Trend Research on Flip-chip CSP LED for Establishing Management of Technology Strategy

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***Abstract*:** *Light emitting diode (LED) technology has been growing these days as a replacement of existing lighting technologies in order to deal with environmental pollution. However, there is a problem of LED because of its high manufacturing cost. Therefore lighting industry is currently developing a new LED technology with flip-chip solution in chip-scale packaging format (FC-CSP LED). It is expected that this would help improving lighting performance as well as reducing manufacturing costs. In this paper, patent analysis has been done in order to understand the technology trend of FC-CSP LED, as well as to establish management of technology strategy in LED market.*

Keywords: *FC-CSP LED, Technology Trend, Patent Analysis, Management of Technology Strategy*

1. Introduction

There have been a lot of attentions toward eco-friendly technology because of severe environmental pollution these days. Among many LED related technologies, flip-chip chip-scale packaging (FC-CSP LED) is considered to be one of the technologies with greater efficiency as well as cost reduction for manufacturing [1].

When manufacturing LED in a traditional way, wire bonding method has been used to connect die and carrier. Therefore, traditional LED was bigger in size and more expensive to manufacture because of the wire in-between. In contrast, FC-CSP technology enables to remove the wire, and to connect die and carrier directly by conductive bump, placed under the die. [1]. As FC-CSP method is used instead of wire bonding, FC-CSP LED has many advantages in terms of smaller and lighter size as well as better performance and reduced manufacturing cost.

This research presents the trend research on FC-CSP LED technology by analysing patent data. Section 2 shows the process of patent analysis in detail, such as data collection, quantitative analysis, and IPC code analysis in order to look for the most active developing area of FC-CSP LED. After all, patent map of the active developing area is drawn to understand the trend of FC-CSP LED.

2. FC-CSP LED Patent Analysis

2.1. Patent Collection Process

For the first step of the methodology, search query should be made with core keywords of FC-CSP LED. For the core keywords, flip-chip, chip-scale packaging, and light emitting device were selected to be included in search query. In addition, synonyms and abbreviations of those keywords were also included such as chip-size packaging, CSP, light emitting diode, and LED. From the patent database called WIPSON, it was possible to build search query as below:

(((chip adj (scale or size) adj packag*) or CSP or (flip adj chip) or (FC adj CSP) or (FCCSP)) AND (LED or (light adj emit* adj (device or diode)))).AB.

The search query was used to collect registered patents in the U.S., with those keywords in abstract sections of each document. As a result, there were 180 patent documents collected to analyse.

2.2. Quantitative Analysis

When performing technology analysis or R&D process, it is efficient to assess new technologies as well as

existing ones by analysing patent data quantitatively [2]. This paper presents patent analysis such as patent holders and application dates in order to understand the R&D trend of FC-CSP LED, technology flow, and competitive companies.

Fig. 1 shows the number of patents which are owned by ten companies. Philips Lumileds Lighting Company owns 14 patents, which makes the company the most dominant position in FC-CSP LED technology. Cree and Toyoda Gosei owns 13 patents respectively, and Samsung Electro-Mechanics have 11 patents. When considering affiliated companies, such as Koninklijke and Samsung Electronics, Philips and Samsung group seems to be the active companies for R&D of FC-CSP LED

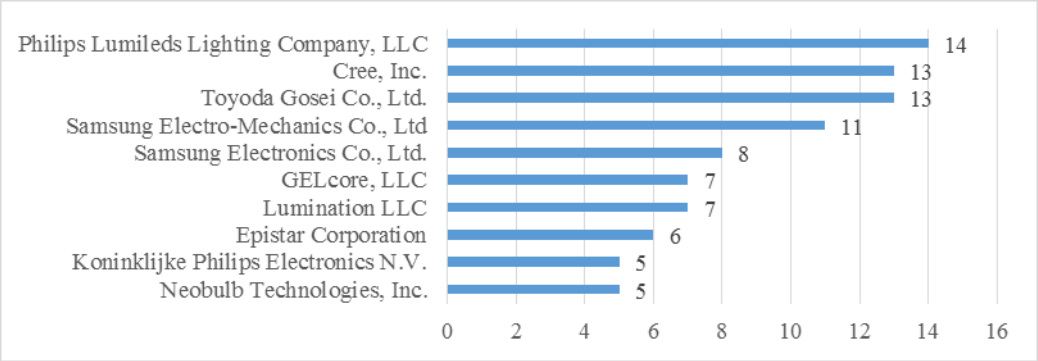

Fig. 1: Number of Patents per Company

In order to understand how the technology has been developed, it is important to know when patent application had been made. Fig. 2 presents the patent application per year. The number of patent application was started to be increased rapidly from the early 2000s. It seems that people's interest in eco-friendly products was increased from the mid-2000s. As of 2006, the number was slightly decreased, but the patents have been applied constantly so far.

