



A Study of Technology Trends Analysis Using Patent Search Systems

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Abstract: Patent information is effective in clarifying the research policy and strategy of a company and its competitors through the analysis of technological trends. In this study, we devised a patent analysis system that incorporates one patent search system, YUPASS (Yamaguchi University Patent Search System), and patent mapping software. In order to confirm the effectiveness of this analysis system, we focused on the differences in technological features of exposure equipment of Canon, Nikon and ASML for use in semiconductor manufacturing and their market share, and attempted to infer the technological reason for the changes in each company's market share through the analysis of patent maps. The analysis result correlated well with the market share investigation report, and we have found that it is a useful analytical tool in clarifying a company's or its competitor's research strategy and policy.

Keywords: Patent information, patent map, IPC, FI, F term, semiconductor, exposure equipment

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INTRODUCTION

Patent information is effective in clarifying the research policy and strategy of a company and its competitors through the analysis of technological trends. In the five years up to 2012, the average number of patent applications in Japan was about 354,000, which represents an enormous amount of information. Therefore, there is a demand for a highly accurate, high-speed and stable patent search system, and a variety of such systems have been proposed. Patent mapping is a technique whereby, using quantitative-, qualitative- and correlation-analysis fitted to technological information within the patent information as the search object, analysis results can be visually represented in a way that is easy to understand, and so patent information keywords are rendered visible, and invisible actualities can be grasped visually. In this study, taking up the example of exposure equipment, which is indispensable in semiconductor manufacturing, and using a patent analysis system that incorporates one patent search system, YUPASS (Yamaguchi University Patent Search System), and patent mapping software, we will investigate patent information technology trends analysis in terms of the impact of technology changes on the market.

FEATURES OF THE PATENT ANALYSIS SYSTEM

In this study, YUPASS was used as the patent search system, and Patent Map EXZ, an all-purpose patent mapping software, was used to map acquired data. YUPASS is a search system that has been being developed since 2004 by Yamaguchi University, and improvements continue to this day. Its main features are as follows:

1. A function to collectively search all text data contained in the bibliographic items within patent publications (including weighted searches).
2. A function to search wording from all text from start to finish (no automatic rounding off of particles and other such parts of speech in search phrases).
3. A function to output the search results report in CSV format, a report citation display function.
4. It is possible to search stably as it is set up on the campus server.
5. Since 1993, there has been full text search support for utility model patents.

Among patent information search services, various systems have been released, from free, simple systems to paid-for multi-functional systems, and by employing a variety of search methods, each search system can output patents matching the search terms. In addition, by statistically processing the analysis elements such as keywords contained in patent information using mapping software, we can find out about technology trends, technology distribution, trends in new technologies, the discovery of new fields of technology, and we can grasp the differences in development between a company and its competitors.

Patent maps are well known as an example of the macro analysis of patent information. They use sets of patent information selected and gathered by patent investigations and searches as the population, perform quantitative-, qualitative- and correlation-analysis matched to the search object on that population, and the results of that analysis are visually presented in a chart or table, which makes it possible to easily visually ascertain the realities of technological development.

There are two types of patent maps, the statistical type and the list type; a different type is used depending on the goal. Also, in order to analyse a large quantity of patent information, and to efficiently create a patent map based on it, there is a need to use mechanical information processing, not the former manual method. The flow of information for the manual and the mechanical method is shown in Figure 1.

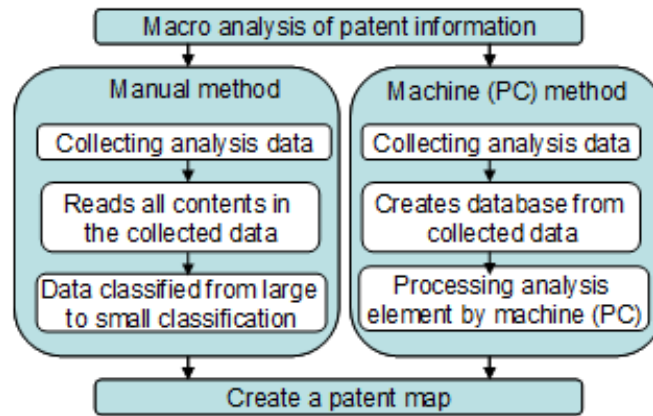


Figure 1 Macro Analysis Method in Manual and Mechanical Styles

Analysis is performed by classifying analysis element into a hierarchical structure from large to small, with the element of analysis being the content in the patent applications. Depending on how the data would be viewed, analysis element will go through various re-arrangement and process before finally rendered visually by a mapping software. One weakness of mechanical system is, it cannot interpret the contents of individual patent applications, which mean that, depending on the analysis element being used, the level of analysis will be easily affected. As shown in Figure 2, patent document contains the detailed description of the invention that applied to be patented. It covers the summary of the application, the scope of the invention claim, challenges and solutions, purpose/utility/operation/effect of the invention, and its implementation. Patents are classed according to the subject of the invention. Usually each patent document has a fixed format and assigned with special identification sign such as the publication, date and classification number to makes its classification more systematic. As shown in Figure 2, the content of a patent application document can be extracted into smaller elements that are:- the numbering system, date system, word system etc. These can be used as an element of analysis alongside other bibliographic items (applicant, inventor, name, and classification).

