Discovering Microfluidics Technology Opportunity Using Patent Analysis

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Abstract

Recent trends of technology innovation emphasize the notion of dominant designs for next-generation products. Technology-based firms, especially in biotechnology field, have to spend plenty of resources in R&D in order to identify appropriate technology opportunities for sustaining their competitive advantages. To help SMEs to discover new technological opportunities with a relative lower cost, this paper applies a keyword-based patent map approach to analyze patent database, allowing them to find the valuable opportunities. According to literature and current patent analysis, Chip substance manufacture technology is one of the most important technologies and is used as case substance.

The methodology used to find bio-technological opportunities comprise three stages. In the first stage of patent collection, we find experts to analyze the company's current products and technologies and use patent search engine and forward citation to find related patents. Experts are requested to define several keywords for the technology and filter patents which have low frequency of these keywords. In the second of patent analysis, we use text mining to excavate the frequency of the keywords and map them by principal component analysis. The final stage of opportunity analysis is to define the vacancy on the map and list all the patents around them. And then, critical analysis and trend analysis are used to evaluate the value of the vacancy.

According to the patent analysis, we have found that chip substance manufacture technology is still in the growth stage and there are several potential technological opportunities for further exploration.

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1. Introduction

Recent trends of technology innovation emphasize the notion of dominant designs for next-generation products thus technology opportunity identification is thought to be the curtail process in many companies. Technology-based firms, especially in biotechnology field, have to spend plenty of resources in R&D in order to identify appropriate technology opportunities for sustaining their competitive advantages. This puts a great challenge for SMEs which usually have severe capability and resource constraints (Yongho Lee, 2014).

Microfluidic biochip is the second generation biochip which is believed to be one of the greatest challenges in the century (Juan G. Santiago, 2015). Traditionally, people required a whole laboratory to do disease detection and analysis. The experiment usually spent lots of materials, equipment and human resources. Microfluidic biochip can narrow the whole laboratory into one small chip which is also called lab-on-chip. With less material cost and higher degree of accuracy, microfluidic biochip is now become one of the most popular issue in biotechnology field.

This paper applies a keyword-based patent map approach (Sungjoo, 2009) to analyze patent database to help biochip firms for discovering new technological opportunities. The method can divide into three parts: patent collection, patent analysis and opportunity analysis. All the patents are found from the USPTO database and the keywords are extracted by Text Mining (Tan, 1999). PCA is used to merge keywords into several axes which are used to map the patents. Finally, experts are required to identify the vacancy/opportunity and analysis the patents around it.

2. Methodology

2.1. Research Framework

In this research, we apply a keyword based patent analyze method developed by Sungjoo (Sungjoo, 2009) to find the possible technology opportunities. The whole research is composed by three parts; they are patent collection, patent analysis and opportunity analysis. At the beginning, we will analyze the technology, product and capability of the target company and investigate the current technology trend to identify the most promising technology which is worth to be invested. Then, we search patents related to the selected technology from Unite States Patent and Trademark Office (USPTO) patent databases. The key words which can represent those patents are extracted from the description part of the patents by Text Mining

(TM) and important keywords are selected by experts. After that, we use Principle Component Analysis (PCA) to map those patents filtered by selected keywords. At the end, we will try to discover the technology opportunities by analyzing the patents around the possible vacancies.

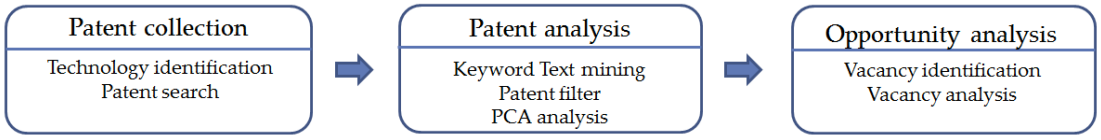


Figure 1. Research framework

2.2. Patent Collection

With different resources, organizational structure, and business strategy, companies have their advantages and limitation. In order to help companies to find the most promising technology which can fit both the company's advantage and the future market, we first analyze the technology, product and capability of the company and the current technology trend. After the investigation, we identify the most promising technology which is worth to be developed. With the analysis of the technologies, we can find several attributes such as materials, application and forms, which can characterize the technology. Experts are required to analyze the technology for the target company and find the key attributes. Those attributes are used in patent search in USPTO patent databases.

Patents found in USPTO patent databases by those attributes may not include all the patents related to the technology. Some patents with this technology may use similar words to describe those attributes. In order to find all the patents related to the select technology, we use forward citation to find the patents which cite the patents we have already found.

