reduced graphene oxide-silver/poly-L-lysine | 2017 | 57 |
| 22. | Divyapriya G et al | An innate quinone functionalized electrochemically exfoliated graphene/Fe3O4 | 2017 | 57 |
| 23. | SF Zhou et al | Enhanced electrochemical performance for sensing Pb (II) based on graphene oxide incorporated mesoporous MnFe2O4 nanocomposites | 2018 | 57 |
| 24. | IV Lightcap et al | Electron hopping through single-to-few-layer graphene oxide films. Side-selective photocatalytic deposition of metal nanoparticles | 2012 | 56 |
| 25. | YJ Mai et al | Preparation and tribological behavior of copper matrix composites reinforced with nickel nanoparticles anchored graphene nanosheets | 2018 | 56 |
| 26. | TB Limbu et al | Green synthesis of reduced Ti 3 C 2 T x MXene nanosheets with enhanced conductivity, oxidation stability, and SERS activity | 2018 | 55 |
| 27. | PT Do et al | A highly sensitive electrode modified with graphene, gold nanoparticles, and molecularly imprinted over-oxidized polypyrrole for electrochemical determination of electrochemical determination of dopamine | 2014 | 54 |

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|---|---|---|---|---|
| 28. | RK Biroju et al | Defect enhanced efficient physical functionalization of graphene with gold nanoparticles probed by resonance raman spectroscopy | 2014 | 54 |
| 29. | K Deng et al | Simultaneous detection of sunset yellow and tartrazine using the nanohybrid of gold nanorods decorated graphene oxide | 2016 | 53 |
| 30. | RT Thomas et al | Synthesis of nanotitania decorated few-layer graphene for enhanced visible light | 2014 | 52 |
| 31. | XF Zhang et al | Simultaneous detection of sunset yellow and tartrazine using the nanohybrid of gold nanorods decorated graphene oxide | 2016 | 51 |
| 32. | Dhara et al | Au nanoparticles decorated reduced graphene oxide for the fabrication of disposable nonenzymatic hydrogen peroxide sensor | 2016 | 50 |
| 33. | P Nagaraju et al | Facile in-situ microwave irradiation synthesis of TiO2/graphene nanocomposite for high-performance supercapacitor applications | 2018 | 50 |
| 34. | M Aamir et al | Graphene oxide nanocomposite with Co and Fe doped LaCrO3 perovskite active under solar light irradiation for the enhanced degradation of crystal violet dye | 2021 | 50 |
| 35. | Zhong et al | Copper phthalocyanine functionalization of graphene nanosheets as support for platinum nanoparticles and their enhanced performance toward methanol oxidation | 2013 | 49 |
| 36. | M Gautam et al | Detection of organic vapors by graphene films functionalized with metallic nanoparticles | 2012 | 49 |
| 37. | RK Matharu et al | Microstructure and antibacterial efficacy of graphene oxide nanocomposite fibres | 2020 | 49 |
| 38. | HY Yu et al | Nanoparticles of magnetite anchored onto few-layer graphene: A highly efficient Fenton-like nanocomposite catalyst | 2018 | 49 |
| 39. | Govinda et al | Decoration of few-layer graphene-like MoS2 and MoSe2 by noble metal nanoparticles | 2012 | 48 |
| 40. | Z Ji et al | Enhanced electrocatalytic performance of Pt-based nanoparticles on reduced | 2012 | 48 |
| 41. | Sen et al | Trimetallic PdRuNi nanocomposites decorated on graphene oxide: a superior catalyst for the hydrogen evolution reaction | 2018 | 48 |

