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# A Bibliometric Survey on Polymer Composites in Energy Storage Applications

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# A Bibliometric Survey on Polymer Composites in Energy Storage Applications

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**Abstract:** Ceramic polymer composites have gained a significant place in energy storage applications for electrical capacitors due to their distinguished properties. There is a huge demand of capacitors with high energy density, high dielectric strength, negligibly low dielectric loss, light weight, chemically less reactive in energy storage applications. These requirements can be fulfilled by ceramic polymer composites only which exhibit all the above-mentioned characteristics. Considering the huge demand of such capacitors, it has attracted the attention of researchers around the world. The present work attempts to summarise all the research conducted on Polymer Composites for energy storage applications and provides an up-to-date research document for the ready reference of the researchers/scientists engaged in the area of Polymer composites. The bibliometric analysis includes Scopus database and software, such as Gephi, Vos Viewer, and Table2Net. The study can be considered as a handbook reflecting the gradual exploration in the field of polymer composites and their applications in energy storage.

**Keywords:** Polymer Composite, Bibliometric analysis, Energy storage, Dielectric constant, Energy density

**1 Introduction:** Increasing demand of electrical energy storage devices used for different applications under different operating propelled the search for dielectric materials with some specific characteristics such as high energy density, high dielectric strength, low dielectric loss and excellent thermal stability etc. Ceramic materials show high dielectric constant and can withstand high temperature applications but their applications are limited due to high dielectric losses and brittle nature. On the other hand, polymers show high dielectric strength, lower dielectric losses and chemically non-reactive behaviour fail at high temperature and have low dielectric constant [1].

Ceramic-polymer composites have gained attention of researchers due to its incredible properties overcoming the limitations of one component dielectrics of ceramic or polymer materials alone. Ceramic polymer composites are also gained more attention because of their small size, light weight and low cost. Due to characteristic dielectric properties make them useful for energy storage applications. High dielectric constant is derived from the ceramic phase and high dielectric strength, low dielectric loss and low density is derived from the polymer phase [2]. Good combability properties of ceramic polymer composites with printing circuit boards are very attractive to embed the ceramic polymer composites for capacitor applications.

The main objective of this paper is to systematically map polymer composite literature for energy storage applications and to provide the fundamental information, conceptual and technological background and the relevant outcomes. The paper gives an overview of the theoretical model for developing polymer composites and their application for energy storage. It also highlights different approaches to fabricate composites with variety of filler materials to achieve desired dielectric properties. The paper describes extensively the bibliometric analysis of polymer composites for energy storage applications. The present work will be very useful for the researchers who wish to carry their research in synthesizing ceramic polymer composites with desired dielectric properties for high energy density capacitors.

## 2 Theoretical Model for designing Polymer Composites

The microscopic property which mainly describes the energy density stored in a dielectric material is called polarization [3]. Energy density is defined by dielectric constant and dielectric strength of a dielectric material. It is given by $U = \int E\, dD = \frac{1}{2} DE = \frac{1}{2} \varepsilon_0 k E_b^2$

Where, $E_b$, k, $\varepsilon_0$ are breakdown field strength, effective permittivity (dielectric constant) of the composite and permittivity of vacuum respectively. In composite, the loading level of filler should be carefully selected so that the combination of k and $E_b$ give the maximum value of energy density [4]–[11].

Various mixing models are proposed, however only few are found to be in good agreement with experimental results. Classical mixing rule expresses the dielectric constant of composite as,

$$ln\, k = \sum_i v_i ln(k_i)$$

Where, k represents effective dielectric constant of composites and $k_i$ and $v_i$ the dielectric constant and volume of $i^{th}$ constituent of composite respectively [12].

Looyenga mixing equation is based on a power-law approximation. It gives the effective dielectric constant of composites as per the following equation,

$$k^{\frac{1}{3}} = (1 - V_1)k_2{}^{\frac{1}{3}} + V_1 k_1{}^{\frac{1}{3}}$$

Where, k represents resultant dielectric constant of composite and $k_1$, $k_2$ are dielectric constants of filler and matrix material respectively, and $V_1$ is filler volume fraction.

The influence of the interaction zone between the filler and the matrix material was not considered by such classical models. The impact of the shape and orientation of filler particles were also not taken into account.

The Modified Interphase power law model considers the interphase interaction and dielectric constant of interphase between filler and matrix material. It can be expressed as the following equation

$$k^{\beta} = v_1 k_1^{\beta} + (1 - V_1)k_2^{\beta} + V'\left(k^{\beta} - k_2^{\beta}\right)$$

where k is the dielectric constant of air (~1) for polymers of large molecules or k is the dielectric constant of the filler for ceramics and polymers of smaller molecules. V' is the volume factor arises due to interphase and can be computed from:

$$V' = V_1 \frac{(1 - V_1)}{(1 + V_1)}$$

Experimental validation of modified interphase power law model has a good accuracy than other theoretical models [13].

## 3 Approach of designing composite with filler strategy

Properties of resultant composites not only depend on individual properties of constituent materials but also depends on various other parameters such as nature, shape, size, fraction of loading of filler material, surface modification, etc. Brief summary of these factors is listed in Table 1.