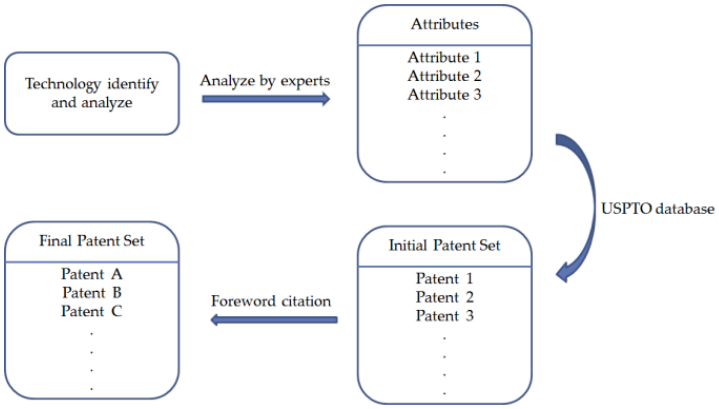


Figure 2. Patent collection process

2.3. Patent Analysis

Patents contain much information such as technology details, applications and relationships, but the information is unstructured which may not allow people to analyze directly. To solve this difficulty, Text Mining, the method of deriving high-quality information from text, is applied to translate unstructured information into structured data.

The words extracted by Text Mining may include lots of conjunction words and common words which don't contain useful information. To delete those redundant words, we use term frequency (TF) and frequency–inverse document frequency (TF-IDF) to preliminary filter the words and then we find experts to do further selection to find the keywords that may be useful to opportunity discovery. Those keywords will be used to re-filter the patents we have found through patent search and patent foreword citation because there might be some patents which have little or no relation with the target technology. After selection, the left patents are thought to include all the patents highly related to target technology.

To analyze the relationship between patents, we use Principal Component Analysis (PCA) to merge the keywords into several principal components. Each of the two components is used as the X-Y axis with the patents map on it. With the permutation and combination, there may be many patent maps. The distance between two patents may represent the relationship between patents.

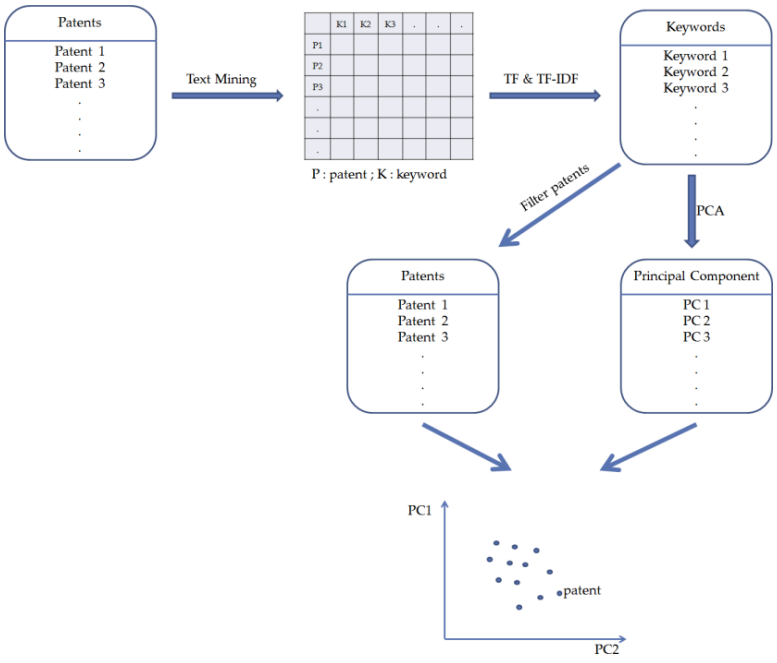


Figure 3. Patent analysis process

2.4. Opportunity Analysis

After map all the patents on the patent map through PCA, we can identify the vacancy on the patent map. Each vacancy may represent a possible technology opportunity, but the accuracy needs further examination. Until now, there is still no standard way to identify the vacancy. The most common way to identify the vacancy is to find experts, relying on their professional knowledge. Here, we decide to find experts to identify the vacancies just like previous researches.

With the identification of the vacancy, patents around them are listed and used to evaluate the accuracy of the opportunity. This is because that the patent map is just a two-axis map, the distance between patents may not be the real distance in the multi-dimension patent map. The patents around the vacancy can be used to determine potential technological opportunities.

