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Scientometric Analysis of Nano Anodic Materials for Secondary Batteries†

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This study analyzes the trend of nano anodic materials for secondary batteries. In an effort to analyze nano anodic materials for secondary batteries, this study includes citation per paper and link to nano anodic materials using VOS viewer. Analyzing the data, it is found that China, USA, Singapore and Australia have been actively investigating nano anodic materials and applied various nano materials.

Keywords: Anode, Nano materials, Secondary batteries, VOS viewer, Scientometric analysis.

INTRODUCTION

This study aims to scientometric analysis of nano anodic materials for secondary batteries by the countries and institutes perspective. Secondary batteries play a role with their volumetric energy, high power density. Furthermore, they have proved to be the most efficient energy storage strategy for a wide range of portable device like cellular phones, laptop and digital electronics. However, the employment of the secondary batteries in hybrid electric vehicles, plug in hybrid electric vehicles and pure electric vehicles need from two to five times more energy density than the present secondary batteries can offer (150 wh/kg). Goriparti *et al.*[1] investigated research trend of developing nano anodic materials and they classified anode into three types according to reaction mechanism (Table-1).

TABLE-1
MOST COMMON ANODIC MATERIALS
USED FOR LITHIUM ION BATTERIES

Active anodic material	Details
Insertion/de-insertion materials	- Carbonaceous (hard carbon, CNTS, graphene) - Titanium oxide ($LiTi_4O_5$, TiO_2)
Alloys/de-alloys materials	- Silicon, germanium, Tin, antimony, Tin oxide, SiO_2
Conversion materials	- Metal oxide - Metal phoshides/sulfides/nitrides

In particular, Chinese Academy of Sciences studied anode of graphene anchored with Co_3O_4 nanoparticles for enhancing capacity[2]. In case of USA, Singapore, Australia and Korea, they studied anodes of silicon, Fe_2O_3, SnO_2 and graphene for enhancing capacity[3-7].

METHODOLOGIES

For scientometric analysis of nano anodic materials, we used WoS (Web of Science) database at the Thomson Reuters. Table-2 shows search query for papers on nano anodic materials for the secondary batteries.

TABLE-2
SEARCH QUERY

No	Search query	Count
1	ts: nano* timespan = 2001-2014	115.744
2	ts: anode* timespan = 2001-2014	49.077
3	ts: (lithium or "li") and batter* timespan = 2001-2014	36.311
4	1 and 2 and 3	6.391

Citation per paper citation per paper index and equation was used as follows:

$$\text{Citation per paper} = \frac{\text{Sum of citation of country (or institute)}}{\text{Sum of citation of total field}} \quad (1)$$

VOS Viewer developed by Leiden University was also used to monitor research trend of major nano anodic materials for the secondary batteries. VOS viewer is a program that uses optimized algorithms based on network relationships to build maps and mapping is divided into random start, convergence and max iteration stages. Random start determines the time it takes to carry out the optimized algorithm. Convergence stage

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determines the standards used in the optimized algorithm. Finally, maximum iterations determines the maximum number of iterations to be carried out resulting from optimization[8-10].

RESULTS AND DISCUSSION

The number of papers related nano anodic materials has increased by year (Fig. 1). In case of analyzing level of countries, China has published papers the most, but citation per paper is known to be below average. Countries that the number of papers and the citation per paper were above average are USA, Australia, Singapore, Japan and Germany. In case of Korea, the number of papers published is above average, but the citation per paper is found to be below average (Fig. 2)

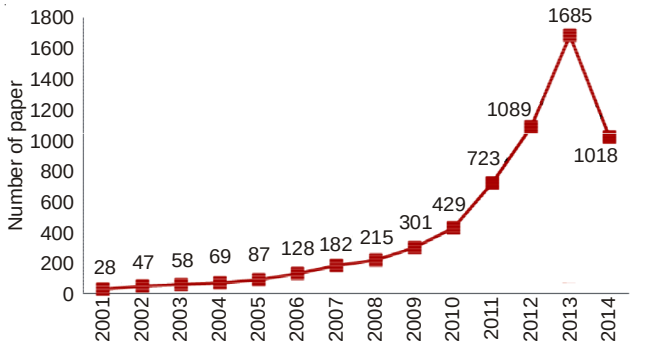

Fig. 1. Trend of paper publication for nano anodic material by year (2001-2014)