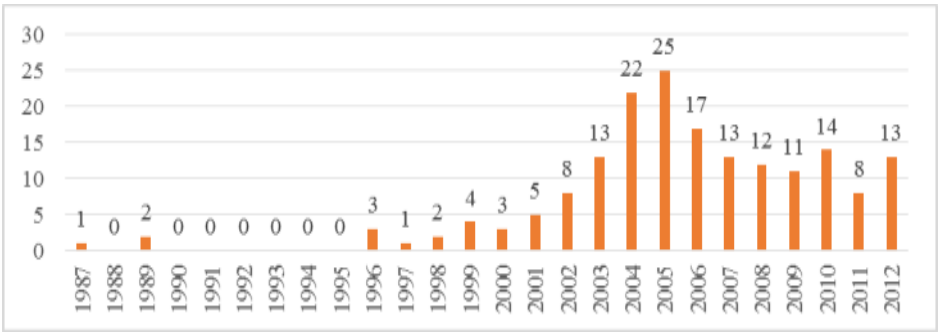

Fig. 2: Patent Applications per year

In the Fig. 2 above, the number of patents applied in 2013 and 2014 are excluded because patents applied to USPTO are usually published after 18 months [3]. It is also possible to realize how FC-CSP LED technology have been developed from the above figures. However, it is necessary to understand the dominant companies' patent activity as well as the patents they applied.

TABLE I: Patents and Applicants according to Application years

	2004	2005	2006	2007	2008	2009	2010	2011	2012
Philips			7626210	7687810 8080828	8062916	8168998		8273587 8450754	8679869
Cree	7087936 7341175 7332365 7259033	7932111	8748920	7608860	8878219		8329482	8759868	
Toyoda	7279723	7211832 7875897 7291865		7768029 7939843	8129743		8545083		8860057
Samsung Electro-Mechanics	7015512 7235818 7294864 7470938	7259447 7297988	7335916 7456438	7648849					
Samsung Electronics	7358541 7190002	7872271	7276740	7491564 7816156		8310023	8202751		
Lumination	7842547 7456035		7385229 7635869 7718449		7749813				

Table 1 represents the top 6 companies' patent application activities. Although Philips Lumileds Lighting and Toyoda Gosei apply patents consistently since 1999, Samsung Electro-Mechanics and Lumination do not hold any related patents since 2008. By constructing this table, it is possible to know the companies' patent activities.

2.3. IPC code Analysis

Using each patent's IPC code in analysis enables researchers to understand technology contents in detail. From the report released by World Intellectual Property Organizations (WIPO), IPC is mentioned as an efficient tool for patent search as well as evaluate the technical power and novelty of patents [4]. In FC-CSP LED patent data set, most of patents are classified in H01L when considering subclass of IPC code, as shown in Fig. 3. So it was necessary to subdivide those codes into main group, and there are H01L-033, H01L-021, and H02L-029 as the figure shows.