**Table 1**: Effect of Filler type on composite

| **Filler Description** | | **Effect on composite** | **Ref** |
|---|---|---|---|
| Filler Type | Conductor/ Semiconductor | Enhancement in dielectric constant but conduction causes high dielectric loss and leakage current. | [14], [15], [12], [16], [17] |
| | Thermal Conductor | Decreases dielectric strength. | [4], [5], [18]. |

| | | | |
|---|---|---|---|
| | Dielectric | Enhances dielectric constant. | [4], [5], [18]. |
| | Wide band gap material | Enhances dielectric strength, Boron Nitride nanosheet (BNNS) also reduce dielectric loss. | [4], [5], [18]. |
| Filler size | Micro size | Higher loading of filler requires to enhance k which ultimately make composite heavier and brittle affecting dielectric strength and loss as well | [14], [19], [10], [20], [21]. |
| | Nani size | Enhancement in dielectric constant but agglomeration and inhomogeneous dispersion of particle affects dielectric strength and loss factor | [14], [19], [10], [20], [21]. |
| Filler Shape | Spherical | Higher breakdown strength than rod shaped particles | [10], [22] |
| | Rod | Higher aspect ratio enhances the interfacial polarisation resulting higher dielectric constant | [10], [22] |
| | Disc | For increasing dielectric strength nano sheets of montmorillonite clay (MMT) and Boron nitride are preferably used | [31] |
| Surface modification | -- | Surface modification enhances dispersion, interfacial interaction, polarisation but thermal conductivity increases. | [15],[25], [26] |

### 4 Bibliometric Analysis

There is huge research data generated with the extensive research being carried out across the globe on composite materials and it is further growing with each passing year. It is essential to have the deep knowledge, understanding and current status of ongoing research in the area of ceramic polymer composite to avoid any duplication of the research. Webometrics, bibliometric, scientometric and H-index are some of the tools which are used to analyse the trends in various research fields. Among all these available tools bibliometric analysis is a conclusive and summative study of quantitative and qualitative research works. It is a common tool to study the trends in research work. The present analysis includes styles of publications, topics, secondary data studies, annual trends in printing, geographical publications and citations [27]. Scopus database is used to conduct a bibliometric analysis. A variety of networks are built on the keywords and titles of the polymer composite research in energy storage applications, authors and citations.

### 4.1 Significant keywords

Keywords for Scopus search were divided into three blocks: master, primary and secondary keywords. Table 2 explains the proposed strategic keywords used for this study.

**Table 2:** The proposed keyword strategy for Scopus database search

| | |
|---|---|
| Master keyword (AND) | "Polymer Composite" |
| Primary keywords (AND) | "Energy Density" OR "Energy Storage" OR "Capacitor" |
| Secondary keywords (AND) | "Dielectric constant" OR "Dielectric Strength" OR "Breakdown Strength" OR "Dielectric loss" OR "Loss Factor" |

### 4.2 Initial search results

The present work focuses on the results obtained from SCOPUS database search through key words. Preliminary search with the keywords resulted in total 1368 publications (2010 to 2020). The subsequent search was then restricted only to publications in English only. This search gave 1335 publications in English. (Table 3).

All x published or unpublished research work was considered for the trend analysis. Table 4 shows the type of publications in "Polymer composite for energy storage application". Maximum number of publications were found to be journal articles on the topic "Polymer composite for energy storage applications". Very few published research work were found as conference papers, books and reports.

**Table 3:** Language trends in publication of "Polymer composite for energy storage application". Source: http://www.scopus.com (accessed on 17 Oct. 2020)

| Sr.No. | Language | Publication |
|---|---|---|
| 1 | English | 1335 |
| 2 | Chinese | 30 |
| 3 | Japanese | 2 |
| 4 | Korean | 1 |
| | **Total** | **1368** |

**Table 4:** Publication sources of "Polymer composite for energy storage application".
Source: http://www.scopus.com (accessed on 17 Oct. 2020)

| Sr.No. | Source | No. of Publication | Publication (%) |
|---|---|---|---|
| 1 | Article | 1000 | 74.90637 |
| 2 | Conference Paper | 218 | 16.32959 |
| 3 | Book Chapter | 50 | 3.745318 |
| 4 | Review | 50 | 3.745318 |
| 5 | Conference Review | 11 | 0.82397 |
| 6 | Book | 2 | 0.149813 |
| 7 | Short Survey | 2 | 0.149813 |
| 8 | Erratum | 1 | 0.074906 |
| 9 | Note | 1 | 0.074906 |

### 4.3 Preliminary data highlights

Over the span of 11 years i.e from 2010 to 2020, the associated documents were journal articles, conference articles, journals, books, studies, etc. Figure 1 shows the yearly trends in publications ing in "Polymer composite for energy storage applications". The trend shows a continuous increase in the research exploration in the area of polymer composite for energy storage applications.

