# Scientometric Analysis of Global Flexible Display Technology

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**Abstract.** Based on the patent data collected in Derwent Innovations Index, this paper uses scientometric analysis to visualize the patent application trends, regional distribution and R&D institutions of flexible display technology. By identifying the hot spots and frontier areas of flexible display, this paper comprehensively understands the development status and future trends of the field. Results show that Chinese enterprises have made breakthroughs in some key technologies, but Korea and Japan still master the important technology. Chinese enterprises need to increase R&D investment in order to occupy the important position of flexible display market.

## 1. Introduction

In recent years, flexible display has attracted more and more attention. According to relevant departments, flexible displays will account for 16% of global display revenue by 2023, compared with 1% in 2013[1]. In addition to having broad market prospects, China is actively promoting the development of flexible display industry, and listed it as the national "13th Five-Year" strategic development focus areas. Chinese enterprises are also beginning to occupy the flexible display market slowly. With the mass production of BOE's 6th generation flexible AMOLED production line, the industry monopoly of Korean has been broken, accelerating the development of China's flexible display industry and greatly increasing the supply of flexible display.

In order to maintain competitive advantage, enterprises usually use patents to protect their technological innovations. According to the statistics of the World Intellectual Property Organization, more than 90% of technological innovations in the world will be reflected in the patent literature[2]. This paper analyzes the relevant patents of flexible display in order to provide basis and reference for relevant departments and researchers to formulate relevant strategies and grasp the direction of scientific research.

## 2. Data collection

The Derwent Innovations Index is the world's most comprehensive database that containing patent information published by more than 40 patent agencies worldwide. Through extensive reading of relevant literature, the IPC related to flexible display is determined. This paper uses the strategy of combining keywords and IPC to collect patents from Derwent Innovations Index. Further, a Python program is developed by authors to clean and integrate the collected data including 8116 patents granted from 1963 to 2018.

## 3. Development status of flexible display technology

### 3.1 Application trend analysis and development stage division

Fig. 1 shows the annual distribution of patent applications. Considering the 18-month lag between patent application and disclosure, the data of 2017 and 2018 are for reference only. It can be divided into the following three stages:

（1）Exploration period：1971-1994

In the more than 20 years since the first appearance of flexible display related patents, there are only 185 patents in the world. In most countries, flexible display technology is in its infancy and

begins to develop slowly. During this period, Japan, the United States and Germany accounted for 90% of the total number of patent applications, of which Japan ranked first with 130 patents.

（2）Slow growth period: 1995-2010

During this period, there were 2351 patents in the world, and Japan's technology still maintained its leading position, while Korea and China also came to the fore, occupying a place in the global flexible display field. Commercial activities have promoted the development of flexible display. Therefore, it has attracted more and more attention, and new research institutes are constantly joining the ranks of R&D.

（3）Rapid growth period: 2011-present

Since 2011, the number of flexible display patent applications has witnessed an explosive growth. Up to the date of retrieval, there are 8116 related patents in the world, and more than 3000 institutions have joined the ranks of technology research and development. Patent applications for flexible display technology in China is growing in a straight line and China is beginning to enter the era of flexible display.

