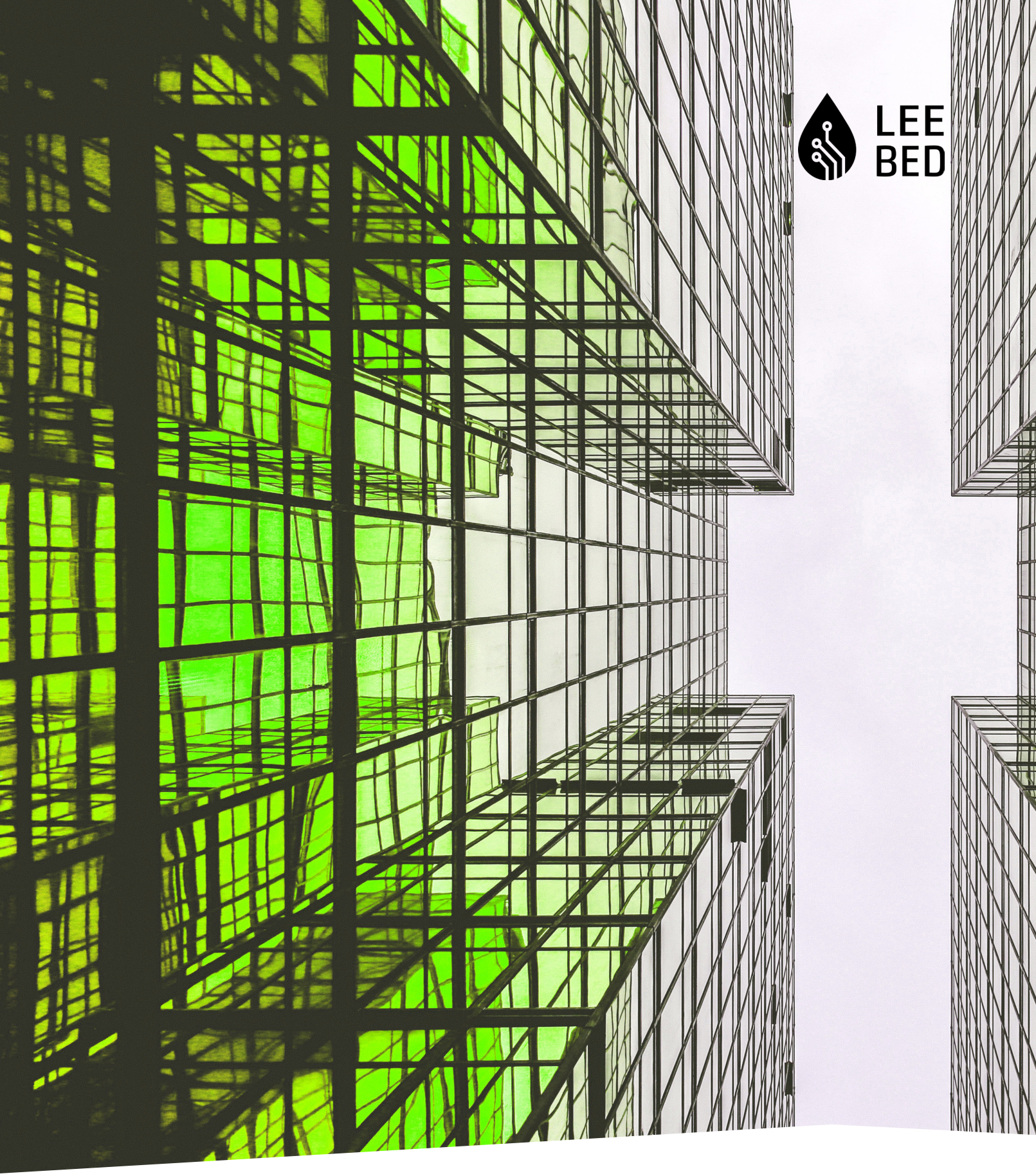

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DANISH TECHNOLOGICAL INSTITUTE