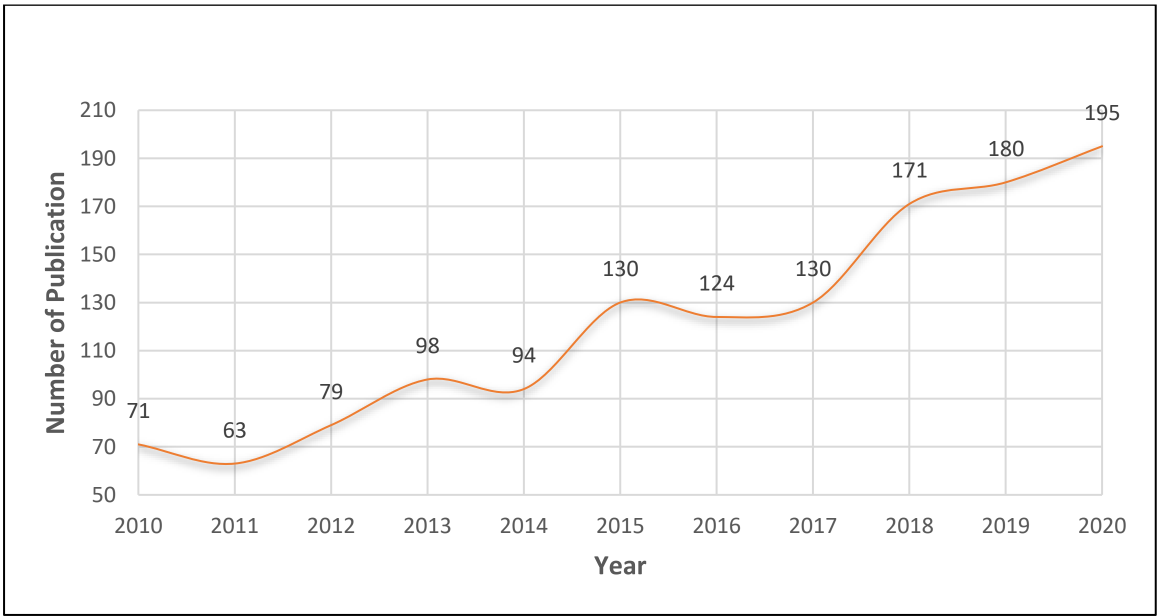


**Fig. 1**: Number of publications on topic "Polymer composite for energy storage application".
Source: http://www.scopus.com (accessed on 17 Oct. 2020)

### 4.4 Bibliometric methods

Bibliometric analysis of "Polymer composite for energy storage application" was carried out by following ways.

- Analysis of geographical region, network, and citations
- Statistics about the keyword, affiliation, author, and journals

#### 4.4.1 Analysis of geographical region

Microsoft Excel map tool is used to draw figure 2, which shows the regional geographic location of the published papers. It is clear that maximum research on the subject "Polymer composite for energy storage applications" has been conducted in China, India and the United States, as shown in Table 5. Other countries include South Korea, Japan, France.

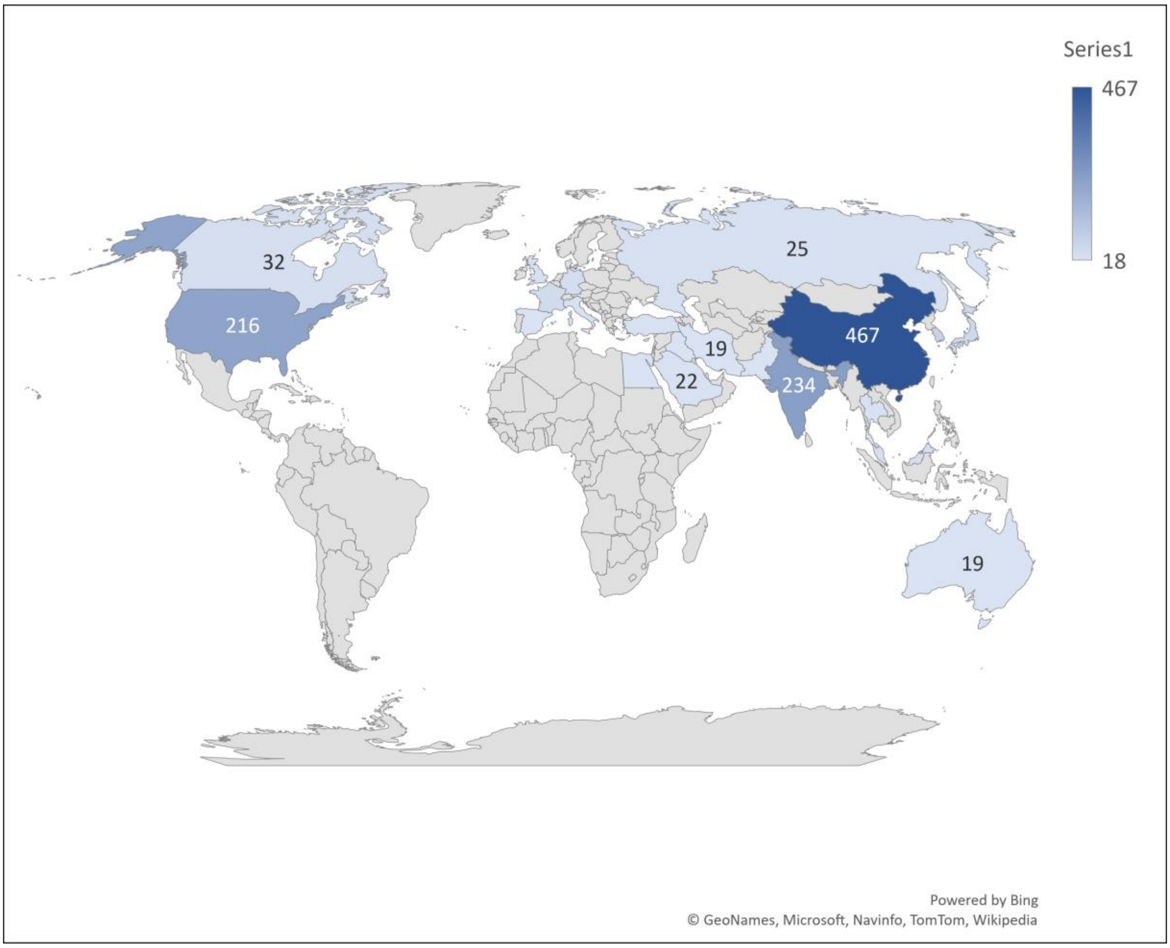


**Fig. 2:** Geographical locations of study for "Polymer composite for energy storage application".

**Table 5:** Top ten countries publishing papers for the study "Polymer composite for energy storage application". Source: http://www.scopus.com (accessed on 17 Oct. 2020)

| Country | No. of Publication | Country | No. of Publication |
|---|---|---|---|
| China | 467 | France | 39 |
| India | 234 | Hong Kong | 34 |
| United States | 216 | Germany | 33 |
| South Korea | 69 | Canada | 32 |
| Japan | 46 | Malaysia | 29 |

### 4.4.2 Keyword Statistics

Table 6 lists the first 20 keywords from publications on "Polymer composite for energy storage application". Keywords indicate what researchers are looking for. The right combination of keywords helps to search for the most relevant information.