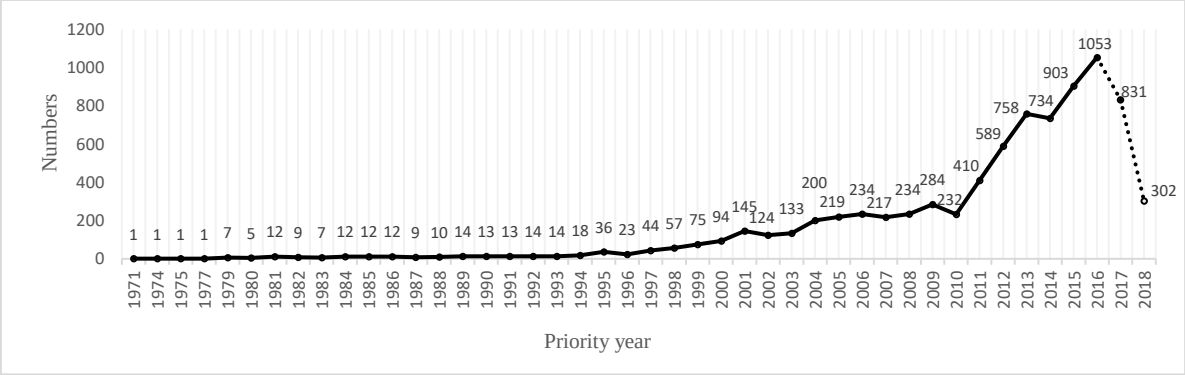


Fig. 1. Time trend chart of patent applications

### 3.2 Analysis of regional distribution

In this paper, 8116 patents are retrieved and extracted according to the priority country. The statistical results are shown in Fig. 2. As can be seen from the figure, the total number of patent applications in Korea, China, Japan and USA has reached 93% of the total global patent applications which indicates that these four countries have strong independent innovation ability and are the major R&D powers in the field of flexible display.

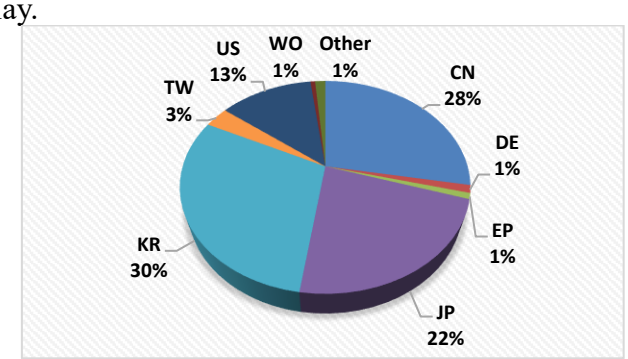


Fig. 2. Regional distribution based on priority

Fig. 3 shows the annual distribution of patent applications in the above four countries from the perspective of priority years. In the early 1970s, the United States began to apply for patents in the field of flexible display. Later, Japan has joined the ranks of R&D, and the development rate is faster than the United States. In the mid and late 1990s, China and Korea began patent application activities one after another, but at this time Japan has made great progress in this field. After 2010, Korea and China have shown a strong momentum of development. Although China's entry into this field is relatively late, domestic enterprises will have more voice in the international arena due to the government's active support policy, which effectively promotes the scale expansion of flexible display industry and the speed of technological upgrading.