GLOBAL TRENDS IN PRINTED ELECTRONICS – PATENT MAPPING

REPORT 2021

Titel:
Global Trends in Printed Electronic - Patent Mapping
Report May 2021

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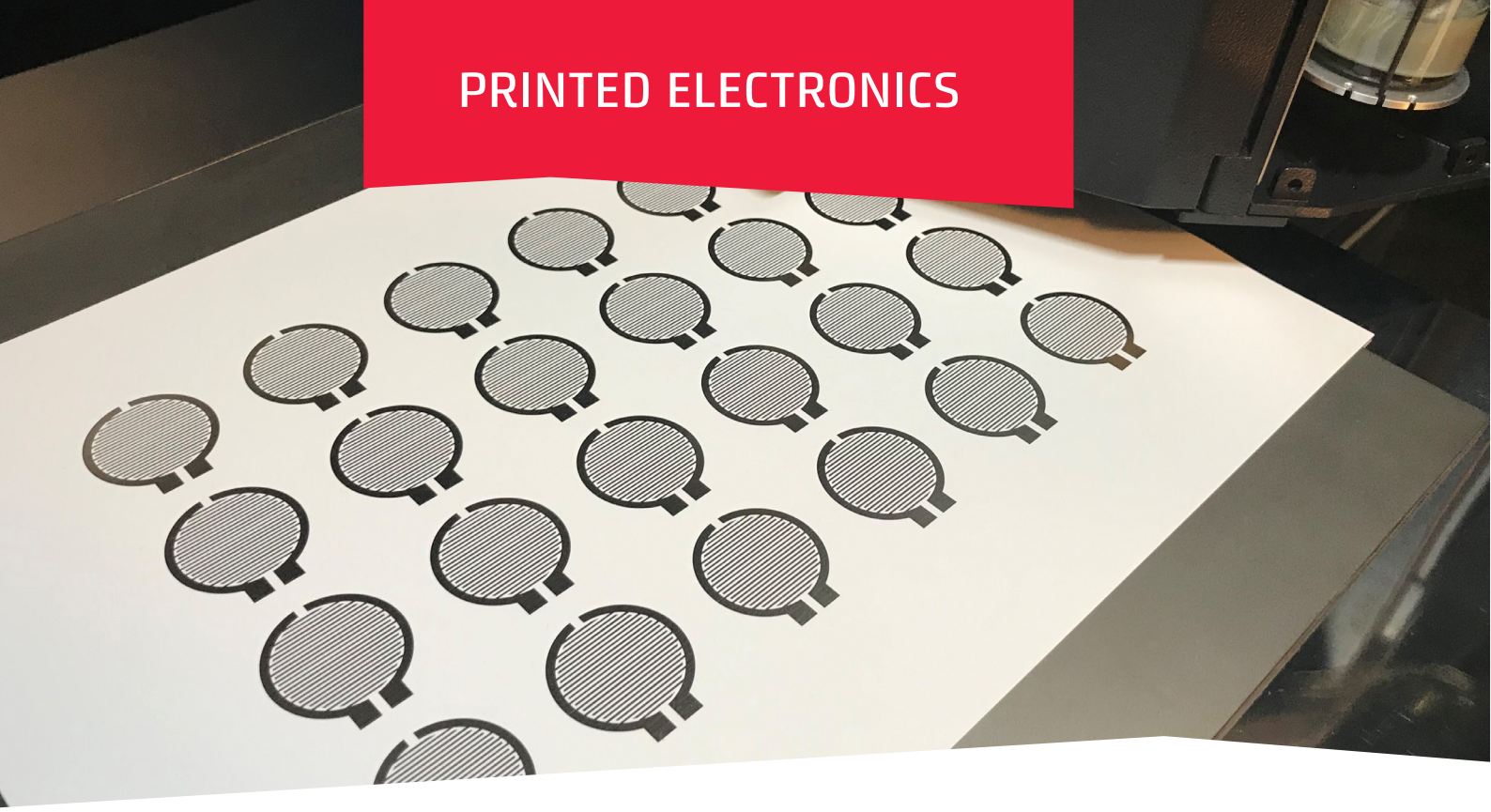
Content



Into the future with printed electronics technologies

Printed electronics is an emerging technology offering technological opportunities to produce embedded electronics that are typically integrated in flexible materials, see Textbox 1.

This report presents an overall review of technology developments within printed electronics described by patent data. Our strategy in the search for re-

TEXTBOX 1: WHAT IS PRINTED ELECTRONICS?

'Printed electronics' is an all-encompassing term for the printing method used to create electronic devices by printing on a variety of substrates. Originally, printed electronics related to organic or plastic electronics that use one or more inks made of carbon-based compounds. As demand for wearable devices and thinner electronics expands, printed electronics is used to form flexible keyboards, antennas, electronic skin patches and more.

Printed electronics has become secure, flexible, and cost-effective, all of which make the technology appealing to a broad range of industries. Printed electronics has the potential to reduce costs and technical constraints typically associated with mass producing electronics.

Source: www.pannam.com/blog/what-is-printed-electronics/

PRINTED ELECTRONICS

levant patents is to identify a core set of patents that are highly relevant to printed electronics. Such a broad scan of patents indicates to which extent the industry should pay attention to printed electronics. Thus, we have identified 18,980 patent families related to printed electronics which can be used as a point of departure for more detailed searches such as searches for specific technological solutions or applications. If your company wants to develop new products incorporating printed electronics, we recommend a detailed search that provides you with strategic business intelligence about current technological solutions and potential competitors/partners[1].