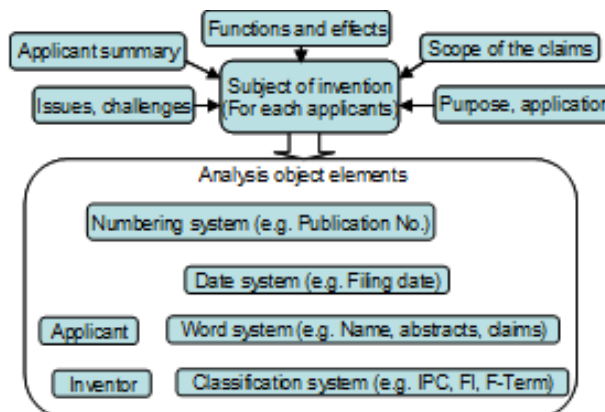


Figure 2 Elements that are the Target of Patent Information Analysis

Analysing Technological Content Using F-Terms

Because mechanical patent mapping is a method of analysis that uses only particular analysis elements, such as the applicant, IPC, or FI, compared to the manual method, whereby individual application contents are read and analysed, the lack of capability to analyse thoroughly the technological content is a problem. When classification system is used as an element of analysis, the analysis level is determined by the type of classification, and depending on the classification there is a possibility that the information to be analysed will be analysed at a high level. As shown in Figure 3, when F-term, a technology (classification system) that was developed for mechanical searching, is used as an analysis element to efficiently conduct the prior art investigation (search) for wide-range classification, IPC main groups, IPC subgroups, Fland patent information investigations, the total number of classifications will be large, so compared to IPC classification and similar systems, when F-terms are the analysis element a higher analytical level can be expected.

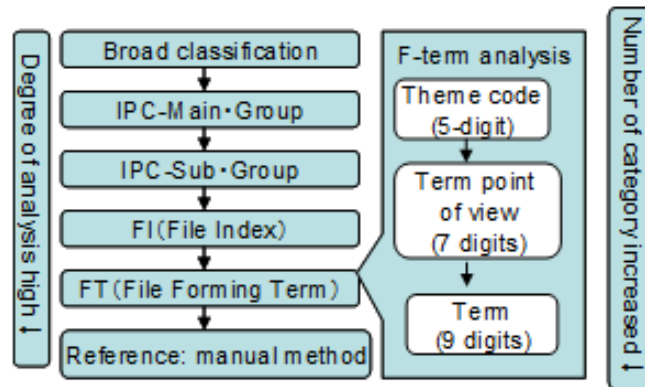


Figure 3 Evaluation of the Degree of Analysis according to the Analysis Element of the Classification System

When using only the current IPC, there is a lot of prior art literature that should be investigated; because F-terms are the product of sub-dividing and re-dividing IPC by specified technological field from various technological viewpoints (objective, utility, structure, material, method of manufacture, processing operation method, means of control), by searching for a combination of F-terms, the search can efficiently be narrowed down to relevant prior art. As shown in Figure 4, F-terms are composed of a 5-digit theme code + 2-digit viewpoint + a 2-digit number. For some themes, a one-character code called the option code is also established. The appended code adds the symbol “.” after the F-term. In F-terms many theme codes for a variety of technologies are provided, and a unique analytic viewpoint is defined for each code.

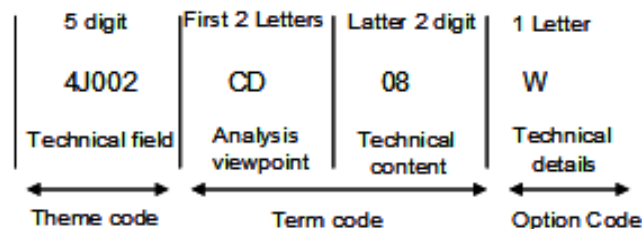


Figure 4 F-term Structures and the Hierarchy of Digit Number by Analytical Element

As the method for this study, we focused on F-terms as the element of analysis, extracted F-terms from patent information to be searched, and created patent maps. In the actual analysis, based on the fact that F-term codes are expressed as 5-digit theme codes and 4-digit term codes, a total of 9 digits (10 including the appended code), the theme code was reset as the large classification, the first two digits of the term code (analysis viewpoint) as the medium classification, and the last two digits (technological content) as the small classification; by changing the depth of the hierarchy (the number of F-terms digits) of classifications expressed as between large and small, analysis could be done from many viewpoints. The overall flow of analysis is shown in Figure 5.

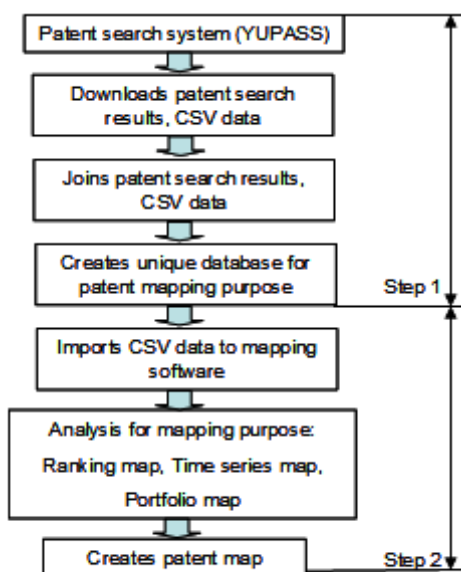


Figure 5 Overall flow of Analysis

Analysis Procedure

As the first step in creating each type of patent map, from the online database of patent literature, we gathered patent literature that was to be analysed, and in order to make a dedicated database, entered keywords suitable for a YUPASS detailed search, and acquired the search result electronic data as a CSV file. YUPASS can produce a search list of up to 100,000 results at a time, and because it can be outputted as CSV data 3,000 results at a time, searches can be done accurately and without omission. Also, because of the fact that literature on patent information to be analysed acquired by search is gathered and stored on each search in the CSV file format, this data could be combined using Excel or similar general-purpose software. Next, the results gathered in their own patent map database were imported into mapping software and ranking maps, chronological maps, portfolio maps and so on were created and analysed. However, because patent maps are for conducting analysis of information, in order to judge the results specialist knowledge on the target of analysis is required.