**Table 6:** First twenty keywords related to "Polymer composite for energy storage application". Source: http://www.scopus.com (accessed on 17 Oct. 2020)

| Keyword | No. of Publication | Keyword | No. of Publication |
|---|---|---|---|
| Polymer Composite | 368 | Polymer Matrix Composites | 204 |
| Dielectric Losses | 351 | Filled Polymers | 173 |
| Composite Materials | 318 | Graphene | 151 |
| Dielectric Properties of Solids | 306 | Energy Storage | 141 |
| Dielectric Properties | 255 | High Dielectric Constants | 141 |
| Fillers | 255 | Scanning Electron Microscopy | 140 |
| Permittivity | 253 | Dielectric Devices | 139 |
| Polymers | 236 | Polymer Composites | 127 |
| Dielectric Materials | 226 | Composite Films | 124 |
| Nanocomposites | 221 | Dielectric Primitivity | 97 |

### 4.4.4 Network analysis

A network analysis can be used to present the relationship between various statistical parameters. Open source programme "Gephi" is used to perform network research. Gephi allows network data to be filtered, navigated, manipulated and clustered. Different authors have displayed using nodes and edges. Keywords, citations obtained, affiliations, title and year are shown. “Fruchterman Reingold” was used in this layout with different manual adjustments. Figures 3, 4, and 5 display networks with various parametric combinations for "Energy storage application polymer composite" derived from Scopus search results. In figure 3 there are 1398 nodes and 942 edges which describe network of author keywords and source titles. Figure 4, defines the publication title cluster and the year of publication. The node size indicates that most of the work was published between 2018 to 2020. There are 1341 nodes and 1330 edges in the network.

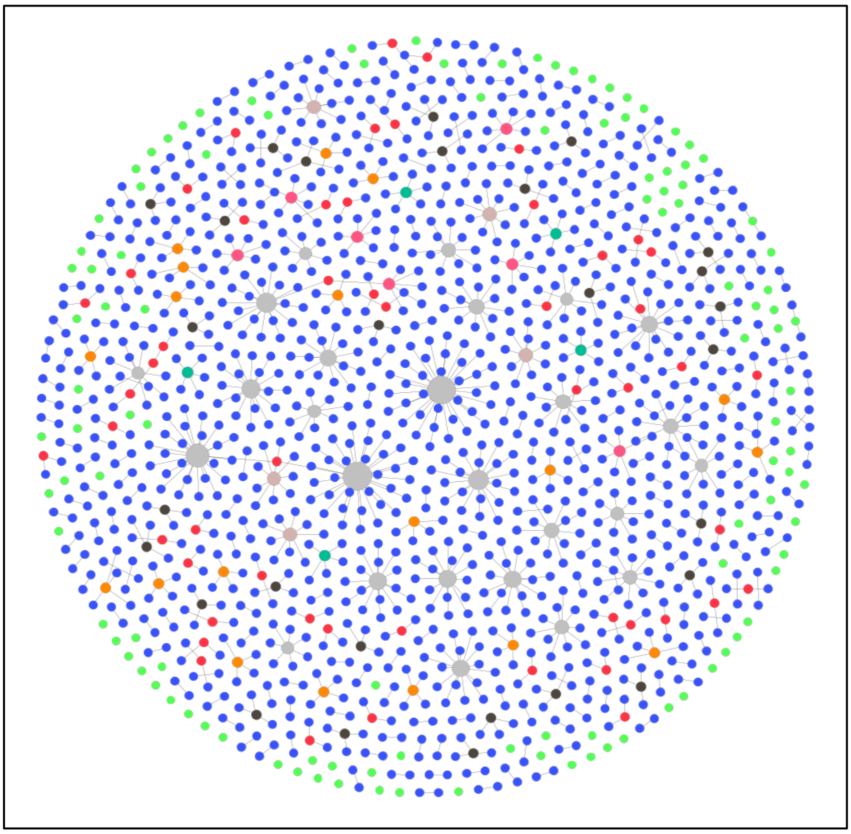

Figure 3: Cluster of keywords used by author and source title (journals)

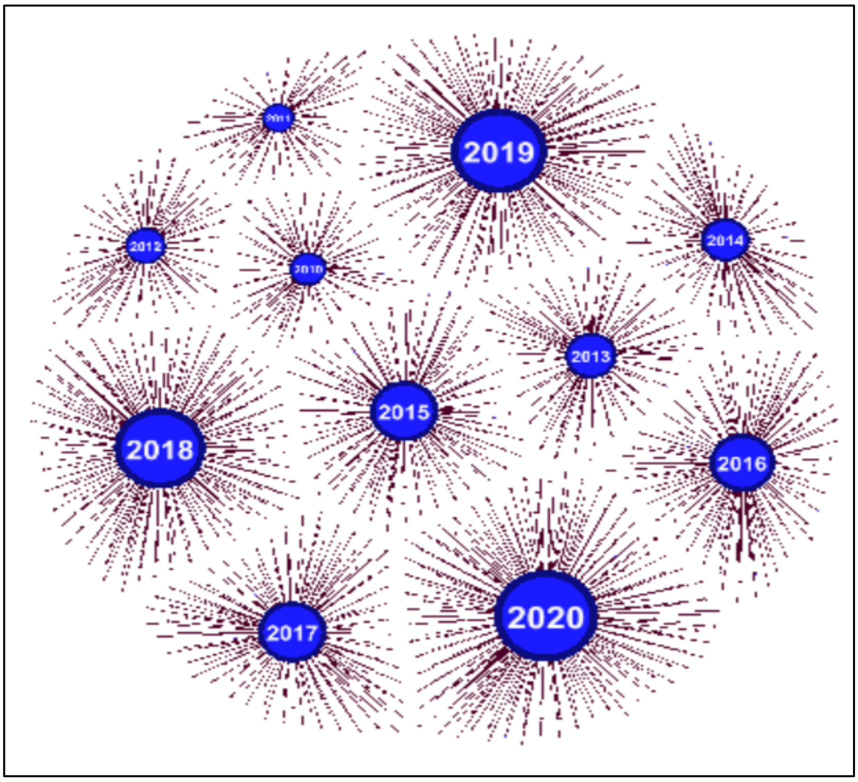


Figure 4: Cluster of publication title and publishing year

The Co-appearance of authors and their keywords among similar papers shown in Figure 5. It was observed that polymer composite, dielectric properties, energy density, dielectric constant and dielectric loss are relevant and significant keywords which are used c extensively in the search of "Polymer composite for energy storage application".

