



# Global Patent Analysis of Foreign Object Detection in Wireless Charging

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**Abstract.** In recent years, wireless charging has become a hot topic, and many component suppliers, car companies, and technology companies have begun testing wireless charging for alternative fuel vehicles. This study uses relevant patent analysis tools to analyze the output of global patents on foreign object detection for wireless charging through patent bibliometric methods. It explores the focus, hot spots, and frontiers of patent research in this scientific field, which helps researchers master the status and development trends of scientific research in this field.

**Keywords:** wireless charging · foreign object detection · patent analysis · global patent

## 1 Introduction

Many countries around the world have vigorously promoted electric vehicles to save energy and reduce environmental pollution [1]. However, due to the limitations of battery capacity and charging infrastructure, charging problems have become one of the main bottlenecks in developing electric vehicles [2]. Since wireless charging technology can solve the interface limitation and safety problems faced by traditional conductive charging, it has gradually developed into the primary way of charging electric vehicles [3–5]. It has the advantages of solid environmental affinity, green energy, convenience, flexibility, safety, and other benefits compared with traditional contact power transmission [6].

This study uses relevant patent analysis tools and patent bibliometric methods to analyze the output of foreign object detection patents for wireless charging in various countries around the world. It also examines the patent research focus, hot spots, and frontiers in this scientific field, which helps researchers understand the current situation and development trends of foreign object detection for wireless charging.

## 2 Methodology

This study adopts INCOPAT, a patent search and analysis tool, to analyze the output of patents for foreign object detection in wireless charging in various countries around the

world. The content involves (1) technical analysis, (2) regional analysis, and (3) applicant analysis. In addition, these types of analysis are used to present the characteristics of technological innovation activities in this field. This study selects multiple indicators of these types of information to explore the focus, hot spots, and development trends of foreign object detection technology in wireless charging in global patents.

Using the INCOPAT database, the data before July 5, 2018, was collected.

The search formula was (TIABC = ((wireless or contactless or non-contact) and (power and trans\* or charg\*) or WPT or inductive power or resonant coupling) or IPC = (H02J7/00 OR H02J7/02 OR B60L11/18 OR H02J5/00 OR H02J17/00 OR H02J50/10 OR H02J50/60 OR H02J50/12 OR H01F27/28 OR H01F27/42 OR H01F38/14 OR G01R33/10 OR G01R33/24 OR H04B7/00 OR G01V3/14 OR G01V3/10 OR G01V3/12)) AND TIABC = ((metal or foreign object or foreign matter or foreign object) (9n) (monitor\* or detect\*) or FOD), 737 patents have been located. Therefore, the global patent analysis of foreign object detection in wireless charging was conducted with 737 patents as the benchmark.

### 3 Analysis of the Global Patent Situation of Foreign Objects of Wireless Charging

#### 3.1 Overview of Patent Applications

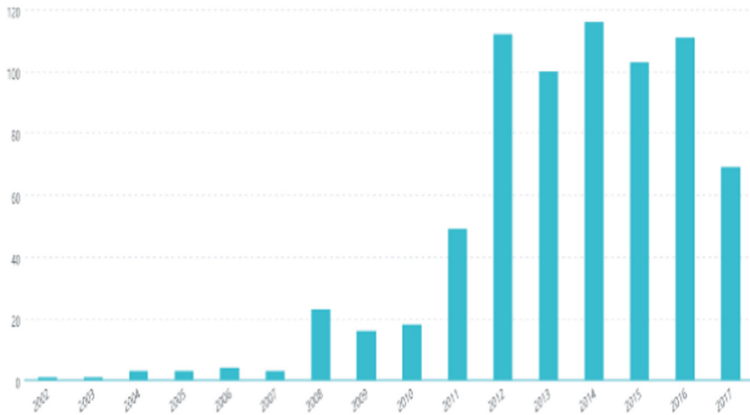
##### 3.1.1 Annual Number of Patent Applications

Figure 1 shows the trend of the number of patent applications for foreign object detection in wireless charging. This trend shows the change in patent application hotness in each period. From 2002 to 2017, the number of patents for foreign object detection in wireless charging worldwide showed a rapid growth trend, reaching the highest number of 116 in 2014. After 2011, a research boom and increased growth of patent applications in this field were observed. Considering the delay in patent disclosure time, the data for 2017 as of the time of search is only a half-year value, which shows that the research in this field continues to be popular.