ANALYSIS OF EXPOSURE EQUIPMENT PATENTS

In the 1990's, Canon and Nikon split the global exposure equipment market share between them. However, entering the 2000s, they surrendered the top share over to ASML, Dutch semiconductor manufacturing equipment maker. Until now, various reasons for Nikon's and Canon's exposure equipment business decline have been examined from the points of view of economics and management; in this study, in order to confirm the effectiveness of the patent information analysis system we have constructed, we focused on the differences in technological features of exposure equipment for use in semiconductor manufacturing and their market share, and attempted to infer the technological reason for the changes in each company's market share through the analysis of patent maps.

Market Share of Exposure Equipment

Figure 6 shows the changes in world market share of Nikon, Canon and ASML as shown by quantity of sales. As can be understood from the graph, in the 1990's Canon occupied 40% of the market share. In the year 1996, Nikon held 50% of the market and Canon held 25%, 75% between them. At that time, ASML's market share was around 15%. Entering the 2000s, the three companies, Nikon, Canon and ASML, started to engage in a fierce battle for market share. In 2001, the semiconductor exposure equipment market was divided between Nikon at 41.6%, Canon at 34.8% and ASML at 22.4%. However, five years later in 2006, ASML's share reached 40%, and 60% in 2010, and it established itself as the world number one semiconductor exposure equipment maker.

From an economic or management point of view, one cause of this trend is said to be that ASML was ahead of the rest of the industry in developing immersion exposure equipment. In August 2004, ASML's Twinscan AT:1150i α -machine immersion exposure equipment was delivered to New York State University's Albany NanoTech, and after that ASML continued to ship out more equipment of this type. In terms of the market for i-line steppers, the simplest lithography technology for making low-end chips, according to the "The Global Market for Equipment and Materials for IC Manufacturing" report, in 2006 Canon held 48.8% of the market, Nikon 34.9%, and ASML 16.3%. Even in 2011 the i-line market share situation hadn't changed greatly, with 52.9% of the market share going to Canon, 40.0% to Nikon and 7.7% to ASML, but the i-line exposure tool is for low end semiconductor manufacturing use, and the market price is low. In addition, ASML holds a large market share in ArF immersion exposure, a high-end type of exposure equipment. In the 2006 immersion exposure market, ASML held a 72.4% share, Nikon held 27.6%, and Canon had not expanded into the high-end market. In 2011, ASML's share expanded yet further to 82.0%, and Nikon's dropped to 18%. In this way, because, at 80%, ASML showed an extremely strong hold on the immersion exposure market share, they became the top market shareholder in the exposure equipment world market. ASML greatly increased their share to 60%, Nikon dropping to 20.5% and Canon to 10%.

From the fact that, in 2008, ASML held 40.7% of market share by number of sales, Nikon 30.2% and Canon 29%, and that in terms of sales proceeds ASML held 65.4%, Nikon 23.3% and Canon 11.3%, we can see that ASML increased its market share across all types of exposure equipment.

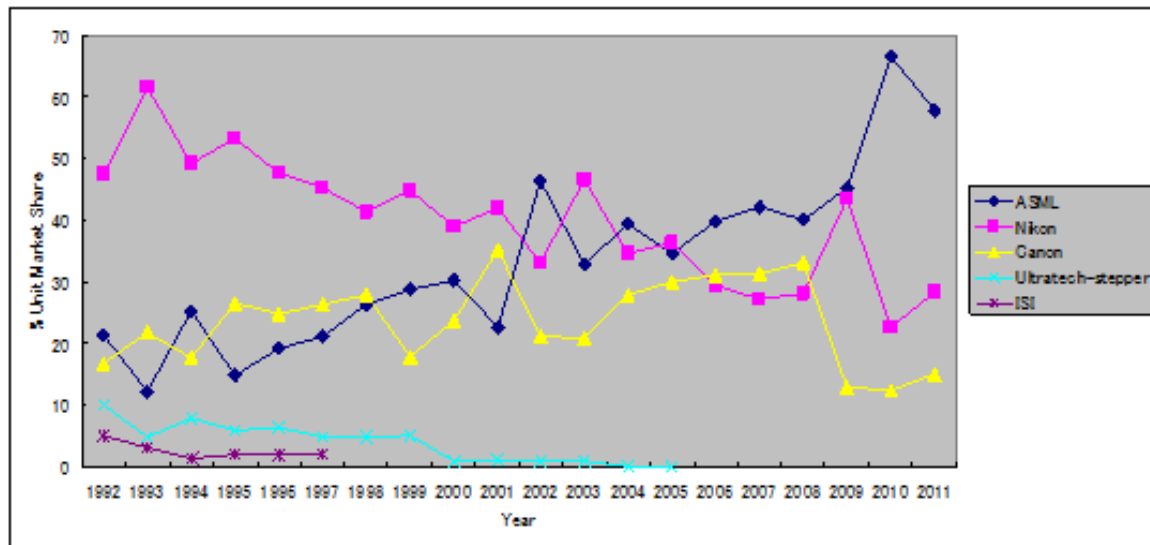


Figure 6 Semi-conductor Exposure Apparatus Manufacturer Market Share Changes

RESULTS OF ANALYSIS

Five-digit F-terms: Large Classification (Technical Field) Ranking Map Analysis

In order to analyse the technical field, we analysed the percentage of applications of each company for inventions in exposure and lithography using ranking mapping of 5-digit F-terms (theme code). Figure 7 shows the results of analysis. As can be understood from the graph, 5-digit F-terms, 5F146 and 5F046 theme codes appeared most frequently for all three companies, ASML, Nikon and Canon, and no difference can be seen in the field of technology between the three companies, which all show the same trend. 5F146, and 5F046 are both seen as the technology field of “exposure for semiconductors (apart from electron and ion beam exposure)”. Table 1 shows the 5-digit F-terms and theme codes of the top four headings by appearance frequency.