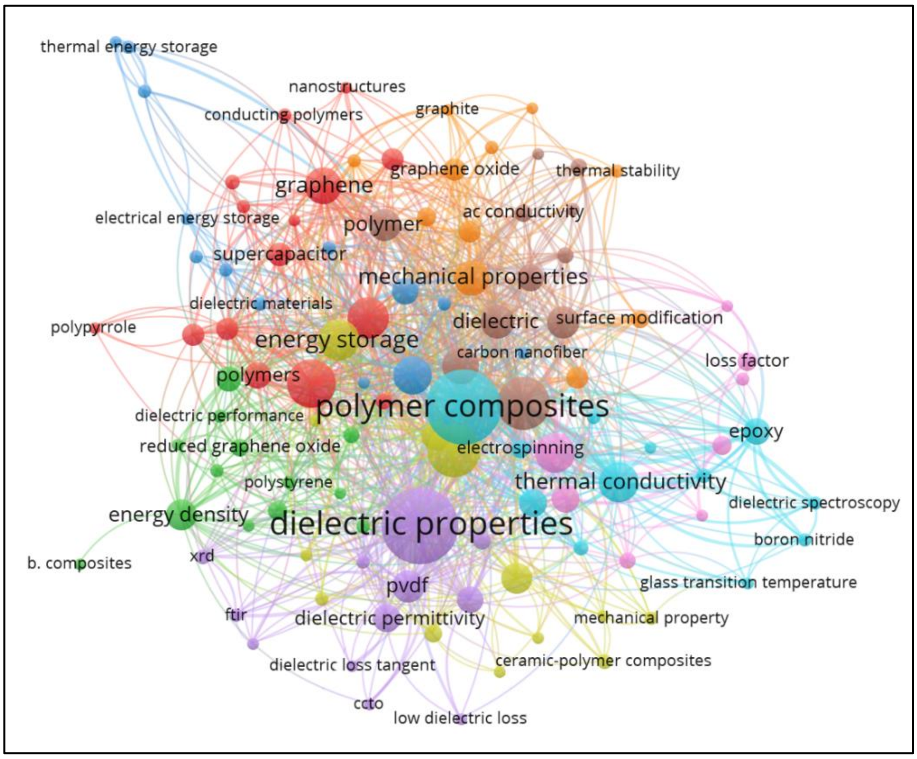


Figure 5: Co-appearance of author and their keywords among similar papers

### 4.4.5 Author statistics

The top fifteen authors contributing to this field are listed in Table 7 to understand the influence of a specific author in "Polymer composite for energy storage application".

**Table 7:** Authors contributing in "Polymer composite for energy storage application". Source: http://www.scopus.com (accessed on 17 Oct. 20)

| Author | No. of Publication | Author | No. of Publication | Author | No. of Publication |
|---|---|---|---|---|---|
| Huang, X. | 25 | Yuan, L. | 22 | Aziz, S.B. | 13 |
| Gu, A. | 24 | Dang, Z.M. | 21 | Zhang, L. | 12 |
| Jiang, P. | 24 | Yu, S. | 16 | Luo, S. | 11 |
| Sun, R. | 24 | Wang, Q. | 14 | Zha, J.W. | 11 |
| Liang, G. | 23 | Wong, C.P. | 14 | Fu, Q. | 10 |

### 4.4.6 Statistics of Affiliation

The top ten contributing universities or organisational affiliations are shown in figure 6. The "Polymer composite for energy storage application" is the research field of interest among the Ministry of Education China, Tsinghua University, Chinese Academy of Sciences.