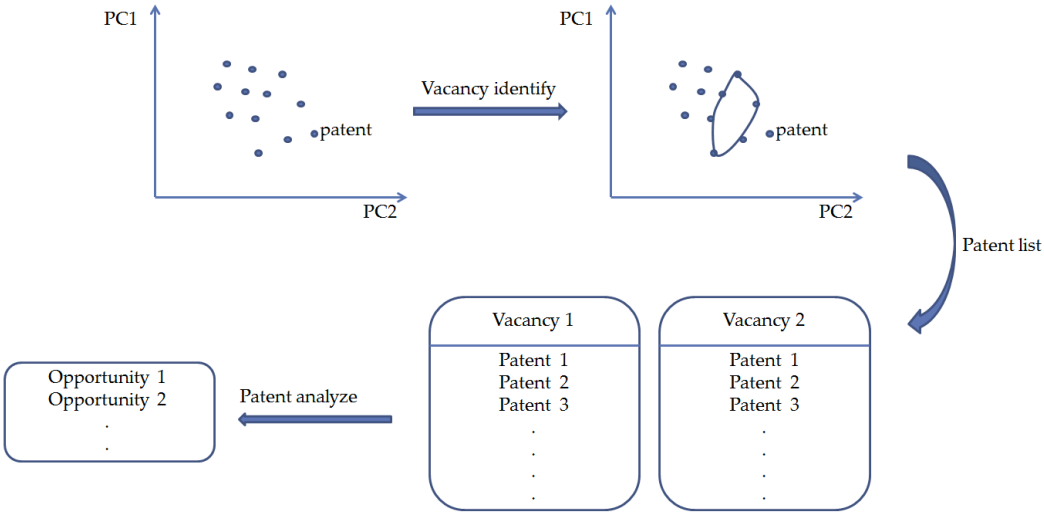


Figure 4. Opportunity analysis process

3. Illustrate Example

This research applies the keyword based patent analysis to the area of microfluidic biochip. Microfluidic biochip is the second generation biochip which is believed to be one of the greatest challenges in the century. With the increasing life quality, people are more willing to pay attention on preliminary disease diagnosis. Thus, rapid disease detection became one of the most popular issues in recent years. With the growing market all around the world, more and more companies try to get involved into microfluidic biochip manufacture. This is the main reason we decide to use microfluidic biochip as the illustrate example.

3.1. Patent Collection

According the second hand data and previous research, we found that microfluidic composed by five sub-technologies (Alliance of Microfluidic production techniques, 2014). They are chip manufacture, fluid and ion control, surface and detection, integration and package and sensor. Each sub-technology contains several different parts (Fig.5). In order to find the most promising technology, we use patent trend to analyze all the sub-technologies (Fig.6). All the patents are found in USPTO from 2000 to 2014. After analyzing the patent trend, we decide to choose "micro valve" as the target technology. In order to make sure whether there are other words have similar meaning with micro valves, we seek advices from experts and search information from previous research. The result shows that there is no similar word with micro valve.

Chip manufacture	Surface & Detection
Lithography	Surface Engineering
Rapid Prototyping	Surface Characterization
Deep reactive ion etching	Infrared thermal imaging
Hot Embossing	**Integration and package**
E-beam evaporation	Bonding
Fluid and ion control	Macro-to-Micro Coupling
Microvalves	Computational Simulations
Electrokinetic switching	Highly Integrated microfluidic chip
Digital microfluidics	**Sensor**
Dielectrophoresis manipulation	Biomedical Sensing
Optical tweezers	Micro Cantilever for bio-sensing