Next, we conducted the analysis of the middle classification, to see what viewpoint each manufacturer focused on within theme code 5F146 (“exposure for semi-conductors [apart from electron and ion beam exposure]”), the field that appeared most frequently in the analysis of the large classification.

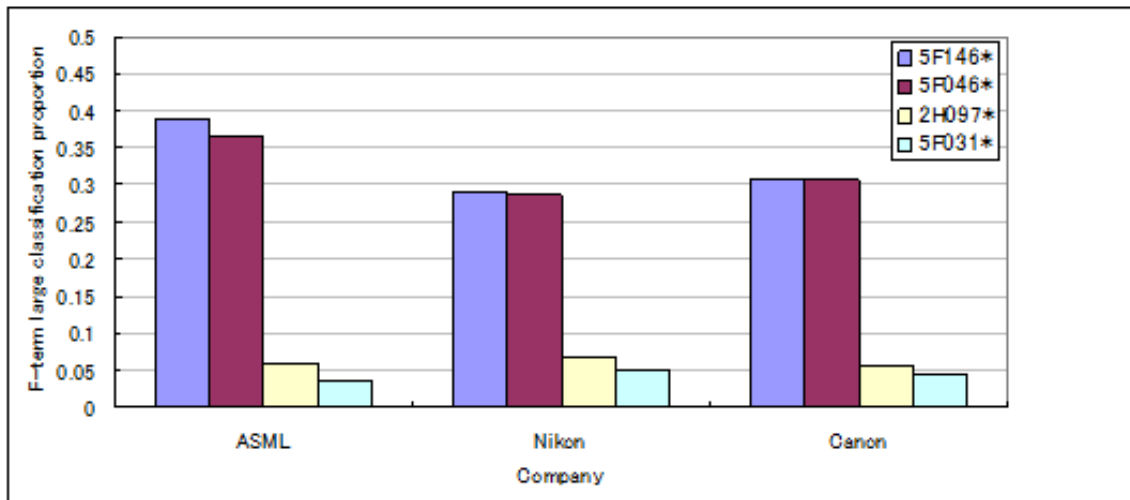


Figure 7 Ranking map of 5-digit F-terms

Table 15-digit F-terms (Technical Field)

FT 6 digits (Large classification : Technical field)	
FT	Theme code
5F146	EXPOSURE OF SEMICONDUCTORS, EXCLUDING ELECTRON OR ION BEAM EXPOSURE (NEW)
5F046	EXPOSURE OF SEMICONDUCTORS, EXCLUDING ELECTRON OR ION BEAM EXPOSURE (OLD)
5F031	CONTAINERS, MOVEMENT, FIXING, AND POSITIONING OF SEMICONDUCTOR WAFERS
2H097	EXPOSURE AND POSITIONING OF PHOTSENSITIVE MATERIALS COMPRISING PHOTORESISTS

Seven-digit F-terms: Middle Classification (Viewpoint) Ranking Map Analysis

Figure 8 shows the ranking map for each company by 7-digit F-term analysis. As can be understood from the graph, ASML, Nikon and Canon shared the trend that within the technology field 5F146, “exposure for semiconductors (apart from electron and ion beam exposure)”, viewpoint BA, “type of UV light exposure”, appeared most frequently. Table 2 shows the codes of the top four viewpoint headings acquired.

Next, the analysis results of the middle classification show that viewpoint BA, “type of UV light exposure”, appeared most frequently within technology field 5S146, “exposure for semiconductors (apart from electron and ion beam exposure)”. Analysis of the small classification was then performed to determine which technology within viewpoint BA each manufacturer focused on.

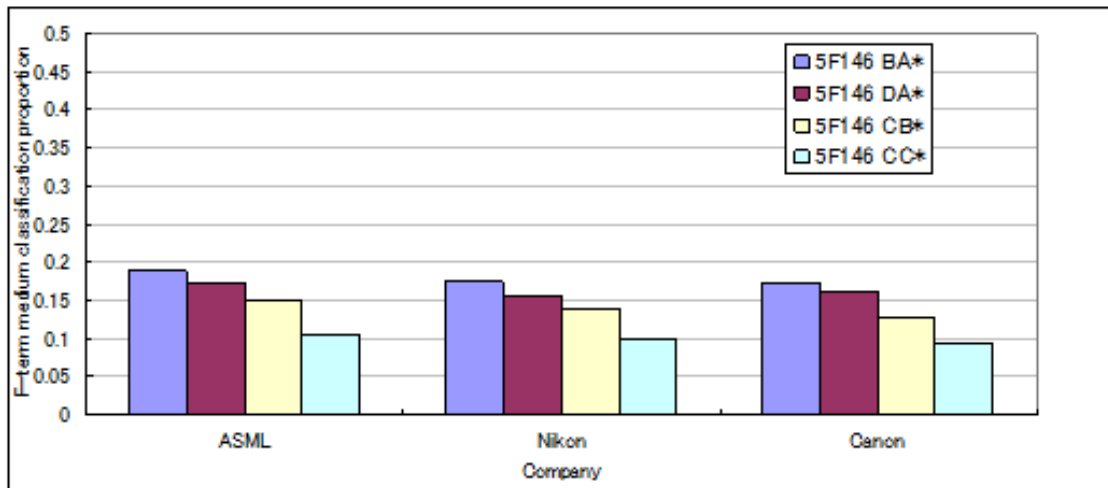


Figure 8 Ranking map of 7-digit F-terms

Table 27-digit F-terms (Viewpoint)