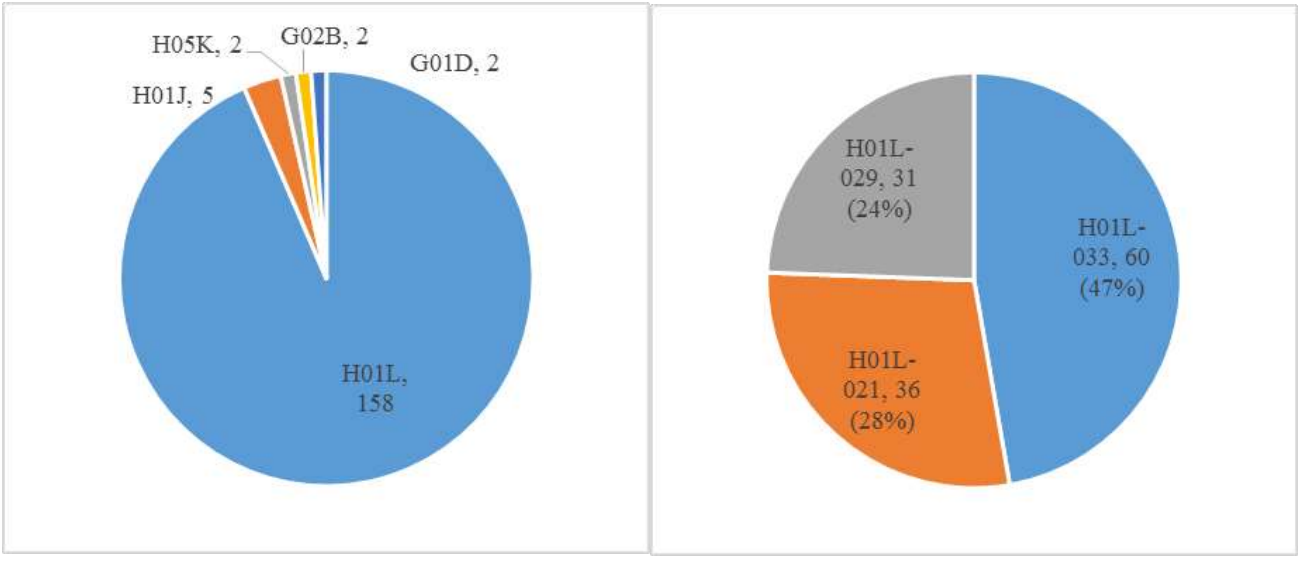

Fig. 3: Technology Classification by IPC codes

In table 2, there are three IPC codes which appear frequently in the dataset. Table 2 shows that IPC code H01L-033 is considered to be the most developed technology. Performing IPC code analysis is effective when attempting to understand details of technology.

TABLE II: Technology Descriptions of FC-CSP LED

IPC codes	Descriptions	Number of Patents
H01L-033	Semiconductor device with potential jump or surface barrier for light emitting device	60 (47%)
H01L-021	Special processes or apparatus for semiconductor device	36 (28%)
H01L-029	Semiconductor device for enlarging, changing, rectifying, or oscillating	31 (24%)

It is of importance for companies to understand how their competitive companies are conducting R&D activity. IPC code-Patent applicant matrix allows to understand who has the strongest competitiveness and patent portfolio in the technology areas. As table 3 shows, Toyoda Gosei has not been developing technology related to H01L-021 but H01L-033. However, Cree has generally developed almost all aspects of FC-CSP LED.

TABLE III: IPC-Applicant Matrix

	Philips	Cree	Toyoda Gosei	Samsung Electro-Mechanics	Samsung Electronics	Lumination
H01L-033	6455878 8080828	7009199 7087936 8748920 8878219	6310364 6445011 6713877 7211832 7875897 7939843 8129743 8860057	6949773 7015512 7235818 7294864	7190002 7872271 7276740	7385229 7635869
H01L-021	8062919 8273587 8679869	7332365 7259033 7932111 8329482		7648849	7491564 8202751	7842547 7456035 7718449 7749813
H01L-029	6876008 7626210 8450754	6888167 7608860 8759868	6878971 7279723 7291865	7470938 7297988 7262440 7335916	7358541 7816156	7358539

It is also possible to understand the technology development cycle by analysing the number of IPC codes application per year.

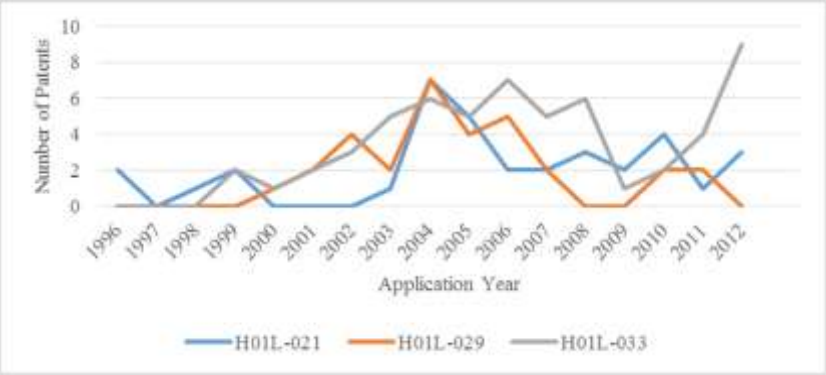

Fig. 4: IPC codes Application per year

Fig. 4 clearly shows that H01L-033 is the one with the most active R&D. As shown in table 3 and Fig. 5, it is determined that H01L-033 has been developing by a lot of major companies and research institutes. As a result, it is decided that potential jump barrier or surface barrier for LED is the core technology in this paper. In the following section, patent mapping for the core technology development is constructed based on the H01L-033 patents owned by the six major companies.

2.4. Patent Mapping

Patent mapping is a method for visualizing patents by graphically modeling patent activities. By mapping patents, it is possible to understand technology flow, development, as well as characteristics of the patents. It also allows to see the relationship among those patents [5].

Patent map of H01L-033 is drawn in Fig. 6. Since a well-drawn patent map gives clear visualization of technology development, it is expected to be helpful when analysing the core technology which is about the semiconductor device with potential jump barrier or surface barrier.