In the last decades, printed electronics has undergone significant technological developments, and especially in the last few years the numbers of patents mentioning printed electronics has increased significantly. In the period 2018-2020, 30% of all patents from 2000-2020 have been published. Currently, significant technological developments are taking place within printed electronics, and market forecasts expect a marked increase in turnover in the printed electronics market in the future. The industry has increasingly focused on the many new possible printed electronics applications and companies, and research organisations have developed an increasing number of unique printed electronics solutions.

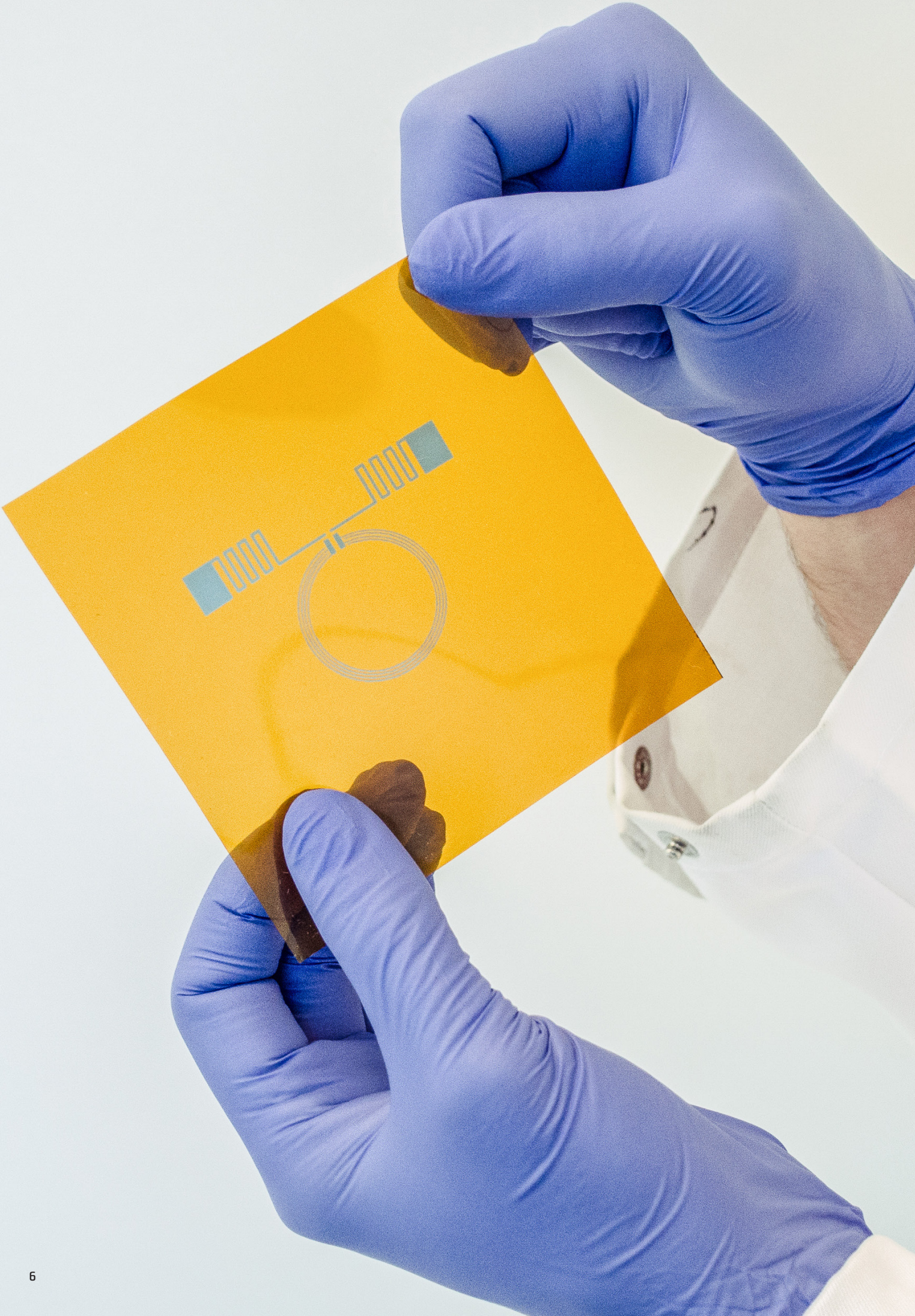
Even though printed electronics represents many different groups of technologies, about one in four patents is classified as printed circuits on flexible materials and a little under a fourth of the patents is characterised by the use of flexible or folded printed circuits.

In 2015, approx. 80% of all assignees, e.g., patenting companies, were based in three countries with Japan topping the list followed by the US and South Korea meaning that Japanese, US, and South Korean companies are the main technological developers of printed electronics. However, in 2015, China entered the printed electronics stage and the numbers of patents granted to assignees in China rose dramatically. In 2020, Chinese assignees stood for most printed electronics patents. Europe is lacking behind with Germany as the exception.