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|---|---|---|---|---|
| 42. | Ahmad et al | Fabrication of sensitive non-enzymatic nitrite sensor using silver-reduced graphene oxide nanocomposite | 2018 | 47 |
| 43. | Lan et al | Photochemical decoration of silver nanoparticles on graphene oxide nanosheets and their optical characterization | 2014 | 47 |
| 44. | Khan et al | A comprehensive review on carbon dots and graphene quantum dots based fluorescent sensor for bio thiols | 2020 | 45 |
| 45. | T Fujigaya et al | A highly durable fuel cell electrocatalyst based on polybenzimidazole-coated stacked graphene | 2014 | 44 |
| 46. | S Benitez et al | Multilayer graphene–gold nanoparticle hybrid substrate for the SERS determination of metronidazole | 2015 | 44 |
| 47. | C Li et al | Surface-amorphized TiO2 nanoparticles anchored on graphene as anode materials for lithium-ion batteries | 2018 | 44 |
| 48. | N Song et al | A novel electrochemical biosensor for the determination of dopamine and ascorbic acid based on graphene oxide/poly (aniline-co-thionine) nanocomposite | 2020 | 42 |
| 49. | J Liu et al | Environmentally friendly synthesis of graphene–silver composites with surface-enhanced Raman scattering and antibacterial activity via reduction with l-ascorbic acid | 2015 | 42 |
| 50. | Z Qian et al | Fabrication of graphene oxide/Ag hybrids and their surface-enhanced Raman scattering characteristics | 2013 | 40 |

3.2. *Research Development in The Field of Graphene – Based Surfaced-Enhanced Raman Scattering*

Table 2 shows the development of research in the field of Graphene-Based Surfaced-Enhanced Raman Scattering studies published in the Google Scholar indexed journal. Based on the data shown in Table 2, it can be seen that the number of researches in Graphene-Based Surfaced-Enhanced Raman Scattering is 920 articles from 2012-2022. In 2012 there were 38 articles. In 2013 there were 49 articles. In 2014 there were 49 articles. In 2015 there were 63 articles, in 2016 there were 80 articles, in 2017 there were 99 articles, in 2018 there were 105 articles, in 2019 there were 116 articles, in 2020 there were 136 articles, in 2021 there were 135 articles and in 2022 there were 107. From the number of publications, it can be seen that research on Graphene-Based Surfaced-Enhanced Raman Scattering (SERS) is still relatively rarely studied every year, especially in the last 10 years (2012-2021). Its development is also quite volatile as can be seen clearly in Figure 1. Figure 1 shows the development of Graphene-Based Surfaced-Enhanced Raman Scattering (SERS) research for the last 10 years in the range of 2012 to 2022. Based on Figure 1, it is known that the development of research related to Graphene-Based Surfaced-Enhanced Raman Scattering (SERS) has decreased from 2020-2021. This decline can be seen from the number of publications in 2012 as many as 136 to 2014 only 135 publications. The development of research on Graphene-Based Surfaced-Enhanced Raman Scattering (SERS) has so far increased from 2012 to 2022. But it has decreased slightly in 2021 compared to 2022. The data shows that the popularity of research on Graphene-Based Surfaced-

Enhanced Raman Scattering (SERS) tends to be stable and research interest on this subject continues to increase every year.

**Table 2.** Development of Graphene-Based Surfaced-Enhanced Raman Scattering (SERS)

| Year of Publications | Number of Publications |
|---|---|
| 2012 | 38 |
| 2013 | 49 |
| 2014 | 49 |
| 2015 | 63 |
| 2016 | 80 |
| 2017 | 99 |
| 2018 | 105 |
| 2019 | 116 |
| 2020 | 136 |
| 2021 | 135 |
| 2022 | 107 |
| **Average** | **88,8** |