##### 3.1.2 Regional Analysis

The patent application countries of foreign object detection in wireless charging mainly include Japan, China, the United States, and South Korea (see Table 1). Among these countries, Japan ranks first in the world with 201 applications, reflecting that Japan plays a leading role in the research of foreign object detection in wireless charging and has a more significant application prospect in this field, prompting all the research subjects to make the patent layout in this country. In May 2011, the University of Tokyo and Nagano Japan Radio Co., Ltd. Developed a magnetically coupled resonant electric vehicle wireless charging system. Furthermore, on March 18, 2016, Toyohashi University of Technology and Taisei Construction Co. Unveiled the world's first battery-free battery car, which generates electricity through an electrified road.

On the other hand, China and the United States are also major countries in terms of patents in this field, with 171 and 130 patents, respectively, ranking second and third.



**Fig. 1.** Patent applications over the years

**Table 1.** Number of patents in the main filing country

Countries of the patent disclosure	Number of patents
Japan	201
China	171
United States	130
WIPO	89
Korea	42
Germany	40
European Patent Office	26
United Kingdom	13

Therefore, this analysis allows us to understand the active situation of technological innovation in different countries and discover the central source countries of technological innovation and the critical target markets.

### 3.1.3 Applicant and Competitor Analysis

Figure 2 shows the ranking of applicants according to the number of patents of their applicants (patent holders). For example, regarding the number of patent applications, Toyota Motor Corporation has 30 basic patent applications, which Panasonic Electric Corporation closely follows with 27.

### 3.1.4 Patent Assignee Analysis

Figure 3 shows the ranking of patent assignees according to the number of patents that have been transferred. This analysis shows the technology introduction of each assignee

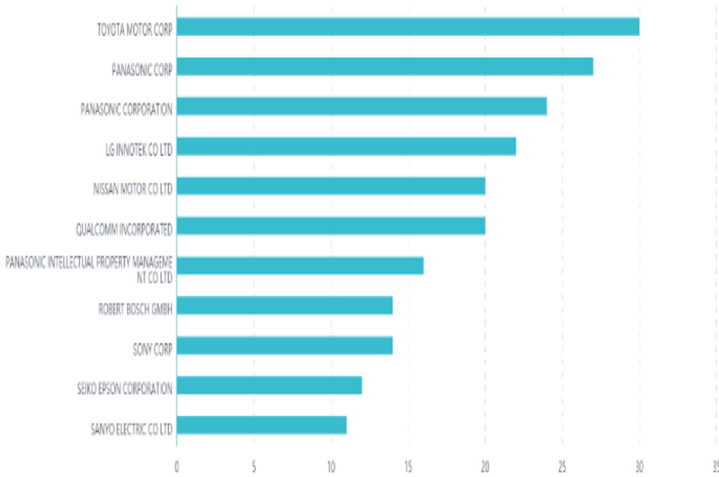


Fig. 2. Ranking of patent applicants

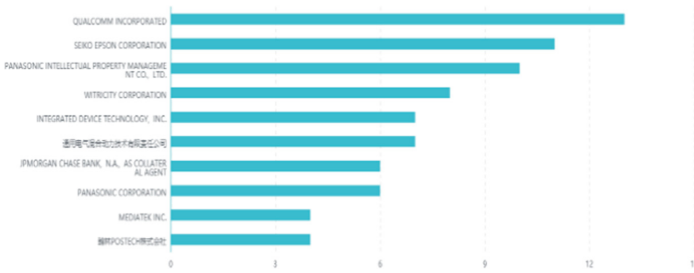


Fig. 3. Ranking of patent assignees

and predicts the direction of its next technology and market deployment. As can be seen from Fig. 3, the top three patent assignees are Qualcomm (13), Cisco Epson (11), and Panasonic IP Management (10). These three companies are optimistic about developing this technology field and have made corresponding patent layouts.

### 3.2 Main Technology Types of Patents

#### 3.2.1 Overview Analysis of Main Technology Types

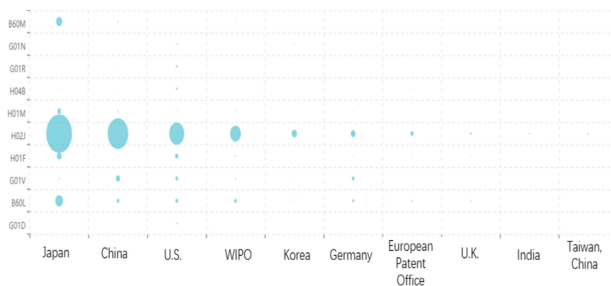
From the leading technology types of patents, patent applications for foreign object detection in wireless charging are mainly concentrated in 11 categories as shown in Table 2.