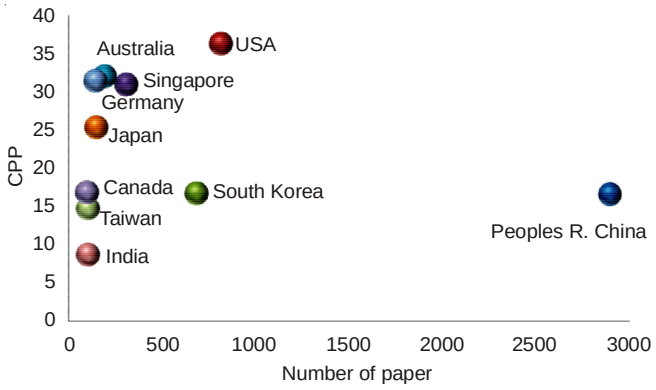

Fig. 2. Strategy map between number of papers and citation per paper in top 10 countries

In case of analyzing level of institutes, China, Singapore, Australia and Korea published more papers than any other institutes and the citation per paper is also higher. On the other hand, USA where the citation per paper is above average had no institutes in top 10 institutes. This means that USA had been developing through various institutes rather than focusing on specific institutes. In case of China, citation per paper of the countries is below average, but of the some institutes are above average (Fig. 3).

We analyzed the research trends of nano anodic materials by period (2001-2007 and 2008-2014) using VOS viewer. In the period of 2001-2007, research using tin, tin oxide and silicon materials were under active. After 2008, research using graphene and carbon nanotube were under active besides tin oxide. Also research using metal oxide (iron oxide, nickel oxide and cobalt oxide) had newly activated (Figs. 4 and 5).

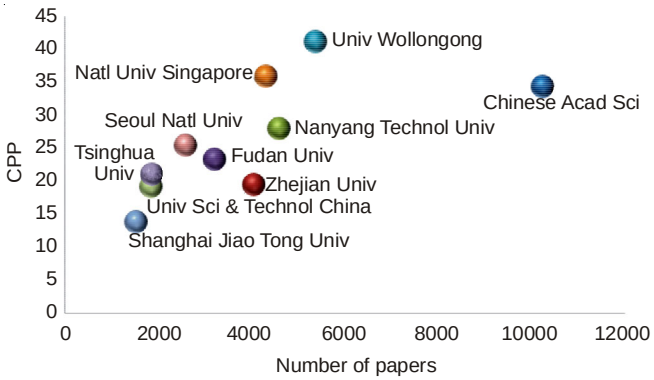

Fig. 3. Strategy map between number of papers and citation per paper by institutes

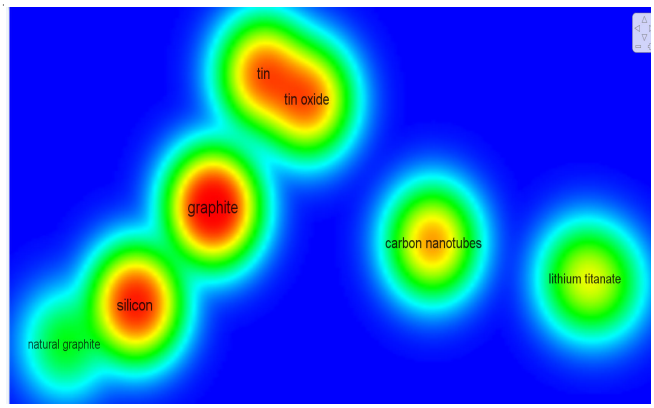

Fig. 4. Mapping between nano materials for the anode (2001-2007)