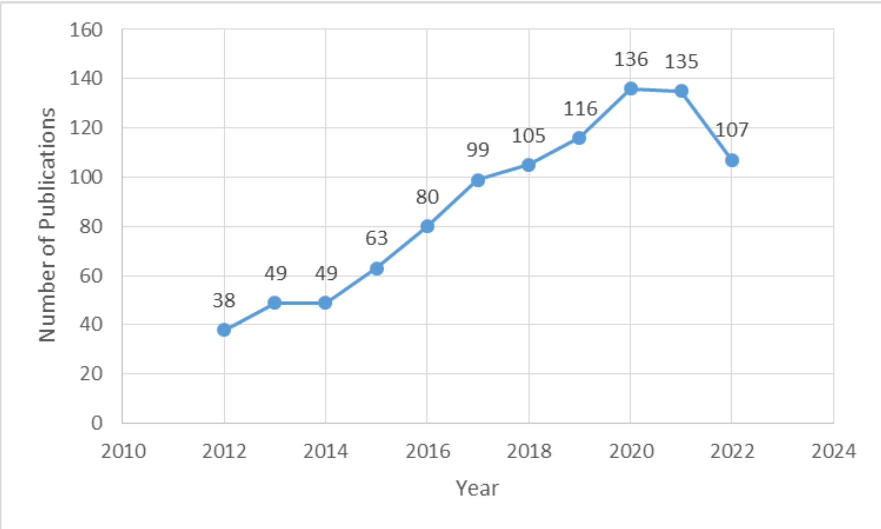


**Figure 1.** Level of development in Graphene-Based Surfaced-Enhanced Raman Scattering (SERS)

### *3.3. Visualization Graphene – Based Surfaced – Enhanced Raman Scattering*

Computational mapping was performed on the article data. VOSviewer is used in computational mapping. From the results of computational mapping found 195 items. Each item found related to Graphene-Based Surfaced-Enhanced Raman Scattering (SERS) in data mapping is divided into 9 clusters, namely:

(i) Cluster 1 has 34 items and marked in red, the 34 items are ability, aggregation, array,assembly, based surfaced, biomolecule, challenge, chemical, degradation, detection, efficiency, gold nanorod, light, metal, noble metal nanoparticle, novel surface, organic pollutant, performance, plasmonic nanoparticle, rapid, rhodamine, self, sensitive detection, sensitive ser, sensitive SERS detection, sensitive SERS detection, sensitive surface, ser, SERS detection, SERS experiment, SERS signal, shape, signal, technology, and ultrasensitive detection.

(ii) Cluster 2 has 31 items and marked in green, the 31 items are active surface, activity, advantage, biosensor, capability, case, catalytic activity, excellent surface, facile synthesis, fluorescence, glucose, high surface, layer, metallic nanoparticle, mos, photothermal therapy, plasmonic, plasmonic property, Raman scattering, Raman scattering activity, research, role, sensitivity, SERS intensity, SERS performance, shell, silver nanoparticle, stability, structure, ultrasensitive surface and weak Raman signal.

(iii) Cluster 3 has 28 items and marked in blue, the 28 items are addition, characterization, discovery, efficient surface, enhancement, graphene oxide, influence, metal nanoparticle, molecule, optical property, organic dye, paper, powerful tool, preparation, property, Raman enhancement, Raman scattering platform, Raman signal, reduction, sensing, ser application, SERS effect, SERS platform, surface plasmon resonace, surfaceenchanced Raman scattering synthesis and trace.

(iv) Cluster 4 has 27 items and marked in yellow, the 27 items are adsorption, analysis, analyte, compound, copper, determination, effect, enhanced Raman scattering, gold, gold nanoparticle, gold nanoparticles, intensity, interaction, ion, nanoparticle surface, phenomenon, Raman spectra, Raman spevtroscopy, resonace, SERS, SERS study, silver, study, surface enhanced Raman spectroscopy, time and variety.

(v) Cluster 5 has 27 items and marked in purple, the 27 items are active substrate, application, attention, bimetallic nanoparticle, concentration, field, graphene, high performance surfaced, high sensitivity, laser, nanostructure, photochemical synthesis, plasmon, presence, Raman scattering application, Raman scattering spectroscopy, Raman scattering suvstrate, Raman spectrum, rapid detection, recent progress, recent year, SERS active substrate, SERS activity, SERS probe, surface and tool.

(vi) Cluster 6 has 17 items and marked in sky blue, the 17 items are area enhancement factor, fabrication, food, hotspot, magnetic nanoparticle, oxide, pesticide residue, powerful analysis technique, Raman scattering detection, Raman spectroscopy substrate, technique and use.

(vii) Cluster 7 has 17 items and marked in orange, the 17 items are combination, development, importance, investigation, mechanism, new surface, Raman, recent advance, reproducibility, sensor, SERS active nanoparticle, SERS measurement, single molecule, single nanoparticle spectra and spectroscopy.

(viii) Cluster 8 has 9 items and marked in brown colour, the 9 items are deposition, film, gap, identification, morphology, nanoparticle, reproducible surface, SERS sensor and substrate.

(ix) Cluster 9 has 5items and marked in pink, the 5 items are charge transfer, probe, surface enhanced Raman scattering and tio.