FT 7 digits (Medium classification: Viewpoint)	
FT	Viewpoint
5F146 BA	KIND OF ULTRA-VIOLET RADIATION OR ULTRA-VIOLET LIGHT EXPOSURE
5F146 DA	OBJECT OF EXPOSURE CONTROL OR ADJUSTMENT, OR CONTENT THEREOF
5F146 CB	OPTICAL SYSTEM
5F146 CC	STAGE OR CHUCK MECHANISM AND OPERATION THEREOF

Nine-digit F-terms: Small Classification (Technological Content) Ranking Map Analysis

Figure 9 shows the analysis results of a ranking map of 9-digit F-terms. The analysis shows that while for both Canon and Nikon the heading BA05, “projection exposure: scanning projection exposure, reflection projection exposure” within BA0, “projection exposure”, appeared most frequently, for ASML BA11, “immersion exposure” appeared most frequently.

In this way, by deepening the analysis, we can finally confirm the point of difference between Canon, Nikon and ASML. From the above results we can see that ASML focused mainly on immersion exposure as a means of making a great profit in the exposure equipment market, with this heading comprising 33.1% of the technological content, while Nikon and Canon had a greater percentage of projection exposure technology. Immersion exposure has been identified in previous studies as the cause of ASML’s success.

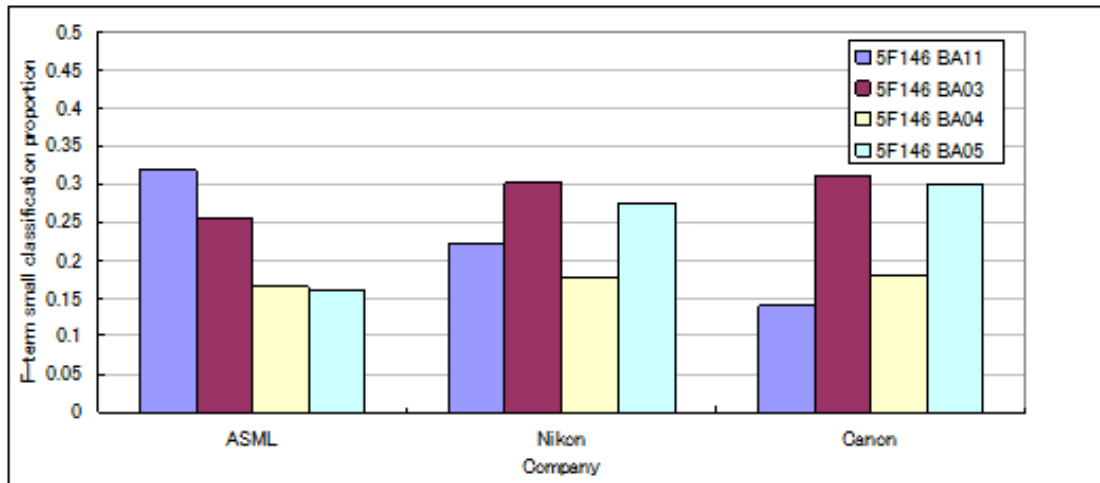


Figure 9 Ranking map of 9-digit F-terms

Table 39-digit F-terms (Technical Content)

FT All digits (Small classification: Technical contents)	
FT	Technical contents
5F146BA11	- IMMERSION EXPOSURE
5F146BA03	- PROJECTION EXPOSURE
5F146BA04	- - REDUCED PROJECTION EXPOSURE
5F146BA05	- - SCANNING PROJECTION EXPOSURE OR REFLECTION PROJECTION EXPOSURE