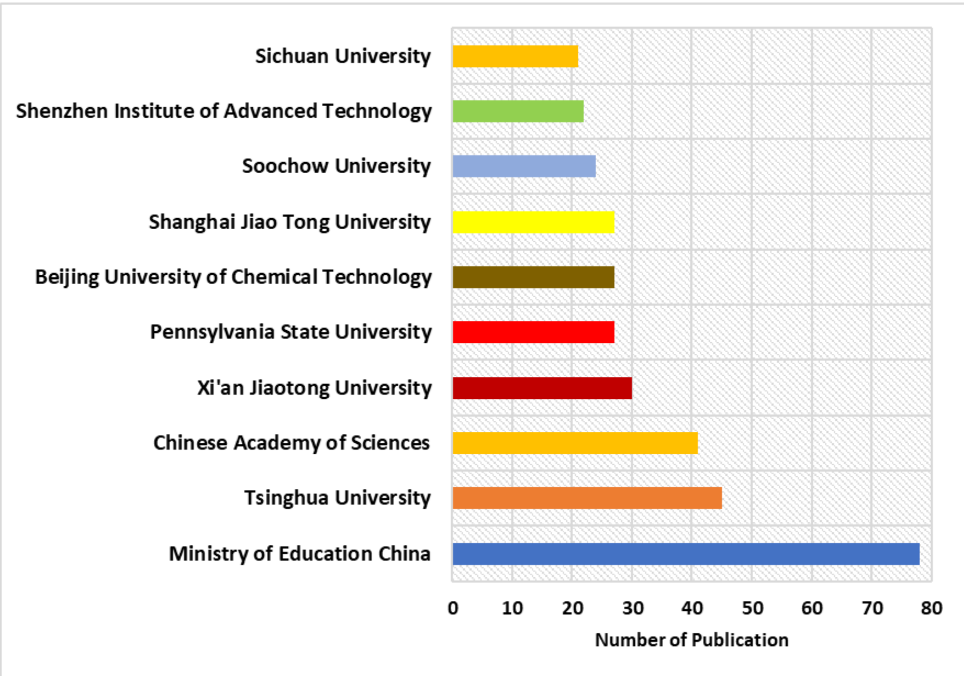


**Fig. 6** Statistics of Journal for publications in study of "Polymer composite for energy storage application" in the most popular top ten journals. Source: http://www.scopus.com (accessed on 17 Oct. 2020)

### 4.4.7 Analysis of Citations

Table 8 displays annual citations received in the field "Polymer composite for energy storage application". A total of 1786 publications have been cited and the citation count is 2752952. Table 9 displays the top ten documents obtained with the highest citations data available till the date of the survey.

**Table 8:** Citations analysis of publications in the study of "Polymer composite for energy storage application". Source: http://www.scopus.com (accessed on 17 Oct. 2020)

| Year | No. of Citation | Year | No. of Citations |
|---|---|---|---|
| <2010 | 406010 | 2016 | 287035 |
| 2011 | 65330 | 2017 | 367160 |
| 2012 | 77104 | 2018 | 447723 |
| 2013 | 89253 | 2019 | 512071 |
| 2014 | 115536 | 2020 | 42709 |
| 2015 | 152016 | **Total** | **2752952** |

### 4.4.7 Statistics of Journal

Figure 7 describes the statistical view of journals publication in the study of "Polymer composite for energy storage application". It is evident that the Journal of Materials in Electronics, ACS applied materials and interfaces and composed materials and technology have maximum number of publications.

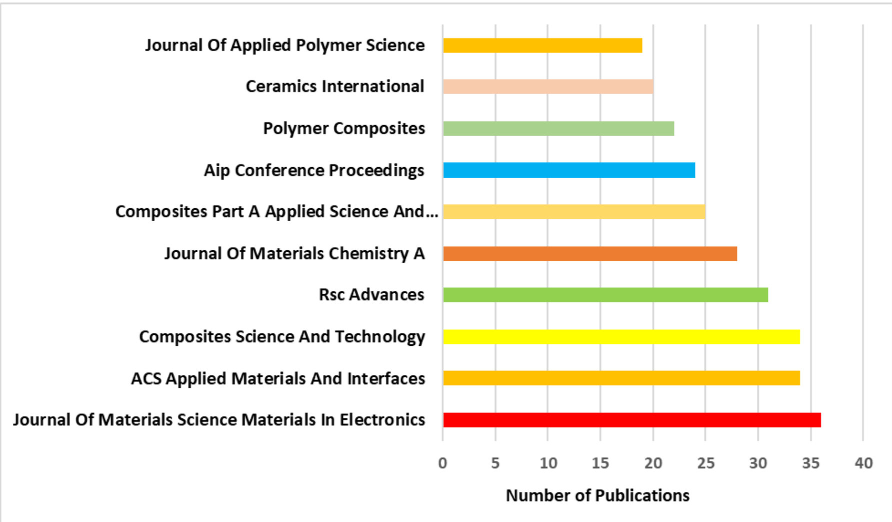


**Fig. 7** Journal statistics for publication in the most common top 10 journals for studying "Polymer composite for energy storage". Source: http://www.scopus.com (accessed on 17 Oct. 2020)

**Table 9:** Analysis of citations of top ten publications in the study of "Polymer composite for energy storage application".

Source: http://www.scopus.com (accessed on 17 Oct. 2020)

| Sr. No. | Document Title | <2010 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Challenges and prospects of lithium-sulfur batteries | 0 | 0 | 0 | 0 | 31 | 145 | 184 | 188 | 215 | 188 | 215 | 174 | 1340 |
| 2 | A review on the mechanical and electrical properties of graphite and modified graphite reinforced polymer composites | 0 | 0 | 8 | 50 | 72 | 82 | 112 | 98 | 96 | 111 | 97 | 74 | 800 |
| 3 | Lithium-sulfur batteries: Progress and prospects | 0 | 0 | 0 | 0 | 0 | 0 | 25 | 110 | 168 | 167 | 194 | 132 | 796 |
| 4 | Toward flexible polymer and paper-based energy storage devices | 0 | 0 | 8 | 48 | 86 | 109 | 124 | 100 | 104 | 80 | 64 | 50 | 773 |
| 5 | Flexible and conductive MXene films and nanocomposites with high capacitance | 0 | 0 | 0 | 0 | 0 | 0 | 25 | 68 | 99 | 124 | 177 | 205 | 698 |
| 6 | Polymer composite and nanocomposite dielectric materials for pulse power energy storage | 0 | 3 | 20 | 22 | 36 | 46 | 69 | 51 | 62 | 73 | 67 | 61 | 510 |
| 7 | Semiconductor quantum dots and related systems: Electronic, optical, luminescence and related properties of low dimensional systems | 452 | 59 | 64 | 63 | 62 | 53 | 50 | 33 | 33 | 29 | 35 | 20 | 501 |
| 8 | Novel Ferroelectric Polymer Composites with High Dielectric Constants | 115 | 40 | 34 | 41 | 53 | 47 | 36 | 49 | 57 | 68 | 38 | 24 | 487 |
| 9 | Harnessing the chemistry of graphene oxide | 0 | 0 | 0 | 0 | 0 | 8 | 60 | 75 | 73 | 81 | 98 | 76 | 471 |
| 10 | High-dielectric-constant ceramic-powder polymer composites | 170 | 40 | 38 | 46 | 50 | 50 | 52 | 26 | 43 | 39 | 50 | 31 | 465 |

#### 4.4.8 Subject areas

For the "Polymer composite for energy storage application," the issue of sectional compartmentation is shown in figure 8 comprising of research in material science, engineering and energy sector in the selected area.