Labels are given to each term with coloured circles. The size of the circle for each term varies depending on the frequency of occurrence of the term. The size of the label circle shows a positive correlation with the occurrence of the term in the title and abstract]. The more often the term is found, the larger the label size. The mapping visualization analysed in this study consists of 3 parts: network visualization (see Figure 2), density visualization (see Figure 3), and overlay visualization (see Figure 4)[49].

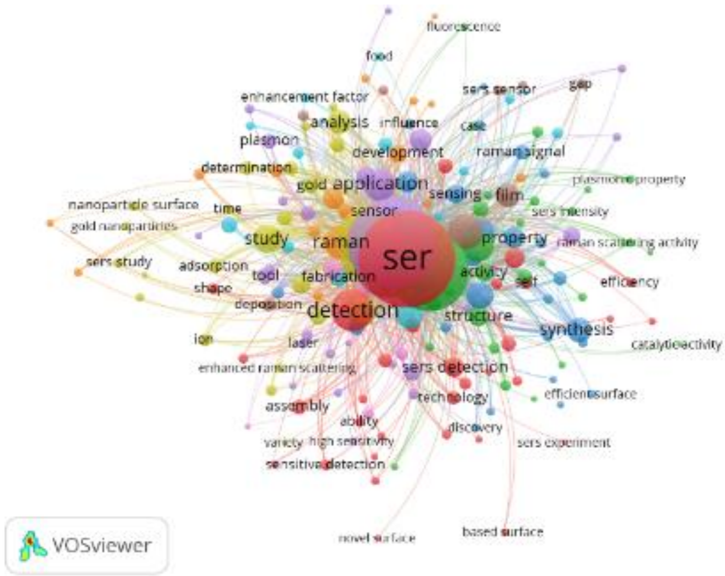


**Figure 2.** Network visualization of Nanoparticle, SERS, Graphene, Graphene Surface-Enhanced Raman

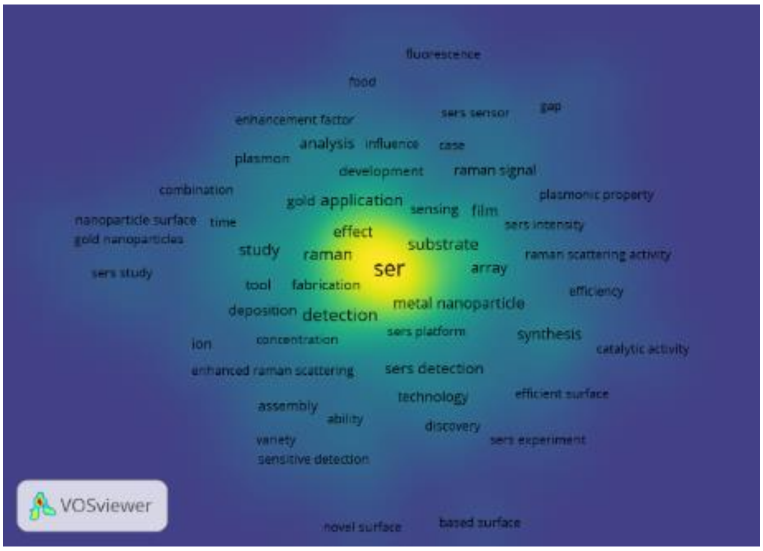


**Figure 3.** Density visualization of Nanoparticle, SERS, Graphene, Graphene Surface-Enhanced Raman Scattering keyword

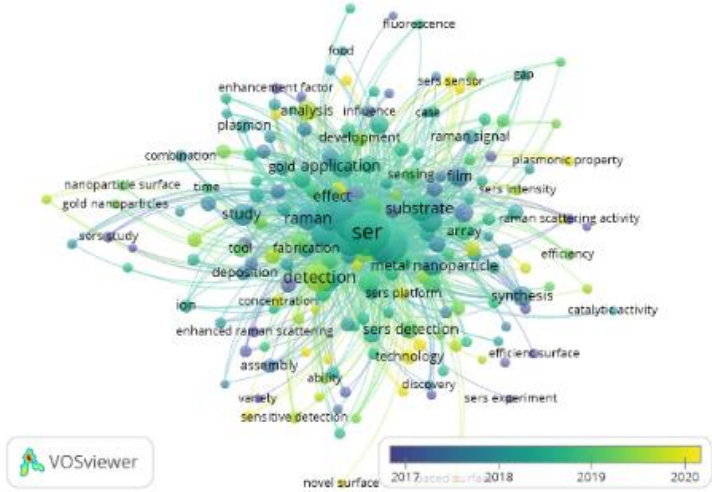


**Figure 4.** Overlay visualization of Nanoparticle, SERS, Graphene, Graphene Surface-Enhanced Raman Scattering keyword.

Figure 2 shows the relationship between terms. The relationship between terms is depicted in an interconnected network. Figure 2 shows the cluster of each term that is often researched and related to the research topic of Graphene-Based Surfaced-Enhanced Raman Scattering (SERS). From the clusters contained in the network visualization, it can be seen that the research Graphene-Based Surfaced-Enhanced Raman Scattering (SERS) can be separated into 4 fields, namely the education term which is included in cluster 4 with 195 links total, 1201 total link strength, and 179 occurrences (see Figure 5). The second term is Graphene-Based Surfaced-Enhanced Raman Scattering (SERS) to cluster 7 with a total of 213 links, a total link strength of 1036, and occurrences of 159 (see Figure 6), and a mechanical engineering education term which belongs to cluster 4 with a total of 157 links, a total link strength of 564, and 77 occurrences (see Figure 7).

Figure 3 shows the density visualization. Density visualization means that the brighter the yellow colour and the larger the diameter of the circle of term labels, the more often the term appears. This means that a lot of research on related terms has been carried out. Vice versa, if the colour of the term fades closes to the background colour, then the number of studies on the term is small. Based on Figure 3, it can be seen that research related to surface, nanoparticle, ser, Raman scattering, Raman spectroscopy has a high number of studies. Figure 4 shows the overlay visualization in mechanical engineering education research. This visualization overlay shows the novelty of research on related