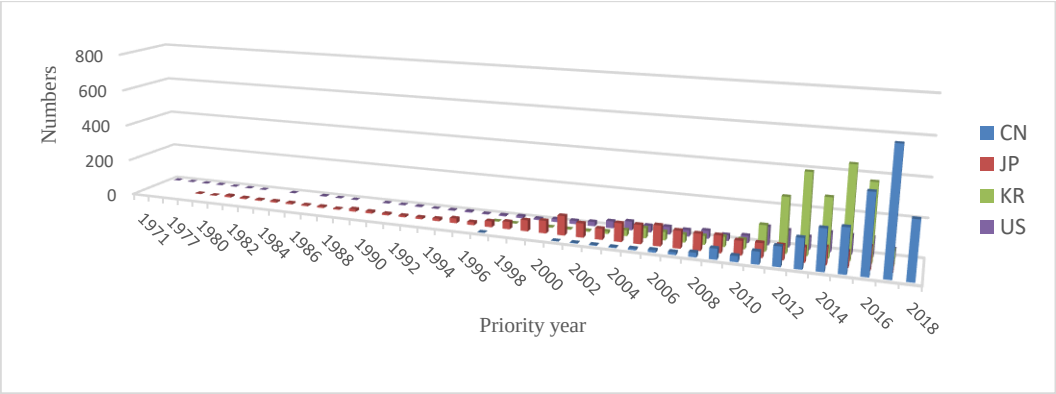


Fig. 3. Annual distribution of patent applications in major countries

### 3.3 Analysis of major R&D institutions

Table 1 lists the top ten patentees and the number of patent applications. As can be seen from the figure, Samsung and LG have the most outstanding technical strength in the field of flexible display and attach great importance to patent application and protection. Following is BOE of China, which has 864 applications. Although there are still many gaps with the top two, but with the mass production of the 6th generation flexible production line, BOE's comprehensive competitiveness in high-performance display products will be greatly enhanced, and meet the growing demand for small and medium-sized display products. At present, many domestic enterprises have jointly contributed to the flexible display market. In the future, more 6th generation production lines will be mass produced in succession. The domestic flexible display industry will develop to a new height.

Table 1. The main patentee and the number of applications

| Patentee | Code | Numbers | Country |
|---|---|---|---|
| SAMSUNG DISPLAY CO LTD | SMSU-C | 2429 | Korea |
| LG DISPLAY CO LTD | GLDS-C | 1201 | Korea |
| BOE TECHNOLOGY GROUP CO LTD | BOEG-C | 864 | China |
| UNIVERSAL DISPLAY CORP | UVDI-C | 710 | USA |
| SHANGHAI TIANMA MICROELECTRONICS CO LTD | CHAV-C | 404 | China |
| WUHAN CHINA STAR OPTOELECTRONICS TECHNO | TCLC-C | 331 | China |
| KUNSHAN GUOXIAN PHOTOELECTRIC CO LTD | VSNO-C | 300 | China |
| PANASONIC LIQUID CRYSTAL DISPLAY CO LTD | MATU-C | 261 | Japan |
| SHARP KK | SHAF-C | 200 | Japan |
| AU OPTRONICS CORP | AUOP-C | 189 | China |

## 4. Hotspot and frontier analysis of flexible display technology

### 4.1 Identification of technological hotspots based on IPC

Through the statistical analysis of IPC, we can get a general understanding of the key technology research in this field, and then master the technology development trend[3]. According to IPC, this paper counts the top ten hot technologies of flexible display, as shown in Table 2.

Table 2. Hotspot IPC and its interpretations

| IPC | Technical interpretation | Numbers |
|---|---|---|
| G09F-009/00 | Indicating arrangements for variable information | 2147 |
| G09F-009/30 | In which the desired characters are formed by combining individual elements | 2009 |
| H01L-027/32 | With components specially adapted for light emission | 1682 |
| H01L-051/00 | Solid state devices using organic materials as the active part | 1396 |
| H01L-051/52 | Details of devices | 1216 |
| H01L-051/50 | Specially adapted for light emission | 1191 |
| G02F-001/1333 | Constructional arrangements | 977 |

| | | |
|---|---|---|
| H01L-051/56 | Processes specially adapted for the manufacture of such devices or of parts thereof | 922 |
| G06F-001/16 | Structural component or configuration | 842 |
| G02F-001/1345 | Conductors connecting electrodes to cell terminals | 602 |

Combined with the division of the three development stages of flexible display above, the radar map of IPC distribution at each stage is drawn (see Fig. 4). As can be seen from the figure, the distribution of IPC in the first stage is quite different from that in the total ranking of IPC (Table 2), but not in the latter two stages. This indicates that the technical hotspots in the germination period have been gradually eliminated with the development of technology, and new technologies have been added. G09F-009/00 and G09F-009/30 are in three stages, and rank the top two in the total ranking of IPC, so the two technologies are the most popular R&D fields of flexible display. H01L-027/32, H01L-051/00 and H01L-051/52 only appeared in the third stage, but they ranked the top five in the total ranking of IPC. It indicates that the three areas have great potential for development, and there is still much room for improvement in the future.