http://mbl.pme.nthu.edu.tw/mftc/big5.php

Figure 5. Microfluidic sub-technologies

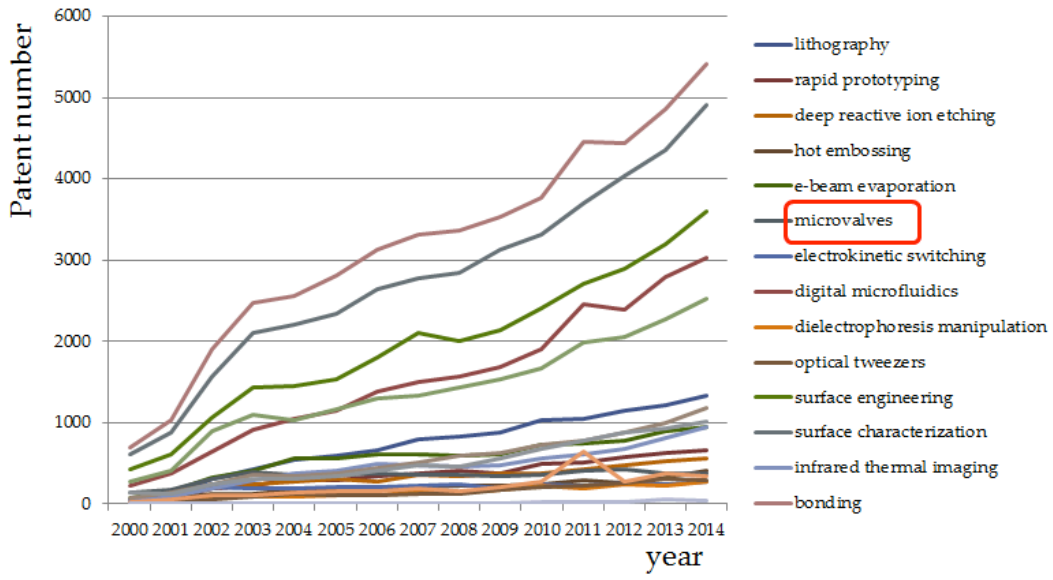
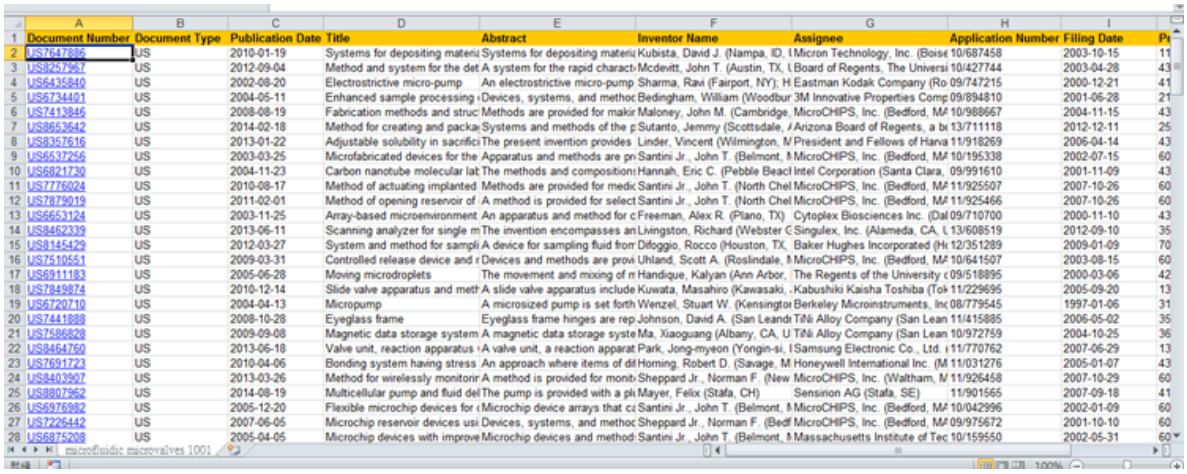


Figure 6. Patent trend of microfluidic sub-technologies

Patents with the keyword “microfluidic micro valve” were searched from the USPTO patent databased and there are total 1429 patents found from 1990 to 2014. These patents may not include all the patents related to micro valve so we use foreword citation to do further collection. There are 915 patents found through foreword citation with the total patent number 2344 (Fig.7).