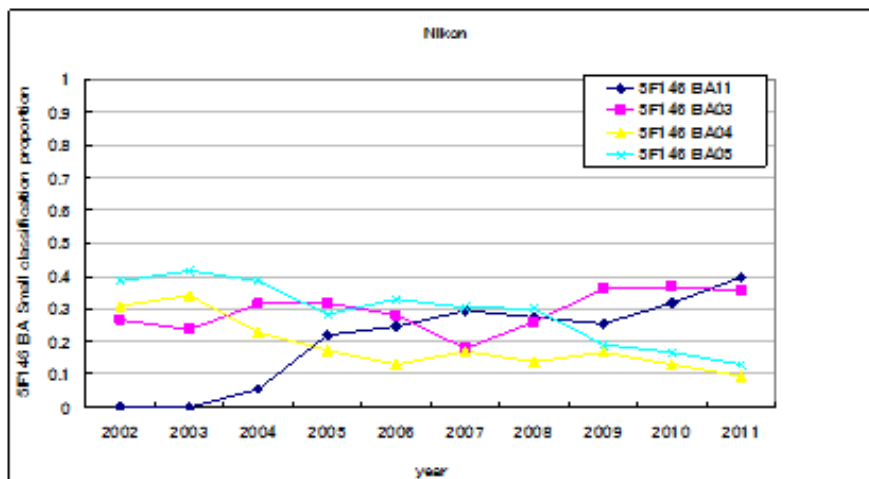
Chronological Map Analysis

We conducted analysis using chronological maps to investigate in detail the variations in each company’s exposure method technology. Figures 11(a), (b) and (c) show the changes in technological content for each company. The vertical axes show the percentage of each technological content heading, and the horizontal axis shows the year from 2002 to 2011. From Figure 10 (a) we can see that in 2002, for Nikon results were equally high for the projection exposure technology of BA05, “projection exposure: scanning projection exposure, reflection projection exposure”, BA04, “reduced projection exposure” and BA03, “projection exposure”, and thereafter the percentage of BA05 and BA03 dropped but that of BA03 levelled off and remained high. BA11 (“immersion exposure”) increased sharply in 2005 before levelling off at a high percentage.

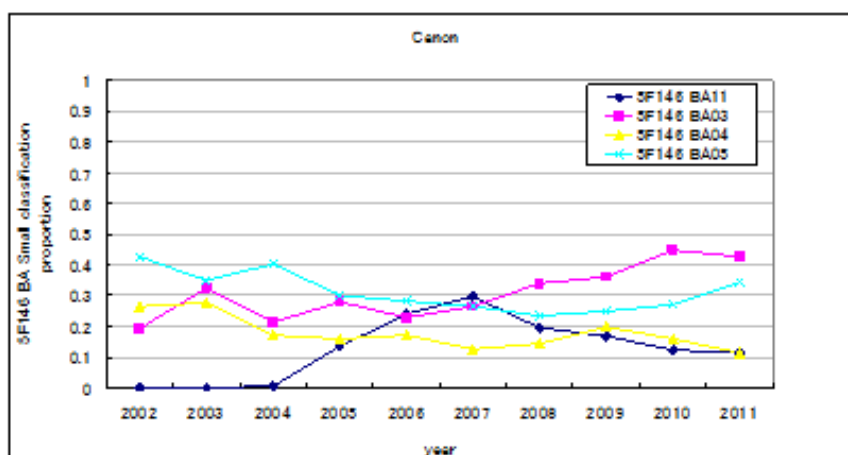
Figure 10 (b) shows the results of analysis for Canon. In the graph we can see that the percentage of BA03 and BA05 is high, and particularly BA03 shows an upward trend. BA11

peaked in 2007 and then dropped. This can be thought to be due to Canon’s focus on low-end i-line stepper over immersion exposure. Figure 10(c) shows that while in 2006 ASML’s percentage was about the same for BA11, BA03, BA04 and BA05, after that the percentage of BA03 and BA11 soared, but after 2009 only BA11 increased while all the other technologies dropped. Especially in 2011 the percentage of BA11 exceeded 50%, and all the other technologies remained low at about 15%. It is thought that this is connected to an attempt to expand market share of immersion technology applied to exposure equipment.

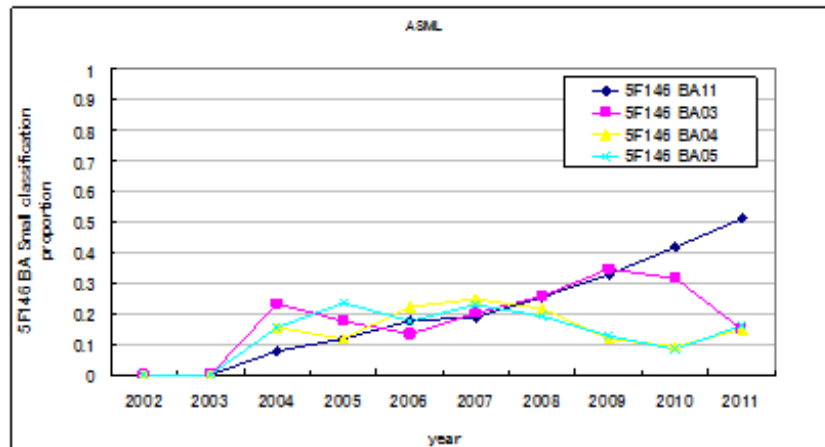
Figure 11 shows variations in market share along with each company’s immersion exposure equipment percentage. Regarding changes in market share relative to changes in the percentage of immersion exposure technology for each company, since 2006 the percentage of BA11 in ASML has been increasing continuously, and at the same time its market share has also increased. Next, looking at the changes in Nikon, up to 2010 BA11 maintained on average a high proportion, and since then there has been an upward trend, but compared to ASML’s increase this upward trend is lagging. Since peaking in 2007, Canon’s market share has declined along with its BA11 percentage. From these points a correlation can be observed between changes in each company’s immersion exposure technology (BA11) and changes in their market share.