Since 2000, most of the patents within printed electronics have been granted in the US. Thus, the US dominated the field by number of published patents and will presumably continue to do so in the future.

This report is divided into two sections, i.e., a global and a European perspective. The first section of the report presents global hotspots with the most frequent keywords in the identified patents and it presents a landscape for printed electronics-related technologies. Furthermore, the global hotspots present the intensity of patent publications across time, by countries and across patenting companies. The second section focuses on patents granted to European companies as we want to examine the global position of European companies as well as geographical differences within Europe.

[1] For a detailed presented of our applied method, see Danish Technological Institute (2019): Patent mapping your idea (www.teknologisk.dk/40890)



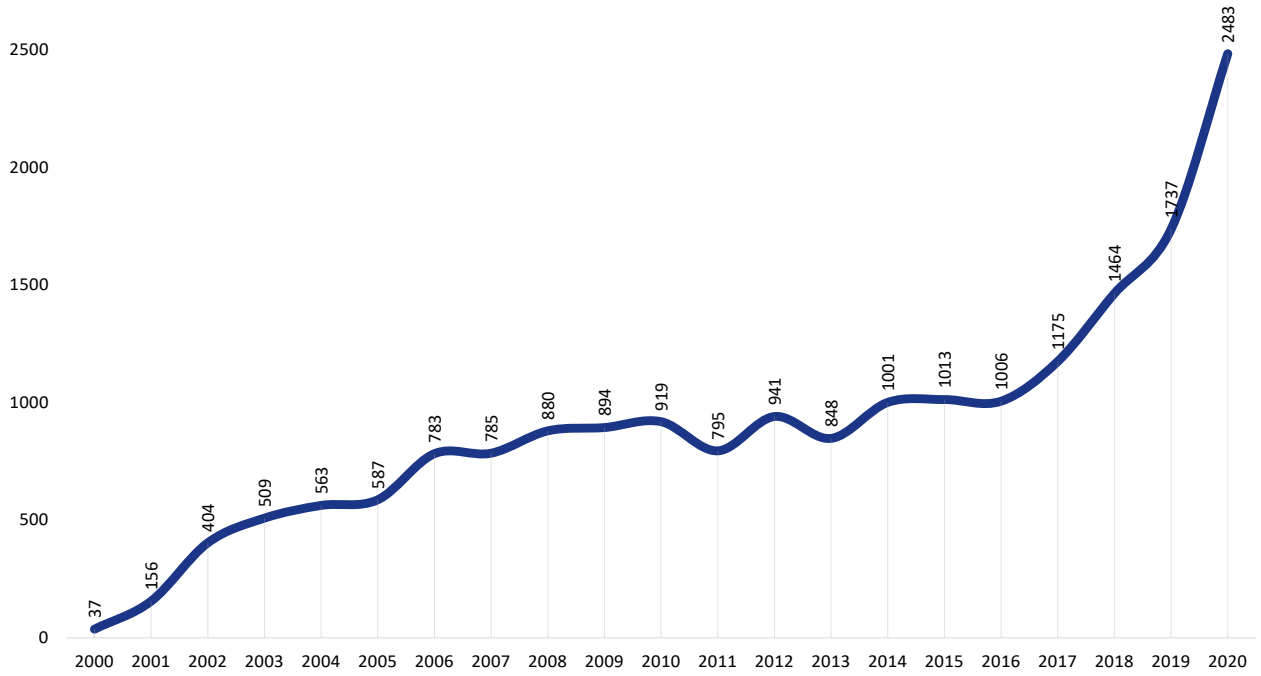
Global hotspots within printed electronics

For the period 2000 to 2020, we have identified 18,980 patent families related to printed electronics. Over this period, the number of printed electronics patent publications developed incrementally until 2015 when the number of patents took off see Figure 1. Since the processing time for patents to be published can last a few years the number of printed electronics patents from 2019 and 2020 is expected to rise even more.

Market studies estimate that the market for printed electronics will grow significantly in the future as the total market is expected to grow from USD 41.2 billion in 2020 to USD 74 billion in 2030[2]. Thus, the number of patents will presumably continue to grow in the future.

[2] IDTechEx: Flexible, Printed and Organic Electronics 2020-2030: Forecasts, Players and Opportunities (https://www.idtechex.com/en/research-report/printed-organic-and-flexible-electronics-2020-2030-forecasts-technologies-markets/687).

FIGURE 1: PUBLISHED PATENTS WITHIN PRINTED ELECTRONICS, 2000-2020



Note: Extract 5. May 2021. N: 18980 patent families.
Source: PatSnap, processed by Danish Technological Institute

Global technological hotspots

We have identified a group of approx. 19,000 printed electronic-related patents using the technological classification system Cooperative Patent Classification (CPC), see Textbox 2[3].