Document Number	Document Type	Publication Date	Title	Abstract	Inventor Name	Assignee	Application Number	Filing Date
US7647886	US	2010-01-19	Systems for depositing materi	Systems for depositing materi	Kubista, David J. (Nampa, ID,	Micron Technology, Inc. (Boise	10/687458	2003-10-15
US8257967	US	2012-09-04	Method and system for the det	A system for the rapid charact	Mcdevitt, John T. (Austin, TX,	Board of Regents, The Universi	10/427744	2003-04-28
US6435840	US	2002-08-20	Electrostrictive micro-pump	An electrostrictive micro-pump	Sharma, Ravi (Fairport, NY); H	Eastman Kodak Company (Ro	09/747215	2000-12-21
US6734401	US	2004-05-11	Enhanced sample processing	Devices, systems, and methoc	Bedingham, William (Woodbur	3M Innovative Properties Comp	09/894810	2001-06-28
US7413846	US	2008-08-19	Fabrication methods and struc	Methods are provided for makir	Maloney, John M. (Cambridge,	MicroCHIPS, Inc. (Bedford, MA	10/988667	2004-11-15
US8653642	US	2014-02-18	Method for creating and packa	Systems and methods of the p	Sutanto, Jemmy (Scottsdale, A	Arizona Board of Regents, a bc	13/711118	2012-12-11
US8357616	US	2013-01-22	Adjustable solubility in sacrifici	The present invention provides	Linder, Vincent (Wilmington, M	President and Fellows of Harva	11/918269	2006-04-14
US6537256	US	2003-03-25	Microfabricated devices for the	Apparatus and methods are pr	Santini Jr., John T. (Belmont, M	MicroCHIPS, Inc. (Bedford, MA	10/195338	2002-07-15
US6821730	US	2004-11-23	Carbon nanotube molecular lat	The methods and compositions	Hannah, Eric C. (Pebble Beach	Intel Corporation (Santa Clara,	09/991610	2001-11-09
US7776024	US	2010-08-17	Method of actuating implanted	Methods are provided for medic	Santini Jr., John T. (North Chel	MicroCHIPS, Inc. (Bedford, MA	11/925507	2007-10-26
US7879019	US	2011-02-01	Method of opening reservoir of	A method is provided for select	Santini Jr., John T. (North Chel	MicroCHIPS, Inc. (Bedford, MA	11/925466	2007-10-26
US6653124	US	2003-11-25	Array-based microenvironment	An apparatus and method for c	Freeman, Alex R. (Plano, TX)	Cytoplex Biosciences Inc. (Dal	09/710700	2000-11-10
US8462339	US	2013-06-11	Scanning analyzer for single m	The invention encompasses an	Livingston, Richard (Webster C	Singulex, Inc. (Alameda, CA, U	13/608519	2012-09-10
US8145429	US	2012-03-27	System and method for sampli	A device for sampling fluid from	Difoggio, Rocco (Houston, TX,	Baker Hughes Incorporated (Ha	12/351289	2009-01-09
US7510551	US	2009-03-31	Controlled release device and	Devices and methods are provi	Uhland, Scott A. (Roslindale, M	MicroCHIPS, Inc. (Bedford, MA	10/641507	2003-08-15
US6911183	US	2005-06-28	Moving microdroplets	The movement and mixing of m	Handique, Kalyan (Ann Arbor,	The Regents of the University c	09/518895	2000-03-06
US7849874	US	2010-12-14	Slide valve apparatus and meth	A slide valve apparatus include	Kuwata, Masahiro (Kawasaki,	Kabushiki Kaisha Toshiba (Tok	11/229695	2005-09-20
US6720710	US	2004-04-13	Micropump	A microsized pump is set forth	Wenzel, Stuart W. (Kensingtor	Berkeley Microinstruments, Inc	08/779545	1997-01-06
US7441888	US	2008-10-28	Eyeglass frame	Eyeglass frame hinges are rep	Johnson, David A. (San Leandr	Tini Alloy Company (San Lean	11/415885	2006-05-02
US7586828	US	2009-09-08	Magnetic data storage system	A magnetic data storage syste	Ma, Xiaoguang (Albany, CA, U	Tini Alloy Company (San Lean	10/972759	2004-10-25
US8464760	US	2013-06-18	Valve unit, reaction apparatus	A valve unit, a reaction apparat	Park, Jong-myeon (Yongin-si, I	Samsung Electronic Co., Ltd. (	11/770762	2007-06-29
US7691723	US	2010-04-06	Bonding system having stress	An approach where items of dif	Horning, Robert D. (Savage, M	Honeywell International Inc. (M	11/031276	2005-01-07
US8403907	US	2013-03-26	Method for wirelessly monitorir	A method is provided for monit	Sheppard Jr., Norman F. (New	MicroCHIPS, Inc. (Waltham, M	11/926458	2007-10-29
US8807962	US	2014-08-19	Multicellular pump and fluid del	The pump is provided with a pl	Mayer, Felix (Stäfa, CH)	Sensirion AG (Stafa, SE)	11/901565	2007-09-18
US6976982	US	2005-12-20	Flexible microchip devices for	Microchip device arrays that ca	Santini Jr., John T. (Belmont, M	MicroCHIPS, Inc. (Bedford, MA	10/042996	2002-01-09
US7226442	US	2007-06-05	Microchip reservoir devices usi	Devices, systems, and methoc	Sheppard Jr., Norman F. (Bedf	MicroCHIPS, Inc. (Bedford, MA	09/975672	2001-10-10
US6875208	US	2005-04-05	Microchip devices with improve	Microchip devices and method	Santini Jr., John T. (Belmont, M	Massachusetts Institute of Tec	10/159550	2002-05-31

Figure 7. Patents search from USPTO database

3.2. Patent Analysis

Patents contain information including many claims, each of which defines a specific property right. However, most of the information is unstructured data which is not easy to analyze them directly. In order to systematically analyzing the unstructured information, Text Mining is used to translate unstructured information into structured data. Text Mining can extract words from the patent documents and list them through

term frequency (TF) or term frequency inverse document frequency (TF-IDF). After Text Mining, there are about 85838 words extracted from the 2344 patents (Fig.8). Those words contain lots of conjunction words, common words and redundant words which need to be deleted.