(a) Nikon



(b) Canon



(c)ASML

Figure 10 Chronological Maps of 9-digit F-terms (Theme Code: 5F146; Viewpoint: BA)

Table 49-digit F-terms (Theme Code: 5F146; Viewpoint: BA)

FT	Technical contents for theme code:5F146 viewpoint: BA
5F146BA01	- CONTACT EXPOSURE
5F146BA02	- PROXIMITY EXPOSURE
5F146BA03	- PROJECTION EXPOSURE
5F146BA04	- - REDUCED PROJECTION EXPOSURE
5F146BA05	- - SCANNING PROJECTION EXPOSURE OR REFLECTION PROJECTION EXPOSURE
5F146BA06	- - PATTERN GENERATORS
5F146BA07	- BEAM SCANNING EXPOSURE
5F146BA08	- INTERFERENCE EXPOSURE
5F146BA09	- HOLOGRAPHIC EXPOSURE
5F146BA10	- OTHERS
5F146BA11	- IMMERSION EXPOSURE

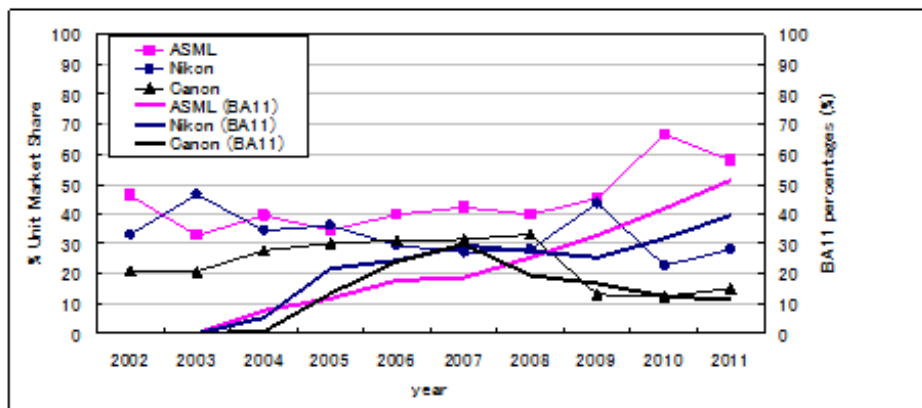


Figure 11 Changes in Immersion Exposure Percentage and each Manufacturer's Global Market Share

In the above way, using patent maps we can analyse changes in the technologies (in this case, exposure methods and immersion exposure) on which each manufacturer focuses. Through F-term small classification ranking maps, we can see that ASML put more emphasis on immersion exposure compared to other manufacturers, and from the immersion exposure by manufacturer chronological map we can deduce what kind of exposure technology each manufacturer is currently proactively developing based on the number and proportion of results for a given heading.

Portfolio Map Analysis

We conducted analysis of the small classification of theme code 5F146, “exposure for semiconductors (apart from electron and ion-beam exposure)” using portfolio maps. Here, the vertical axes show growth, and the horizontal axes show the composition ratio. “Growth” expresses the changes in the number of applications in the target period relative to the reference period, showing the number of applications (in this case the number of F-term small classifications) in the target period and the reference period as a logarithm. Composition ratio represents the ratio of various technological contents contained within a given technological field. The reference period for the portfolio maps was from 2002 to 2005, and the target period was from 2006 to 2011.

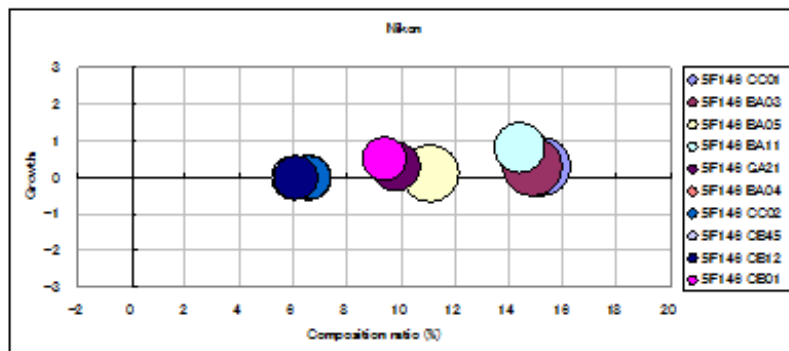


Figure 12 Nikon: PortfolioMap of 9-digit F-terms (Theme Code: 5F146)

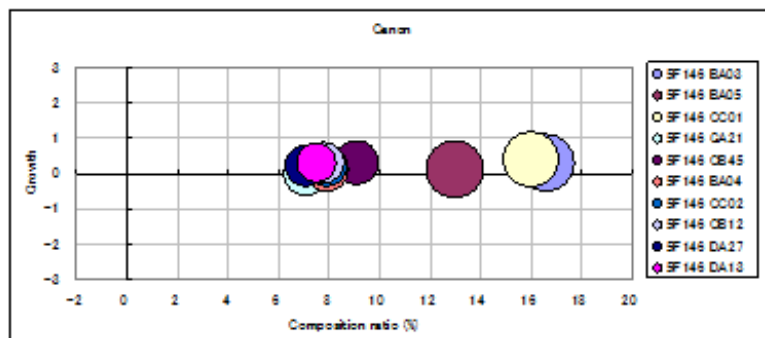


Figure 13 Canon: PortfolioMap of 9-digit F-terms (Theme Code: 5F146)

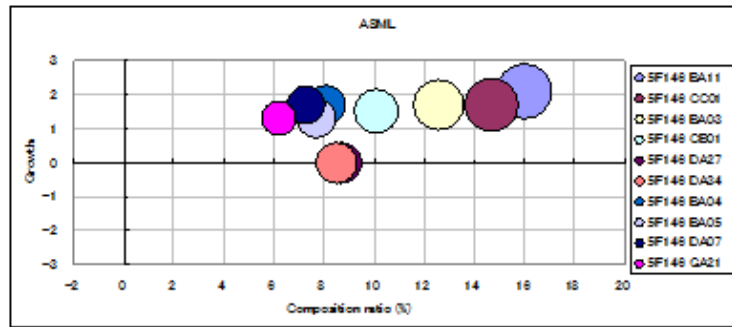


Figure 14ASML: PortfolioMap of 9-digit F-terms (Theme Code: 5F146)