Patents usually feature more than one CPC-code. Hence the total numbers of patents distributed by CPC-codes will exceed 18,980 in Figure 2.

[3] See page 19 for an introduction to the applied method

TEXTBOX 2: SHORT INTRODUCTION TO THE SYSTEM USED TO CLASSIFY TECHNOLOGY

The Cooperative Patent Classification (CPC-codes) is an internationally compatible classification system for technical documents, especially patent publications. The CPC-classification system is an extension of the IPC (International Patent Classification), which is administrated by the World Intellectual Property Organization (WIPO). The CPC-classification system is more detailed than the IPC-system. CPC is managed by the European Patent Office (EPO) and the US Patent and Trademark Office (USPTO). The two patent offices have agreed to harmonise their existing classification systems and migrate towards a common classification scheme.

The CPC-codes are divided into nine sections, i.e., A-H and Y, which in turn are subdivided into classes, sub-classes, groups, and subgroups. There are approx. 250,000 classification entries.

Source: Website of Cooperative Patent Classification: www.cooperativepatentclassification.org

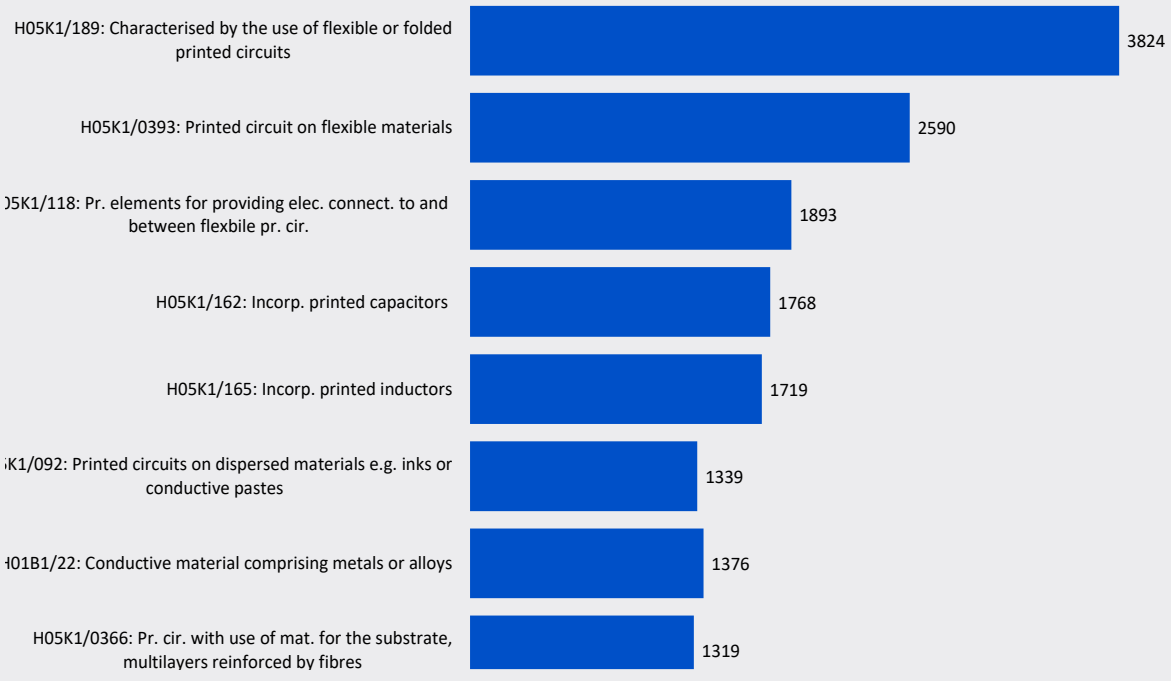
GLOBAL HOTSPOTS

In the group of printed electronics related patents, the two most applied codes may be of particularly interest. About one in four patents is classified as printed circuits on flexible or folded printed circuits and a little under a fourth of the patents is characterised by the use of printed circuits on flexible materials. The two CPC-codes about flexibility and printed circuits will therefore most likely capture some of the same patents and this is one of the reasons why the sum is above 18,980 in the bar chart.

Flexibility is a main characteristic of printed electronics, but it is not a necessary condition for being classified as printed electronics. Therefore, other codes are necessary for capturing printed electronics related patents. The third most frequently used CPC-code is about printed elements for providing electronic connection to and between flexible printed circuits.

Apart from the CPC-codes, patents are also described by key words. By clustering keywords, we can create a 'landscape'. A high density of patents is illustrated as a peak or a plateau in Figure 3. The peaks are marked with related keywords behind the patents.