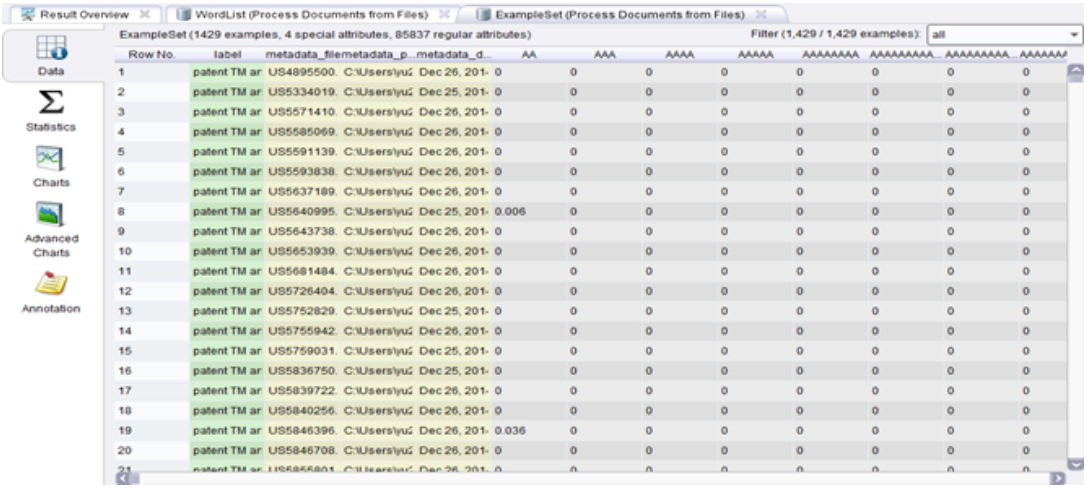


Figure 8. Words extracted by Text Mining using RapidMiner

To filter these words, we use term frequency (TF) and term frequency inverse document frequency (TF-IDF) to do the first selection. This selection will repeat several rounds. In each round, the top 50% of the word lists based on TF and TF-IDF will be compared with each other and the word which involved both in both lists of TF and TF-IDF will be kept. After 5 rounds selection, there are 25 words left. They are oxygen, membrane, MEMs, sensor, stream, porous, ICL, cornea, intraocular, conjunctiva, lid, osmotic, pump, bearing, JR, plastic, separation, nucleic, cartridge, MOVe, tubing, elastomeric, amplification, electric and gel. Although TF and TF-IDF are often used in keyword selection for many years, there are still some limitations. The high TF or TF-IDF words may still be redundant words. In order to do further examination, we find experts to evaluate the 25 words and delete the redundant words. In this selection, 12 keywords are filtered eventually. They are MEMs, membrane, porous, osmotic, ICL, cornea, intraocular, conjunctiva, pump, elastomeric, electric and gel (Fig.9).

MEMs	ICL	Pump
Membrane	Cornea	Elastomeric
Porous	Intraocular	Electric
Osmotic	Conjunctiva	Gel

Figure 9. Twelve selected keywords

The 12 keywords are thought to represent the key attribute of the micro valve technology. We use these keywords to re-filter the 2344 patents we have found in USPTO databases to delete the patents which have low or no relation to micro valve technology. Patents which did not include any one of the 12 keywords will be deleted. Finally, there are 465 patents left.

Next step is to find the relationship between the 465 patents. We use Principal Component Analysis (PCA) to achieve this goal. The patent-keyword matrix is used as the input data. After PCA, the 12 keywords are merged into 4 principal components with the cumulative percentage 83.966 (Fig.10). According to the definition and previous research, the value of cumulative percentage should be higher than 80% with sometimes 70% is also acceptable. The four principal components are named tonometer system (A system to measure the pressure by the moving distance on the cornea), membrane system (A system to filter materials through membranes), osmotic pump (A kind of pump which push fluid through osmotic) and gel electrophoresis (A method to separate materials by electromotive force through electric charge, size and structure) (Fig.11). The four principal components will be used as the X-Y axis to form the patent map. With the permutation and combination, there are 6 different patent maps (Fig.12). The distance between patents represents the strength of the relationship. A short distance between two patents means they are closely related.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	4.027	33.562	33.562	4.027	33.562	33.562	4.009
2	2.681	22.339	55.901	2.681	22.339	55.901	2.842
3	1.953	16.299	72.200	1.953	16.299	72.200	1.904
4	1.412	11.766	83.966	1.412	11.766	83.966	1.789
5	.922	7.685	91.651				
6	.463	3.861	95.512				
7	.395	3.290	98.802				
8	.117	.978	99.780				
9	.022	.182	99.962				
10	.004	.037	100.000				
11	3.798E-5	.000	100.000				
12	-3.900E-16	-3.250E-15	100.000				

Extraction Method: Principal Component Analysis.

a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.

Figure 10. Total variance explained

- PC1: Tonometer system
- PC2: membrane system
- PC3: Osmotic pump
- PC4: Gel electrophoresis

	Component			
	1	2	3	4
ICL	.999	-.014	-.027	-.159
cornea	.999	-.015	-.028	-.160
intraocular	.996	-.016	-.029	-.169
conjunctiva	.992	-.014	-.027	-.157
MEMBRANE	-.015	.972	-.027	-.154
MEMs	-.015	.972	-.027	-.154
POROUS	-.017	.843	-.029	-.166
PUMP	-.028	-.030	.970	-.049
OSMOTIC	-.022	-.024	.969	-.093
ELASTOMERIC	-.086	-.075	-.061	.863
ELECTRIC	-.120	-.125	-.124	.824
GEL	-.114	-.131	.009	.419

Figure 11. Four principal components

Fugure 12. Six patent maps created by PCA

3.3. Opportunity Analysis

After mapping all the patents on the 6 patent several maps, we can discover possible vacancies. From previous research, we found that there is no effective way to identify the vacancy. Most of the researchers rely on the experts' professional knowledge to identify possible vacancies. In this research, we also find some experts to help us to identify the possible vacancies. In this 6 patent maps, 5 vacancies were identified and the patents around them were analyzed (Fig.13). We found that there are two vacancies containing potential opportunities.