Table 5 F-term Numbers and Explanations

Viewpoint	5F146BA	Kind of ultra-violet radiation or ultra-violet light exposure
Technical content	5F146BA03 5F146BA11 5F146BA04 5F146BA05	•Projection exposure •Immersion exposure ••Reduced projection exposure ••Scanning projection exposure or reflection-projection exposure
	5F146CC	Stage or chuck mechanism and operation thereof
	5F146CC01 5F146CC02	•Wafer stages •Mask stages
	5F146CB	Optical system
	5F146CB01 5F146CB12 5F146CB41 5F146CB44 5F146CB45	•Optical system elements ••Lenses •Position of optical system ••Between mask or reticle and wafers •••Projection optical systems
	5F146GA 5F146GA21	X-ray exposure or EUV exposure •Exposure wavelength is EUV
	5F146DA	Object of exposure control or adjustment, or content thereof
	5F146DA07 5F146DA27 5F146DA34	•Wafers or vicinity of wafers •Pressure or atmospheres •Maintain performance of immersion lithography
	5F146DA11 5F146DA12 5F146DA13	•Projection exposure ••Projection optical system •••Magnification, optical path lengths or distortion
	5F146DA11 5F146DA12 5F146DA13	•Projection exposure ••Projection optical system •••Magnification, optical path lengths or distortion

Figure 14 shows ASML’s portfolio map. Table 5 describes the portfolio map’s F-term headings. As can be seen from the figure, within ASML’s F-term small classification, BA11 (immersion exposure) has a component ratio of 16.3%, the highest in the F-term small classification, and growth is above +1. Also, in the small classification viewpoint DA (exposure control, target of adjustment, contents), the F-term with the most growth was DA34 (immersion exposure equipment performance support), with growth of ∞. This is because it had no appearances in the reference period but it made an appearance in the target period. It is shown on the 0 axis on the map due to a limitation of the software. The fact that in ASML’s portfolio map the growth of all small classification F-terms is 1 or above demonstrates how actively they have been engaged in development relative to the reference period. Also, the high component ratio of BA11 (immersion exposure) and the highest growth of DA34 (immersion exposure equipment performance support), reflect the fact that ASML has been focused on and expanding development in immersion exposure methods and related technology.

Figure 12 shows Nikon's portfolio map. From the graph we can see that, as for ASML, the highest component ratio belongs to BA11 (immersion exposure), but that growth is low compared to ASML and compared as a whole to ASML, the overall growth in the appearance of small classification F-terms is not high. This indicates that compared to ASLM the progress of development was lagging.

Figure 13 show Canon's portfolio map. As the graph shows, the exposure method BA03 (projection exposure) represents the highest component ratio, and as for Nikon overall growth is not high. In addition, it can be considered that much of the negative growth can be accounted for by the downward trend in technological development.

Looking at the above results, if we assess the differences and features of each manufacturer, we can see that ASML has focused on immersion exposure and related technology; many of the small classification F-terms have shown positive growth, and the company is actively pursuing development. However, the growth of Nikon and Canon is not very large, there is also some negative growth, and it can be deduced that they are not as actively engaged in development as ASML. From these results, it can also be thought that the state of development work on the particular technology each company focused on is one factor that affects the company's market share.

DISCUSSION

By analysing technology trends with regard to the influence on the market of technological changes in exposure equipment used in semiconductor manufacturing, using a patent analysis system that incorporates a search system and patent mapping software, the following conclusions were reached.

(1) By analysing F-terms, it is possible to not only find out about the fields of technology, but also to attain detailed information about various viewpoints within those fields.

(2) By analysing different hierarchy depths of F-terms, it is possible to specifically analyse a variety of information in each technological field, in which the depth of the hierarchy leads to highly detailed classification. In this study, when F-term hierarchy depth was analysed in large to medium classifications, the viewpoint of the exposure method (in the field of semiconductor exposure) upon which ASML, Nikon and Canon were focusing could be understood. When further analysis was done into small classifications, the fact that ASML focused more than Nikon and Canon on immersion exposure became clear. In other words, the greater the complexity of classification, the more the differences and features of each company can be identified.

(3) By analysing F-terms by different hierarchy depths, it can be seen that ASML's special feature was immersion exposure, which correlates well with information on market share obtained from economic investigation.

(4) Using patent maps, it is possible to analyse changes in the technology (in this case, exposure methods and immersion exposure) upon which each manufacturer focuses. Through a ranking map of F-term small classifications, it can be seen that ASML emphasized immersion exposure more than other manufacturers, and from a chronology map of immersion exposure by manufacturer, we can deduce from the number and proportion of appearances of a given heading what kind of exposure technology each manufacturer is currently proactively developing.

(5) If we assess the differences and features of each manufacturer based on portfolio maps of ASML, Nikon and Canon, we can see that ASML has focused on immersion exposure and related technology, that many of the small classification F-terms show positive growth, and that the company is actively pursuing development. On the other hand we can see that the growth of Nikon and Canon is not very large, and that there is also negative growth, and it can be deduced that they are not as actively engaged in development as ASML. From these results it can also be thought that the state of development work on the particular technology each company focused on was one influencing factor on the company's market share.

(6) In this study, the analysis of patent maps correlated well with the market share investigation report. Accordingly, the application of the patent analysis system used in this study to analyse technology trends in patent information can be a useful analytical tool in clarifying a company's or its competitor's research strategy and policy.

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