FIGURE 2: NUMBER OF PATENTS BY THE OFTEN-USED CPC-CODES (TOP 8 CPC-CODES)



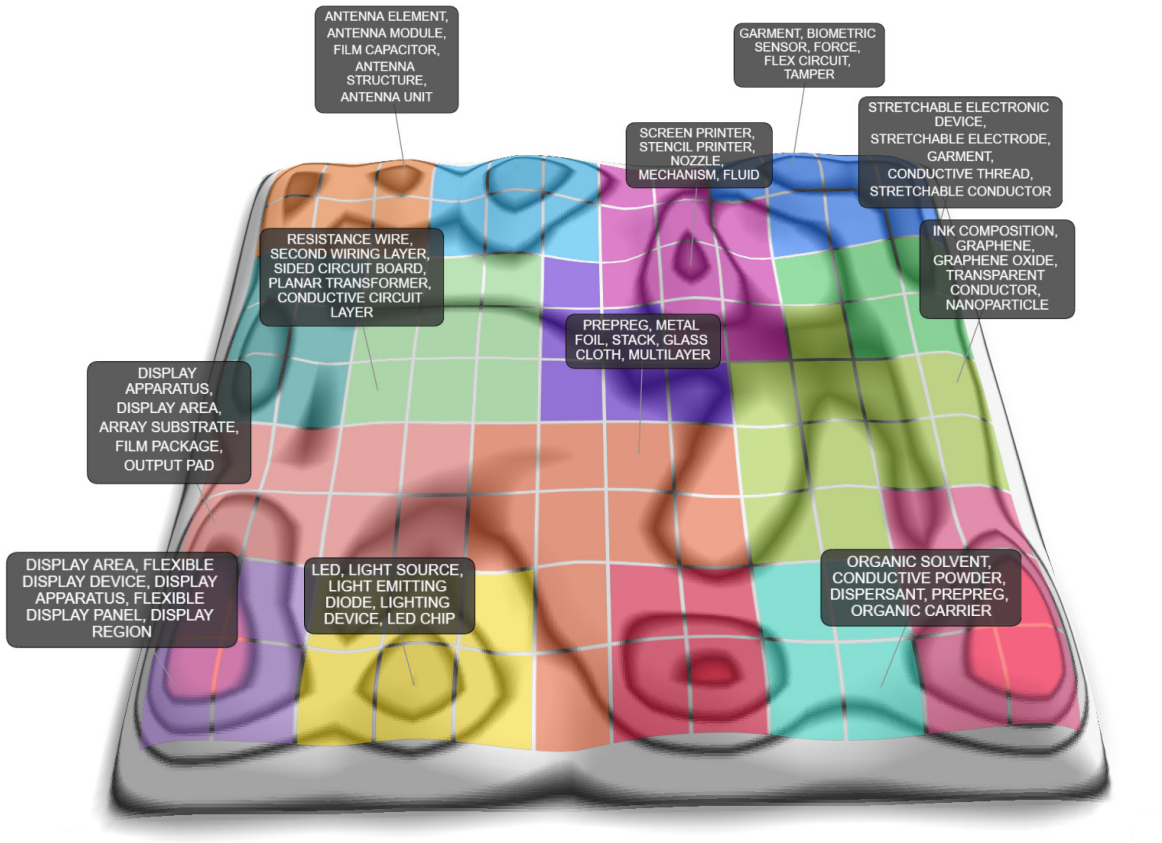
Note: Extract 5. May 2021. N: 18980 patent families. Source: PatSnap, processed by Danish Technological Institute

GLOBAL HOTSPOTS

Among all printed electronics related patents, we can identify 16 subgroups, i.e., groups that have verbal similarity and IPC commonality. The peaks are of most interest as they indicate technological density or patent development, while lowlying areas represent untapped areas for potential growth and expansion into new territories - or areas of no interest.

The interpretation of the map can only be made in broad terms, but it does indicate an interrelationship of keywords. The purple area of the map (in the right corner below) has for instance a peak in the middle of the area. In this area a group of patents is accumulated and has the following common characteristics: Flexible display.

FIGURE 3: INNOVATION LANDSCAPE FOR PRINTED ELECTRONIC-RELATED TECHNOLOGIES



Note: Extract 5. May 2021. N: 18980 patent families.
Source: PatSnap, processed by Danish Technological Institute