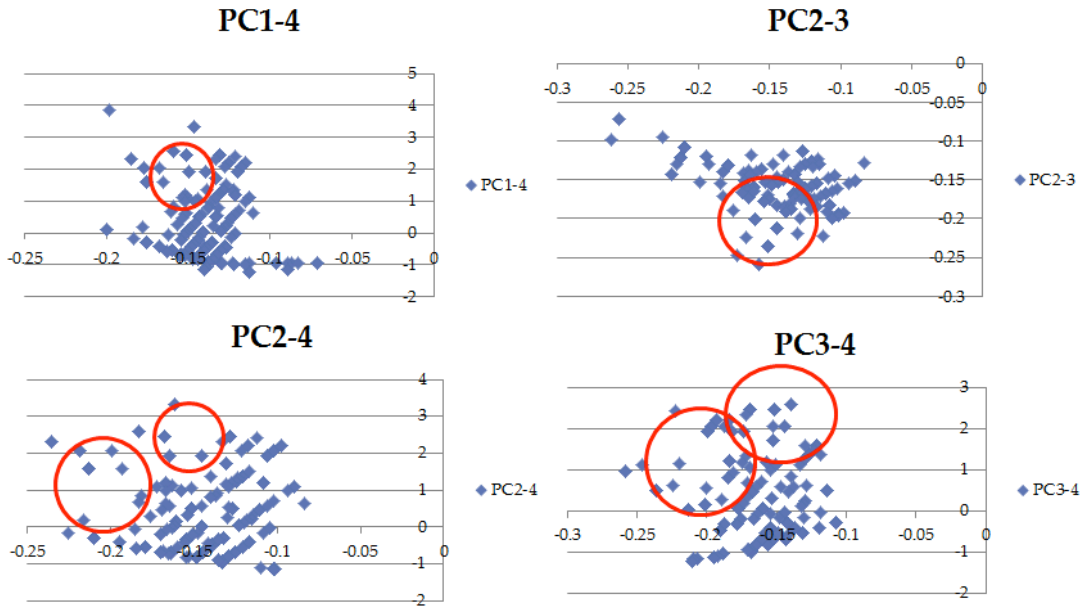
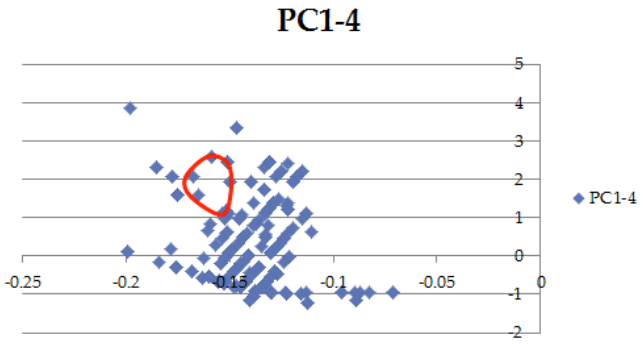


Figure 13. Five vacancies identified by experts

The first vacancy is in map PC1-4 with 12 patents around it (Fig.14). The trend of these 12 patents shows that there was a develop gap in 2010, but was overcame in 2011. In USPTO_databases, it usually takes about a year to examine the patents, so there will be a year delay (Fig.15). The related technology is still under development in recent year with the core concepts "Rapid detection of polynucleotide and protein" and "Elastic layer and fluid channel". The second vacancy is in map PC3-4 with 26 patents around it (Fig.16). The patent trend also shows that the related technology is still on development in recent years (Fig.17). The core concepts of these patents are "Temperature control system", "Membrane and Electrophoresis" and "Crystallization".