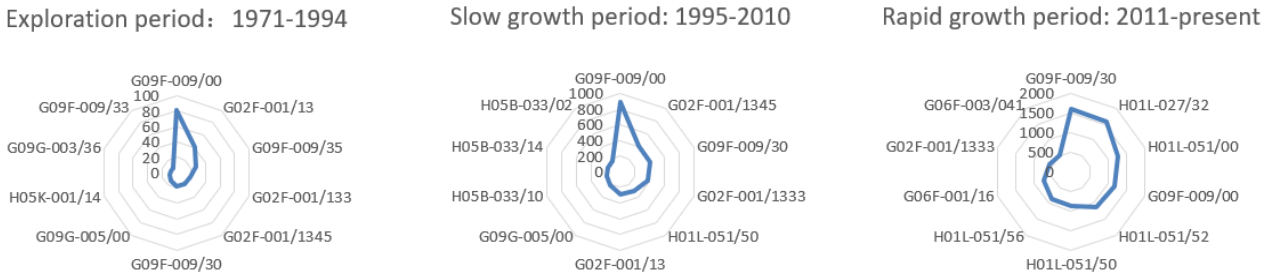


Fig. 4. Radar map of IPC distribution at each stage

## 4.2 Identification of frontier technologies based on Derwent Classification

Research hotspots and research frontiers are two concepts that cannot be confused. Professor Chen pointed out that the research frontier is a set of emerging dynamic concepts and potential research problems [4]. In this paper, CiteSpace is used as an analysis tool. Table 3 shows the analysis results of the emerging words in the flexible display field. The frequency change rate is expressed by burst intensity. The higher the burst intensity is, the higher the word frequency change rate will be. It can be used to determine the frontier field and development trend of a technology[5].

As can be seen from Table 3, P85 and P81 have high frequency and high burst intensity. These two kinds of technologies have been emphasized since the early development of flexible display. Combined with the analysis of the hot spots above, P85 and P81 are still the frontier concerns of flexible display technology. X26, T04 and V05 began to emerge in the slow growth period. They are the basic technologies of flexible display that enterprises should master and try to develop and break through. E11 and E19 are technologies that have emerged in recent years. The intensity and frequency of emergence are not very high, and they have great potential. They are the frontier technologies of flexible display that enterprises should focus on.

Table 3. Frontier technologies of flexible display

| DC | Technology field | Burst intensity | Frequency | Begin | End |
|---|---|---|---|---|---|
| P85 | Education, cryptography, adverts | 188.9784 | 1893 | 1979 | 2006 |
| P81 | Optics | 163.5075 | 990 | 1979 | 2006 |
| W05 | Alarms, Signalling, Telemetry and Telecontrol | 57.6184 | 323 | 1983 | 2007 |
| X26 | Lighting | 46.4128 | 269 | 1995 | 2009 |
| T04 | Computer Peripheral Equipment | 27.3369 | 939 | 1992 | 2004 |
| V05 | Valves, Discharge Tubes and CRTs | 26.3506 | 243 | 1998 | 2007 |
| X15 | Non-Fossil Fuel Power Generating Systems | 19.0998 | 214 | 2010 | 2012 |
| E11 | Containing P and/or Si | 12.9489 | 85 | 2016 | 2018 |
| E19 | Other organic compounds general | 12.8396 | 78 | 2014 | 2018 |
| U14 | Memories, Film and Hybrid Circuits | 10.649 | 2565 | 2004 | 2005 |

## 5. Summary

In recent years, with the continuous expansion of the flexible display market, various new technologies are emerging and developing rapidly, and patent applications in China are also rapidly increasing. Chinese enterprises have made many breakthroughs in key technologies of flexible display. However, at this stage, Korea and Japan have obvious advantages in patent layout due to their mature technologies. Domestic companies still face many technical difficulties. If they want to compete with Korea and Japan in the future, they need to increase R&D investment and maintain a high degree of innovation sensitivity, while strengthening cooperation with upstream and downstream enterprises in the industrial chain to increase market share.

As the next generation of mainstream display technology, flexible display has broad prospects for development. Low power consumption, flexibility and other characteristics enable flexible display to meet the screen requirements of different types of equipment. Enterprises should be brave to explore the development and demand of display technology in the future, design flexible display products that can truly meet the personalized and functional needs of consumers, and grasp the opportunities and challenges brought by industrial change.

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