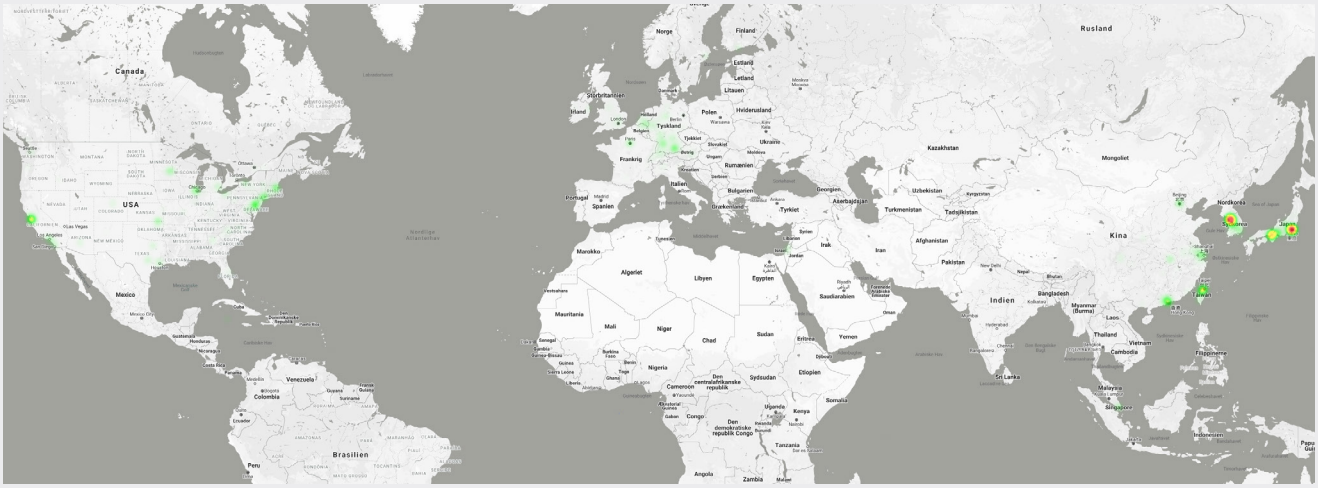
Geographically hotspots

Geographical hotspot can be identified by studying the number of patents either by the locational pattern of the assignees or where the assignees have been granted the patent.

First, we study the number of patents by the locational pattern of the assignees. The heat map illustrates that assignees are in a relatively few countries, see Figure 4. From 2000 to 2020 the assignees were mainly located in Asian countries such as Japan and South Korea, at the East and West Coast of the US, in Central Europe and in China. There is a particularly high concentration of patenting companies in Japan and South Korea. However, the present locational pattern for printed electronics seems to represent the same geographical areas where the global high-tech industries and research centres are located.

[4] Current assignee is the person or entity to which this patent is currently assigned which includes private companies, universities, research and technology organisations, etc.

FIGURE 4: NUMBER OF PATENTS BY THE LOCATION OF THE ASSIGNEES, NUMBER OF PATENTS FROM 2000 TO 2018



Note: Extract 5. May 2021. N: 18980 patent families. Source: PatSnap, processed by Danish Technological Institute

