Analysis of Convergence Trends in Secondary Batteries

Young-Duk Koo[1] and Dae-Hyun Jeong[2]

[1] *ydkoo@kisti.re.kr*
Korea Institute of Science & Technology Information, Gyeonggi-Inchon Branch, 145 Gwanggyo-ro, Yeongtong-gu, Suwon0si, Gyeonggi-do (Korea)

[2] *gregori79@kisti.re.krt*
Korea Institute of Science & Technology Information, Dept. of Creativity Implementation, 66, Hoegi-ro, Dongdaemun-gu, Seoul (Korea)

Introduction

Convergence refers to the creation of new technologies (or industries, markets) through the combination of two or more technologies (or industries, markets), which is promoted by technical changes, innovations, and technology diffusion, and plays a key role in changing gradual innovations to destructive innovations. Furthermore, convergence is a key factor in accelerating changes in the growth curve of technologies and the life cycle of products (Pennings & Puranam, 2001). This study was conducted to analyze convergence trends in secondary batteries and find their implications. For this purpose, useful papers and patent data for analysis were selected, collected, and processed to calculate the convergence index. This attempt is expected to provide the foundation for predicting convergence by identifying major causes that accelerate convergence. To effectively measure convergence status in this study, the diversity index suggested by Yegros Yegros et al. (2003) was used. The diversity index, which is used to measure interdisciplinary studies, considers three aspects: variety, balance, and disparity. An interdisciplinary study means the integration of different disciplines, thereby creating new academic disciplines. In this study, the convergence index was derived by the integration of different technologies into one technology.

Method of Analysis

For this purpose, the diversity index suggested by Yegros Yegros et al. (2013) was used for analysis, and IPC International Patent Classification) was used for the analysis of patents. IPC codes are assigned to individual patents and multiple codes can be specified depending on the case. In this study, IPC codes were used to analyze the convergence phenomena in secondary batteries (Stirling, 1998, Purvis et al., 2000, Stirling, 2007). The equation for each variable is given below.

$$\text{Variety} = n$$

$$\text{Balance} = -\frac{1}{\ln(n)}\sum_i p_i \ln p_i \quad (1)$$

$$\text{Disparity} = \frac{1}{n(n-1)}\sum_{ij} d_{ij} \quad (2)$$

(d_{ij} = 1-cosine coefficient)

In this equations, n means that number of IPC codes and p_i means that ratio of i IPC code.
In this study, U.S. patents about secondary batteries that had been opened or registered between January 1, 1998 and December 31, 2011 were analyzed with the IPC code for secondary batteries H010-010 using the USPTO database. In this study, we use patent data until 2011 because patent data is valid until 2011.

Table 1. Search formula for secondary batteries

Data	Search formula	Number of patents
USPTO	IPC=H01M-010*, PY=19880101~20111231	8,181

Result and Discussion

The measurement of variety through the number of IPC subclasses about patents in secondary batteries by year showed that the variety value was increasing sharply over time. In particular, the variety value greatly increased after 2009 when the number of applicants in medium- and large-sized secondary batteries increased rapidly, indicating that the variety value of secondary batteries increased with the active research related to medium- and large-sized secondary batteries. The measurement of balance by year showed that the balance value decreased between 1988 and 2000, and steadily increased again after 2003. This suggests that with the beginning of the development of the medium- to large-sized secondary batteries, research and development of various technologies have been carried out to develop the required technologies. The measurement of disparity values by year showed that the disparity value has been decreasing over time. This suggests the decreasing distance between technologies and the progress of convergence.

Figure 1. (left) Trend of variety by year; (middle) Trend of balance by year; (right) Trend of disparity by year.

In particular, the distance between technologies has become very low after 2001. As analyzed above, with the emergence of medium- to large-sized secondary batteries, convergence with other technology fields such as eco-friendly cars and solar cells has been going on.

Figures 2 and 3 show the network structure of IP codes for secondary batteries by period (1988-2000, 2001-2011). The node size indicates the number of IPCs and the length of link indicates the distance between different IPCs. The network structure of IPC codes shows that IPCs have gathered together since 2001, indicating that the relationships among different technologies have been strengthened and the distances shortened since 2001. Furthermore, IPCs related to new application fields for medium- and large-sized secondary batteries such as solar cells and wind power energy have appeared, and the distance between them and the representative IPC for secondary batteries has become closer since 2001. In other words, with the research and development of medium- and large-sized secondary batteries since 2001, the convergence in secondary batteries has become conspicuous.

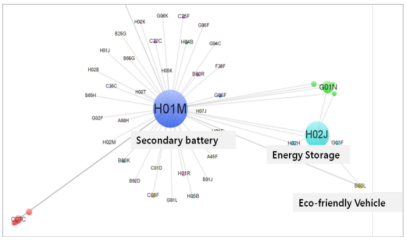

Figure 2. IPC network structure (1988-2000)

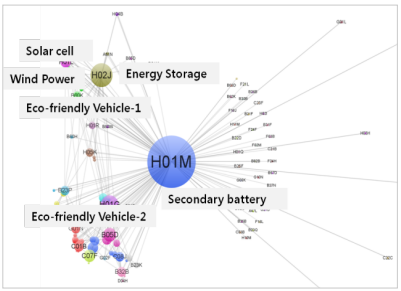

Figure 3. IPC network structure (2001-2011)

Conclusion

In this study, we analysis of convergence trend using patent data of secondary battery. As a result, it can be summarized as follows: First, as passing by year, convergence of secondary battery has increased, especially, in terms of variety and balance. This means that as increasing convergence, various field has merged and increased similarity between fields. Second, as the comparing result of IPC mapping between 1998-2000 and 2001-2011, convergence in secondary batteries is greatly increasing around the medium- and large-sized secondary batteries with the progress of convergence with eco-friendly vehicles, wind power energy, and solar energy and the decreasing distance between technologies. Predicting the convergence trends in secondary batteries has great implications to countries and companies in that they allow us to predict future industries and search for new markets and strategic partners. Furthermore, considering that existing studies used patents in a limited way due to limitations of patent analysis and limited use of time-series patent data so far, the analysis in this study was useful.

Acknowledgments

This work was supported by Construction of SMB Support System based on Industry-University-Institute Knowledge Ecosystem (K-15-L04-C01-S01).

References

Pennings, J.M. & Puranam, P. (2001). Market convergence & firm strategy: new directions for theory and research, *ECIS Conference*. *The Future of Innovation Studies*.

Purvis, A. & Hector, A. (2000). Getting the measure of biodiversity. *Nature*, *405*, 212-219.

Stirling, A. (1998). On the economics and analysis of diversity. *SPRU Electronic Working Paper.*

Stirling, A. (2007). A general framework for analysing diversity in science, technology and society. *Journal of the Royal Society Interface*, *4*(15), 707-719.

Yegros Yegros, A., D'Este Cukierman, P., & Rafols, I. (2013). Does interdisciplinary research lead to higher citation impact? *35th DRUID Celebration Conference.*