#### 3.2.2 Distribution of Main Technology Types by Country/Region

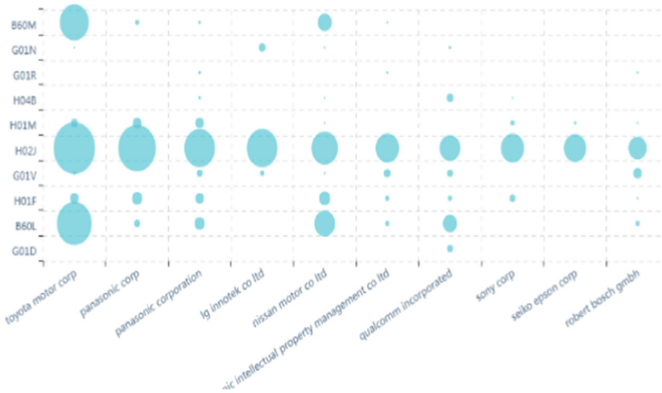
From the distribution of the main technology types, the one proposed for the patent application is mainly concentrated in H02J, which shows that the patent technology of

**Table 2.** Distribution of major IPC patents

IPC number	paraphrase	Number of patents
H02J	Circuit devices or systems for power supply or distribution; electrical energy storage system; electrical energy conversion with circuits or devices, such circuits or devices	701
B60L	Electric vehicle power unit	165
G01V	geophysics; gravimetry; detection of substances or objects; Tracer	96
H01F	Magnet; inductance; transformer; choice of magnetic material	95
B60M	Power lines for electric vehicles or devices along rails	64
H01M	A method or device used to directly convert chemical energy into electrical energy, such as a battery pack	52
H04B	Transmit	38
G01R	Measurement of electrical variables; measure magnetic variables	26
G01N	Testing or analyzing materials by determining their chemical or physical properties	17
G01D	Measurements that are not specific to specific variables; devices for measuring two or more variables not included in other separate subclasses; billing equipment; measurement or tests not included in other categories	8
G01S	Radio orientation; radio navigation; use radio wave ranging or speed measurement; localization or presence detection using reflection or re-radiation of radio waves; similar devices with other waves	8

**Fig. 4.** Country/region map of major technology types

wireless charging foreign object detection is used primarily on the power supply device of electric vehicles. However, the United States has comprehensive technology coverage in this field, covering almost all types of technology in Fig. 4.



**Fig. 5.** Distribution of major technology types and technology fields

### 3.2.3 Distribution of Applicants in Major Technology

Figure 5 shows the distribution of applicants' patents in each technology field. This analysis aims to study the technical areas, technical directions, and technical strengths that the principal applicants focus on from a technical point of view. The distribution of primary technology-type applicants is shown in Fig. 5.

As seen from the Fig. 5, the basic patent applications of research institutions in foreign object detection for wireless charging are mainly focused on H02J, B60L, B60M, and H01F. The patent layout of foreign object detection for wireless charging is primarily on the power supply system of the power unit of electric vehicles. It is noteworthy that Toyota is ahead of other organizations in the patent application for the power line or the device along the road track of the B60M electric vehicle. Almost all organizations have apparent involvement in the H01F technology direction, which involves magnets; inductors; transformers; selection of magnetic material; and other technology research directions and is a relatively common patent application technology area. It also reflects that foreign object detection research hotspots are concentrated in this field.

## 3.3 In-Depth Analysis of Foreign Object Detection Patents for Wireless Charging

### 3.3.1 Patent Technology Map Analysis

From the technical themes of the 737 essential patents on foreign object detection technology for wireless charging, the technical focus of the patents is mainly on mode detection (see Fig. 6). Also, it includes charging systems, wireless induction, power transmission, and radio transmission. The number of patent applications in this technology area is wireless induction (213), pattern detection (179), charging system (134), and power transmission (117).

Figure 7 shows the patent layout of the main patent application institutions in this technology area regarding the main technology topics. It indicates that each institution has a different focus.