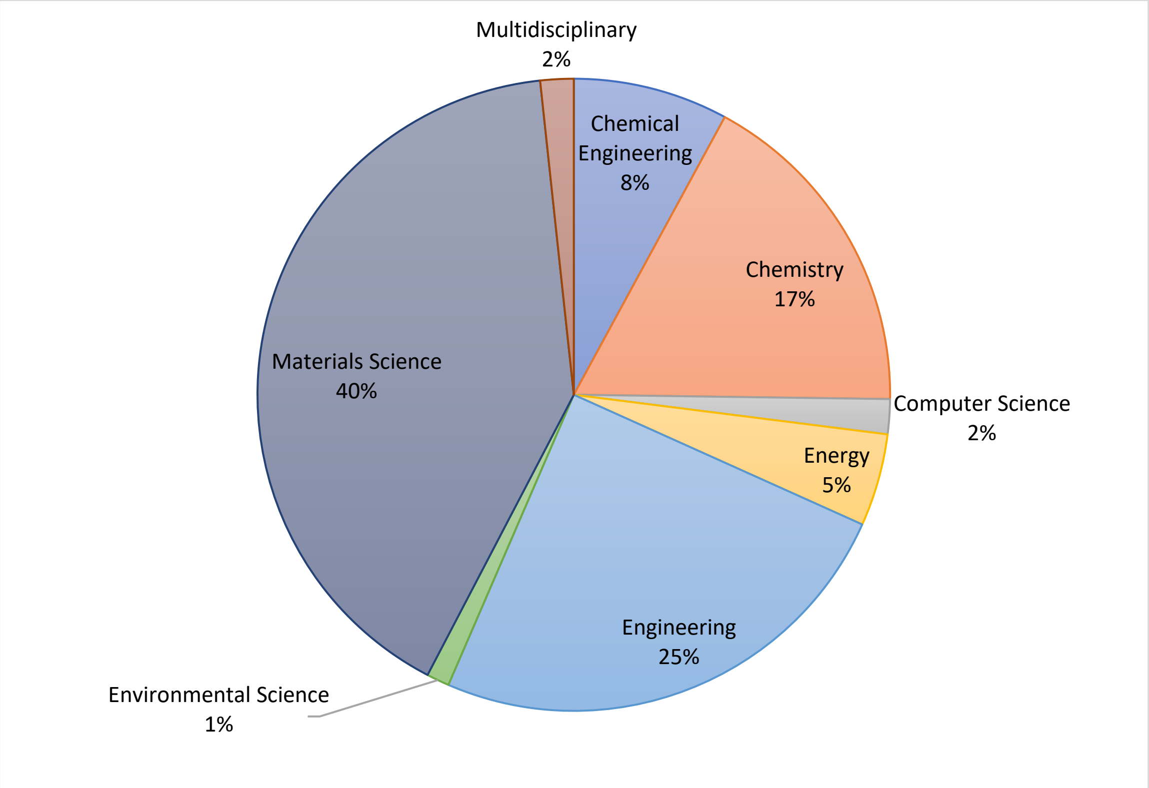


**Fig. 8:** Top subject areas publishing article related to "Polymer composite for energy storage application". Source: http://www.scopus.com (accessed on 17 Oct. 2020)

### 5 Future scope

The research on "Polymer composite for energy storage application" is continuously getting explored worldwide. Industrial sector perhaps demands the desirable and promising solution in energy storage applications. Hybrid electrical vehicle, oil industries and aerospace application are the largest demanding sectors for a new kind of energy storage capacitor operating at high temperature.

### 6 Confines of the present study

This article explores a combination of keywords in the Scopus database. During the data collection processing phase of this report, some major journals and periodic papers were not available in the Scopus database so they could not be included in this report. This analysis also limits research papers only in English.

## 7 Conclusion

The worldwide research in the field of “Polymer composite for energy storage application” is growing continuously.  The huge demand for energy and energy storage devices in various industries can only be fulfilled by designing and developing new, more functional materials with desired properties and focussed research.

## References


[1] B. Fan *et al.*, “Dielectric materials for high-temperature capacitors,” *IET Nanodielectrics*, vol. 1, no. 1, pp. 32–40, 2018.

[2] M. Cao, L. Li, W. Bin Hong, S. Y. Wu, and X. M. Chen, “Greatly enhanced permittivity in BaTiO3-epoxy dielectric composites with improved connectivity of ceramic phase,” *J. Mater.*, vol. 7, no. 1, pp. 1–7, Jan. 2021.

[3] R. Ratheesh and M. T. Sebastian, “Polymer-Ceramic Composites for Microwave Applications,” in *Microwave Materials and Applications 2V Set*, Chichester, UK: John Wiley & Sons, Ltd, 2017, pp. 481–535.

[4] P. Kim *et al.*, “High energy density nanocomposites based on surface-modified BaTiO 3 and a ferroelectric polymer,” *ACS Nano*, vol. 3, no. 9, pp. 2581–2592, 2009.

[5] F. Liu *et al.*, “High-Energy-Density Dielectric Polymer Nanocomposites with Trilayered Architecture,” *Adv. Funct. Mater.*, vol. 27, no. 20, pp. 1–7, 2017.