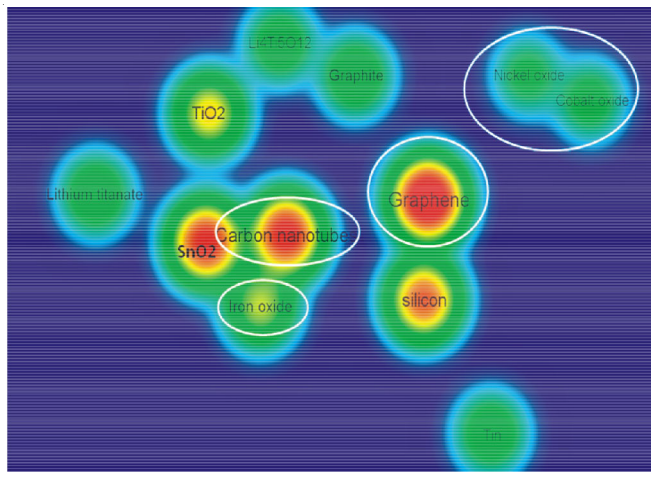

Fig. 5. Mapping between nano materials for the anode (2008-2014)

Conclusions

This study has attempted to scientometric analysis of the nano anodic materials for the secondary batteries by the countries and institutes perspective.

As the result of analyzing data in the nano anodic materials for the secondary batteries, China published papers the most, but the citation per paper is found to be below average. but some institutes of China published excellent papers. The countries whose number of published papers is above average and the citation per paper of papers is high are USA, Australia, Singapore and Japan. But for USA and Japan, there is no institute in top 10 rank by the number of published papers. This

means that in USA and Japan not only particular institutes but many other various institutes are investigating the topic. In case of Australia and Singapore, some specific institutes are conducting the development for the nano materials. In the period of 2001-2007, tin and tin oxide have actively been developed. Otherwise, after 2008, graphene, carbon nanotube have actively been developed besides tin oxide. Also, recently, metal oxide is being investigated.

In hybrid electric vehicles, plug in hybrid electric vehicles and pure electric vehicles, the secondary batteries having high energy density are essential factor. Therefore, it is important to develop nano anodic materials, but each nano anodic materials have advantage and disadvantage, *i.e*., insertion/de-insertion materials have low cost and good safety, but they have low energy density. Alloys/de-alloys materials have high energy density and good safety, but they have poor cycling and large irreversibility. Conversion materials have high energy density, but they have short cycle life and high cost of production. Therefore, the proper selection and strategies are needed according to each nano materials and co-research with countries that have high quality research.

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REFERENCES

1. S. Goriparti, E. Miele, F. De Angelis, E. Di Fabrizio, R. Proietti Zaccaria and C. Capiglia, *J. Power Sources*, **257**, 421 (2014).
2. S.W. Zhong, W.C. Ren, L. Wen, L. Gao, J.P. Zhao, Z.P. Chen, G.M. Zhou, F. Li and H.-M. Cheng, *ACS Nano*, **4**, 3187 (2010).
3. M.V. Reddy, T. Yu, C.H. Sow, Z.X. Shen, C.T. Lim, G.V. Subba Rao and B.V.R. Chowdari, *Adv. Funct. Mater.*, **17**, 2792 (2007).
4. X.P. Wang, X. Shen, J. Yao and J. Park, *Carbon*, **47**, 2049 (2009).
5. Y. Wang, H.C. Zeng and J.Y. Lee, *Adv. Mater.*, **18**, 645 (2006).
6. H.L. Chan, H. Peng, G. Liu, K. McIlwrath, X.F. Zhang, R.A. Huggins and Y. Cui, *Nat. Nanotechnol.*, **3**, 31 (2008).
7. S. Han, B. Jang, T. Kim, S.M. Oh and T. Hyeon, *Adv. Funct. Mater.*, **15**, 1845 (2005).
8. N.J. Van Eck and L. Waltman, *Scientometrics*, **84**, 523 (2010).
9. L. Waltman, N.J. Van Eck and E.C.M. Noyons, *J. Informetrics*, **4**, 629 (2010).
10. N.J. Van Eck and L. Waltman, *Newsletter*, **7**, 50 (2011).