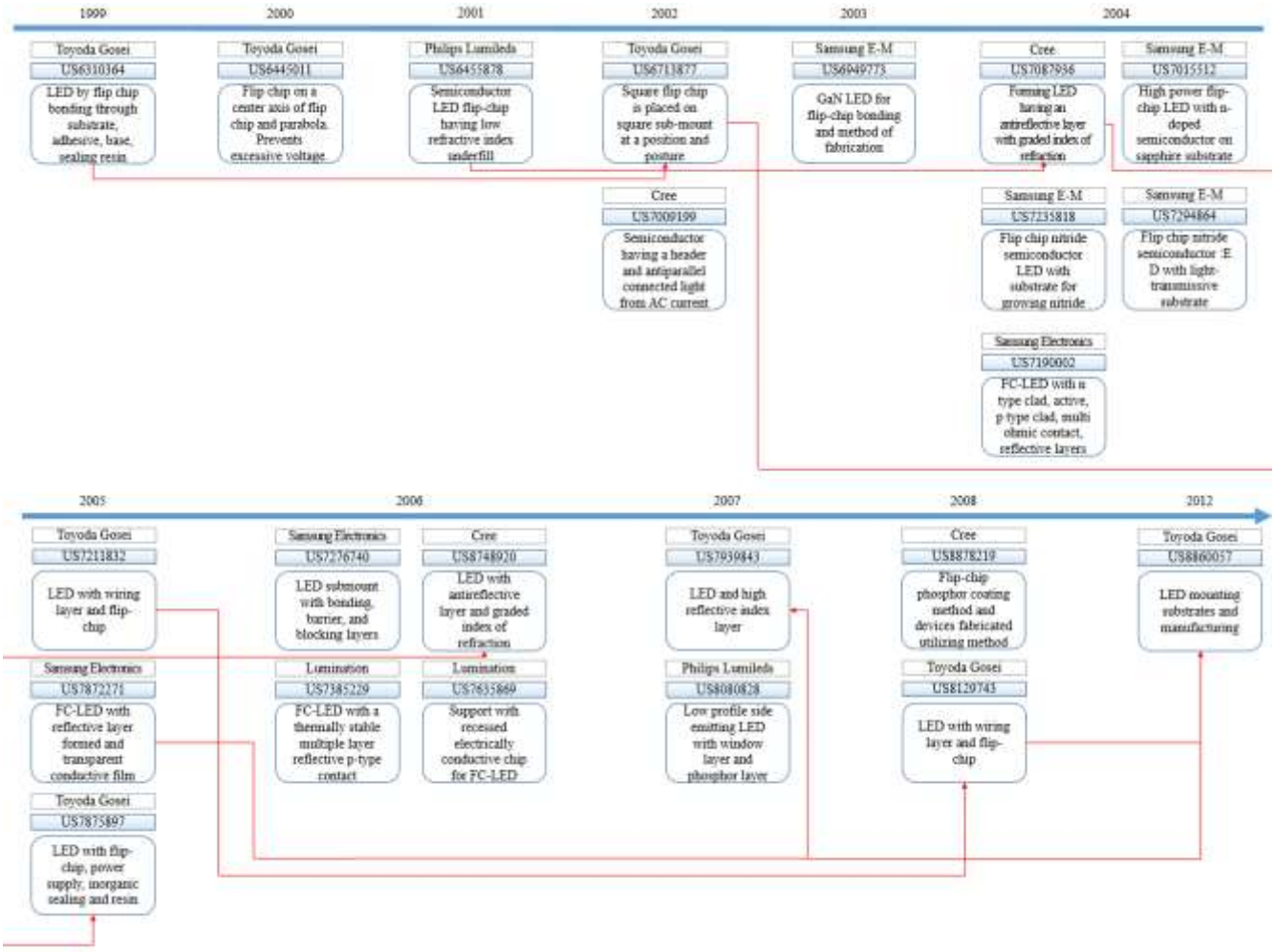

Fig. 5: Patent Map for Visualizing Technology Development

The big blue arrow indicates the time series of application year, while red arrow shows the influence from older patent through the following patent. Starting from 1999 with Toyoda Gosei's first patent, it is possible to grasp how FC-CSP LED technology has been developing so far. Utilizing this patent mapping is helpful to understand applicants' patent activities as well as future trends of technology

3. Conclusion

This paper analyzes the research trends in FC-CSP LED technology, which can make up existing LED's weakness, by patent analysis. This research shows that there are Philips Lumileds, Cree, Toyoda Gosei, and Samsung that possess the strongest technological power and patent portfolio in the field of FC-CSP LED. Among several related technology areas, research in potential jump barrier or surface barrier of LED appears to be active. Therefore, patent map for technology development is drawn in order to understand the R&D direction.

Therefore, this research is expected to be useful when seeking for core patents and vacant technology forecasting for FC-CSP LED. In the future study, data mining techniques can be applied based on IPC code mining, patent indicators, and this research methodology for the better accuracy for FC-CSP LED technology forecasting. Finally, the future study will be able to contribute to technology competitiveness as well as to establish management strategy for successful business.

4. Acknowledgements

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