terms.. Figure 4, which is clarified in Figure 8, shows that research on Graphene-Based Surfaced-Enhanced Raman Scattering (SERS) was mostly carried out from 2017 to 2018. The time for the popularity of the term Graphene-Based Surfaced-Enhanced Raman Scattering (SERS) in research has been quite long. Thus, we can easily create new research on Graphene-Based Surfaced-Enhanced Raman Scattering (SERS). Figure 5 shows a network of ser relations with other terms, namely

Figure 3 shows the density visualization. Density visualization means that the brighter the yellow color and the larger the circle diameter of the term label, the more often the term appears. This means that a lot of research on related terms has been done. 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. Based on Figure 3, it can be seen that research related to surface, nanoparticles, ser, Raman scattering, Raman spectroscopy has a high number of studies. Figure 4 shows the overlay visualization in mechanical engineering education research. This visualization overlay demonstrates the novelty of research on related terms.

Figure 4 which is clarified in Figure 8 shows that research on Graphene-Based Surfaced-Enhanced Raman Scattering (SERS) was mostly carried out from 2017 to 2018. It's time for the popularity of the term Graphene-Based Surfaced-Enhanced Raman Scattering (SERS) in research for a long time. . Thus, we can easily make new research on Graphene-Based Surfaced-Enhanced Raman Scattering (SERS).

## 4. Conclusion

The purpose of this study is to examine the development of research related to Graphene-Based Surfaced-Enhanced Raman Scattering (SERS) through a bibliometric approach to computational mapping analysis using VOSviewer. The article data was obtained from the Google Scholar database using the publish or perish reference manager application. The keywords used to guide the process of searching for the title and abstract of the article were "Nanoparticles, SERS, Graphene, Graphene Surface-Enhanced Raman Scattering". A total of 920 articles were found that were considered related to the topic of this research. The research period used was the last 10 years, which was published in the range of 2012 to 2022. The results showed that the Graphene-Based Surfaced-Enhanced Raman Scattering (SERS) research significantly increased from 2012 to 2020 and decreased in 2021. The results of this study indicate that there is a high possibility of Graphene-Based Surfaced-Enhanced Raman Scattering (SERS) research for future researchers who will conduct research related to this topic.

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