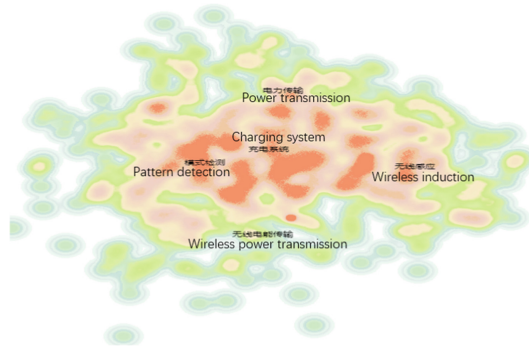


Fig. 6. Patent technology map

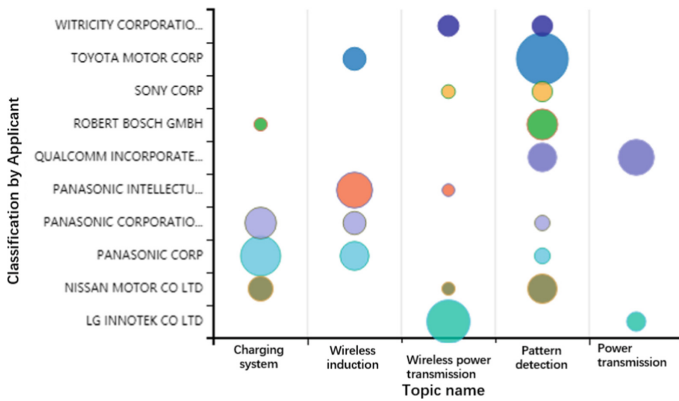


Fig. 7. Distribution of patents by major patenting institutions in the main technology subject

### 3.3.2 3D Patent Sandbox Analysis

A three-dimensional (3D) patent sandbox is an advanced tool for patent strategy analysis. By conducting simulations in the sandbox, we can quickly focus on the hot spots of patent layout and understand competitors' R&D direction and structure to improve our patent quality and market competitiveness. The 3D patent sandbox shows the competitive situation of technology with a 3D topographic map, with peaks representing technology-intensive areas and troughs representing technology gaps. Different colors can mark diverse patent applicants to show the competitive situation clearly. Each point represents a patent, and the closer the issues are, the higher the relevance of the technology. The 3D patent sand chart in Fig. 8 shows that the technology-intensive areas are foreign object detection/quality factor; transmission device/power; resonant circuit; power; coil/power device/foreign object, and fierce competition.

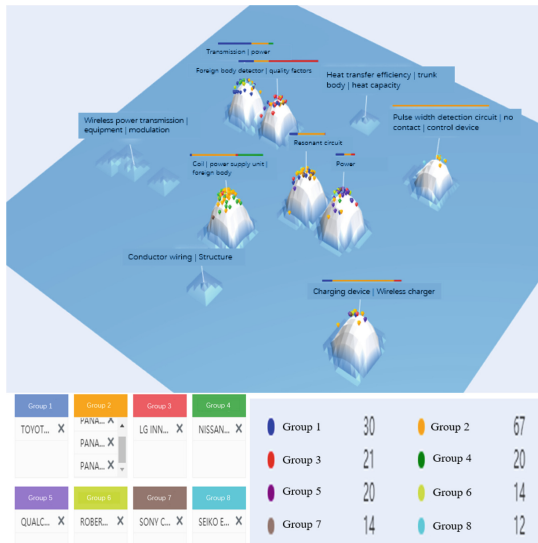


Fig. 8. D Patent Sandbox Analysis

## 4 Conclusion

The analysis reveals that the global patent of foreign object detection in wireless charging has rapidly grown in the period of 2002 to 2017. From the perspective of international countries who apply for patent applications, the ones who apply for patents for foreign object detection in wireless charging mainly include Japan, China, the United States, and South Korea. Japan ranks first in the world regarding the number of applications, reflecting its dominant position in researching foreign object detection in wireless charging. From the perspective of the leading technology types of patents, the patent applications for foreign object detection in wireless charging mainly focus on the power supply system of the power unit of electric vehicles. The technology-intensive areas are foreign matter detection/quality factor; transmission device/power; resonant circuit; power; coil/power supply device/foreign matter; and intense competition.

This paper analyzes the global patents of foreign matter detection of wireless charging to understand technology development. It aims to help researchers understand the current situation and development trend of scientific research and provides a reference for the subsequent patent strategy and layout in this field.

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