[6] Q. Li, K. Han, M. R. Gadinski, G. Zhang, and Q. Wang, “Energy Storage: High Energy and Power Density Capacitors from Solution-Processed Ternary Ferroelectric Polymer Nanocomposites (Adv. Mater. 36/2014),” *Adv. Mater.*, vol. 26, no. 36, pp. 6356–6356, Sep. 2014.

[7] W. Xia, Z. Xu, F. Wen, and Z. Zhang, “Electrical energy density and dielectric properties of poly(vinylidene fluoride-chlorotrifluoroethylene)/BaSrTiO 3 nanocomposites,” *Ceram. Int.*, vol. 38, no. 2, pp. 1071–1075, Mar. 2012.

[8] P. Hu *et al.*, “Topological-structure modulated polymer nanocomposites exhibiting highly enhanced dielectric strength and energy density,” *Adv. Funct. Mater.*, vol. 24, no. 21, pp. 3172–3178, Jun. 2014.

[9] B. Chu, “A Dielectric Polymer with High Electric Energy Density and Fast Discharge

Speed," *Science (80-. ).*, vol. 313, no. 5785, pp. 334–336, Jul. 2006.

[10] N. Guo, S. A. DiBenedetto, P. Tewari, M. T. Lanagan, M. A. Ratner, and T. J. Marks, "Nanoparticle, Size, Shape, and Interfacial Effects on Leakage Current Density, Permittivity, and Breakdown Strength of Metal Oxide-Polyolefin Nanocomposites: Experiment and Theory," *Chem. Mater.*, vol. 22, no. 4, pp. 1567–1578, 2010.

[11] S. Gupta *et al.*, "Evaluation of poly(4-methyl-1-pentene) as a dielectric capacitor film for high-temperature energy storage applications," *J. Polym. Sci. Part B Polym. Phys.*, vol. 55, no. 20, pp. 1497–1515, Oct. 2017.

[12] H. Liu *et al.*, "A new kind of electro-active polymer composite composed of silicone elastomer and polyethylene glycol," *J. Phys. D. Appl. Phys.*, vol. 45, no. 48, 2012.

[13] M. Ezzat, N. A. Sabiha, and M. Izzularab, "Accurate model for computing dielectric constant of dielectric nanocomposites," *Appl. Nanosci.*, vol. 4, no. 3, pp. 331–338, Mar. 2014.

[14] K. S. Deepa, S. Kumari Nisha, P. Parameswaran, M. T. Sebastian, and J. James, "Effect of conductivity of filler on the percolation threshold of composites," *Appl. Phys. Lett.*, vol. 94, no. 14, p. 142902, Apr. 2009.

[15] K. Yang, X. Huang, L. Xie, C. Wu, P. Jiang, and T. Tanaka, "Core-shell structured polystyrene/BaTiO3 hybrid nanodielectrics prepared by in situ RAFT polymerization: A route to high dielectric constant and low loss materials with weak frequency dependence," *Macromol. Rapid Commun.*, vol. 33, no. 22, pp. 1921–1926, 2012.

[16] Y. Deng, N. Li, Y. Wang, Z. Zhang, Y. Dang, and J. Liang, "Enhanced dielectric properties of low density polyethylene with bismuth sulfide used as inorganic filler," *Mater. Lett.*, vol. 64, no. 4, pp. 528–530, 2010.

[17] S. M. R. Billah, "Dielectric Polymers," 2019, pp. 241–288.

[18] D. Ramesh, "One-step fabrication of biomimetic PVDF-BaTiO 3 nanofibrous composite using DoE," *Mater. Res. Express*, vol. 5, no. 8, 2018.

[19] J. Y. Li, L. Zhang, and S. Ducharme, "Electric energy density of dielectric nanocomposites," *Appl. Phys. Lett.*, vol. 90, no. 13, pp. 13–16, 2007.

[20] T. S. Sasikala and M. T. Sebastian, "Mechanical, thermal and microwave dielectric properties of Mg2SiO4 filled Polyteterafluoroethylene composites," *Ceram. Int.*, vol. 42, no. 6, pp. 7551–7563, 2016.

[21] Y. Thakur *et al.*, "Enhancement of the dielectric response in polymer nanocomposites with low dielectric constant fillers," *Nanoscale*, vol. 9, no. 31, pp. 10992–10997, Aug. 2017.

[22] N. Guo *et al.*, “Supported metallocene catalysis for in situ synthesis of high energy density metal oxide nanocomposites,” *J. Am. Chem. Soc.*, vol. 129, no. 4, pp. 766–767, 2007.

[23] X. Zhang *et al.*, “Ultrahigh energy density of polymer nanocomposites containing BaTiO3@TiO2 nanofibers by atomic-scale interface engineering,” *Adv. Mater.*, vol. 27, no. 5, pp. 819–824, Feb. 2015.

[24] Y. Shen, Y. Lin, and Q. M. Zhang, “Polymer nanocomposites with high energy storage densities,” *MRS Bull.*, vol. 40, no. 9, pp. 753–759, Sep. 2015.

[25] X. Huang and P. Jiang, “Core-shell structured high- k polymer nanocomposites for energy storage and dielectric applications,” *Adv. Mater.*, vol. 27, no. 3, pp. 546–554, 2015.

[26] D. He, Y. Wang, X. Chen, and Y. Deng, “Core–shell structured BaTiO3@Al2O3 nanoparticles in polymer composites for dielectric loss suppression and breakdown strength enhancement,” *Compos. Part A Appl. Sci. Manuf.*, vol. 93, pp. 137–143, Feb. 2017.

[27] A. Chaudhari and P. Mulay, “A bibliometric survey on incremental clustering algorithm for electricity smart meter data analysis,” *Iran J. Comput. Sci.*, vol. 2, no. 4, pp. 197–206, Dec. 2019.