Patent List	
US8440093	US7462449
US8845914	US7501245
US7442556	US7351376
US7526741	US7622081
US7820427	US8129176
US8163492	US8257666

Figure 14. The first vacancy

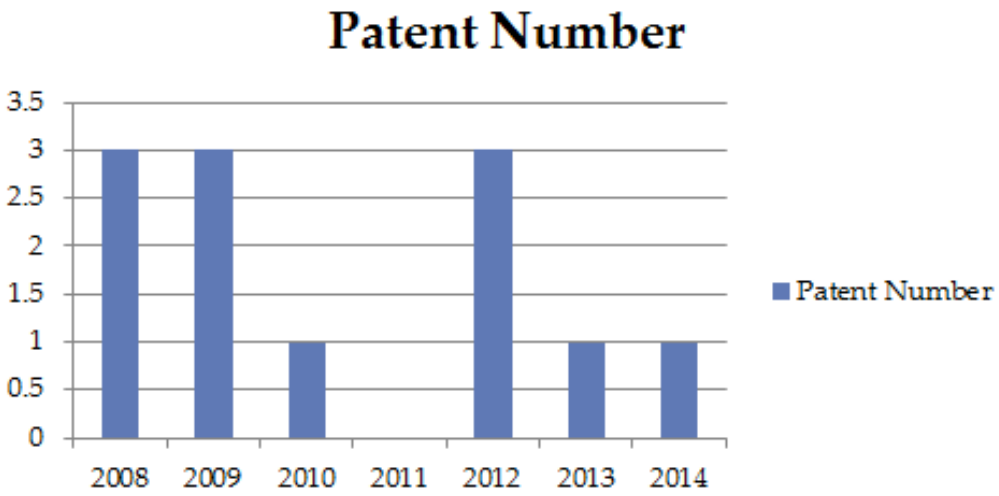
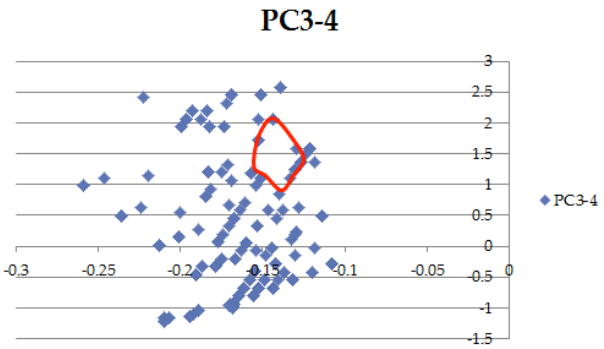


Figure 15. Patent trend of the first vacancy



Patent List	
US7833708	US8052792
US8486636	US7195670
US7459022	US7279146
US7927422	US7306672
US8691010	US7479186
US7820427	US7704322
US8163492	US8002933
US7143785	US8021480
US7291512	US8104515
US7052545	US8382896
US7670429	US8695640
US7217321	US8709152
US7244402	US7526741

Figure 16. The second vacancy

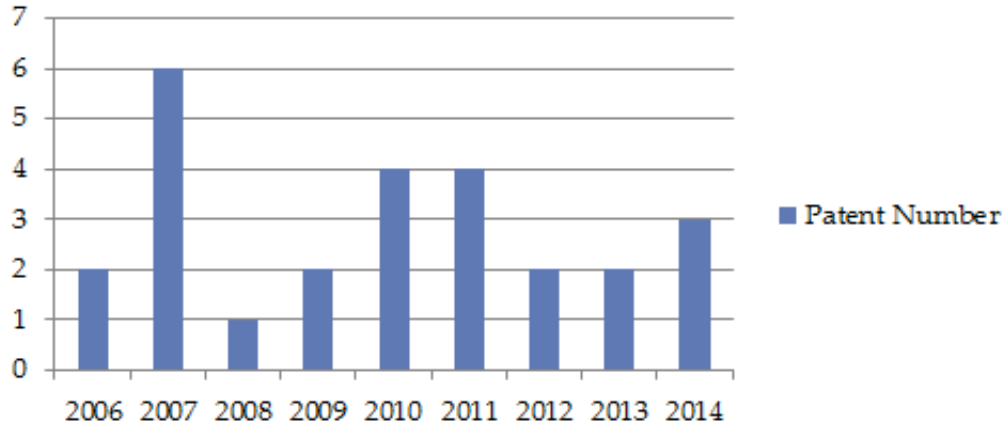


Figure 17. Patent trend of the second vacancy

4. Conclusion

According to the biochip literature (Transparency Market Research, 2014), the future trend of microfluidic technology will be used to customize disease diagnosis. In the future, traditional large detection machines will be replaced by customizing biochips. With the biochip, people can easily examine their health any time and any place. The key technology of customizing disease detection is “Rapid separation and detection of polynucleotide and protein” which is the same to our result.

This research shows a useful way to find technology opportunities through keyword based patent analysis. Companies can reduce development costs and time to discover potential technological opportunities. The opportunities may exist in patents around identified vacancies, so that firms can use them as a reference to find possible technological opportunities. It makes SMEs have more chance to develop their own technologies and products.

However, there are still some limitations in this research. First, this method is suggested to support incremental innovation rather than radical innovation. This is because that the opportunities are found through the relationship between current technologies. Second, the vacancy we have found may not be a real opportunity, managers have to do further evaluation before making investment decisions.

References

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