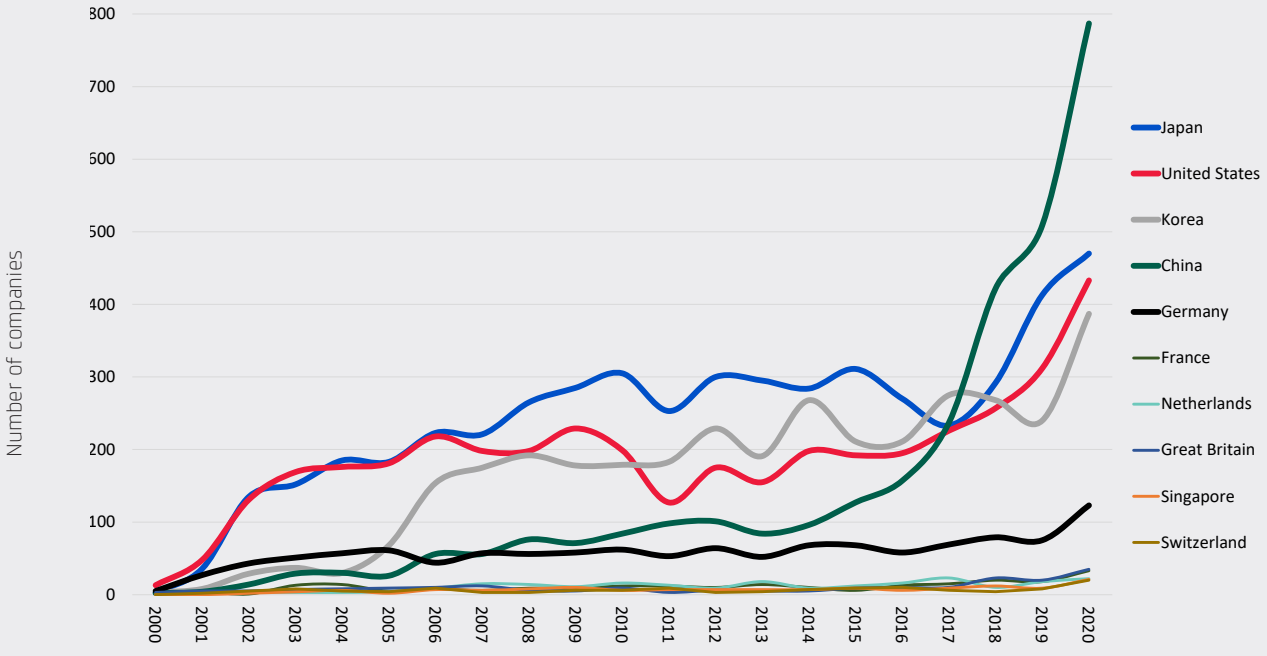
GLOBAL HOTSPOTS

Since 2000, assignees in the US and Japan have been granted the highest number of patents within printed electronics, but in mid-00's Japan became the country in which assignees took out the most patents for printed electronics, see Figure 5. Along with Japan having a dominating position in issuing the most patents the development of the technology increased in South Korea. From the mid-00's to mid-10's South Korea and the US follow each other as second and third rank. In 2015, approx. 80% of all patents were granted in these three countries. This implies that the Japanese, US and South Korean assignees represented the main geographical hotspots for technological developments within printed electronics at the time.

Around 2015, China entered the stage of printed electronics. The numbers of patents granted to assignees in China are soaring. From 2015 to 2020 the numbers of patents rose 619% in China. This steep increase in Chinese patenting assignees made China the world's most patenting country in 2020.

In Europe, the number of patents granted to European assignees within printed electronics is relatively low. Nevertheless, Germany could be seen in the market taking out patents related to printed electronics during the same period, and there was an increase in the number of patents taken out by German companies which reached a preliminary peak in 2020 with 123 patents.

FIGURE 5: NUMBER OF PATENTS, THE LOCATION OF THE ASSIGNEES WITHIN PRINTED ELECTRONICS, TOP 10 COUNTRIES



Note: Extract 5. May 2021. N: 18980 patent families. Source: PatSnap, processed by Danish Technological Institute

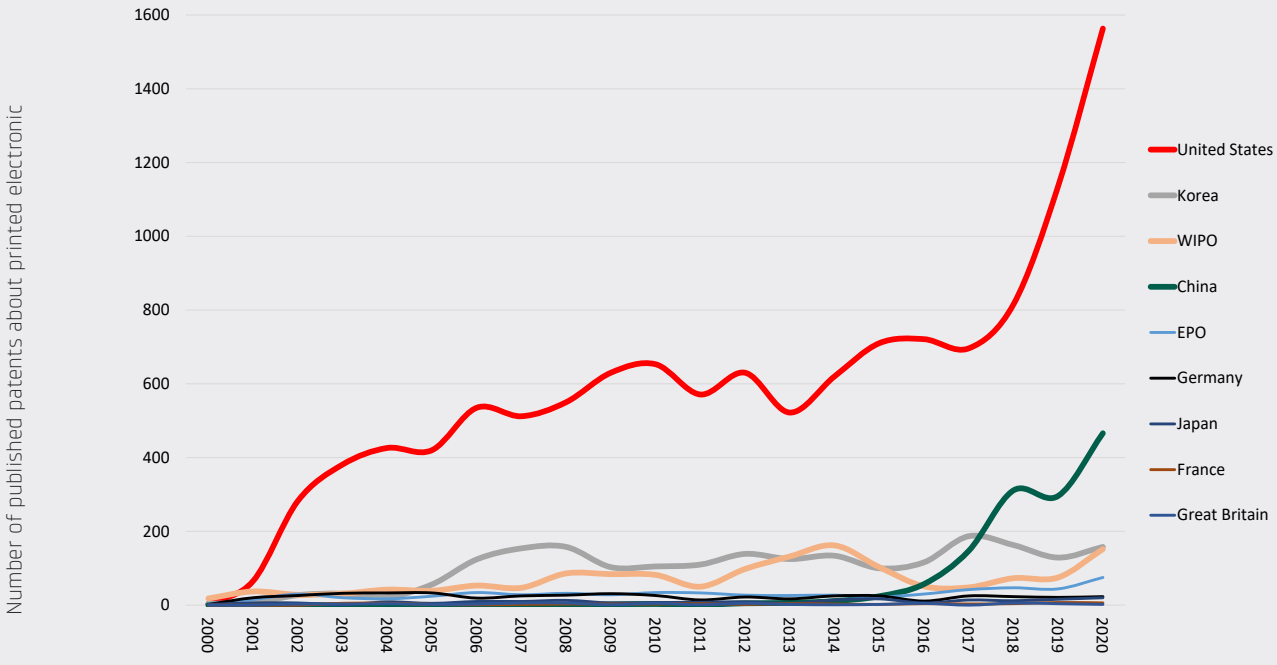
GLOBAL HOTSPOTS

Reviewing the number of published patents by the region or country where the patents have been granted uncover a radically different locational pattern, see Figure 6. By number of published patents, the US has been granting most patents within printed electronics since 2000 and will presumably continue to do so in the years to come. It means that most printed electronics related patents were aimed at the US market, which indicates that the US is the main and most competitive market for using printed electronics.

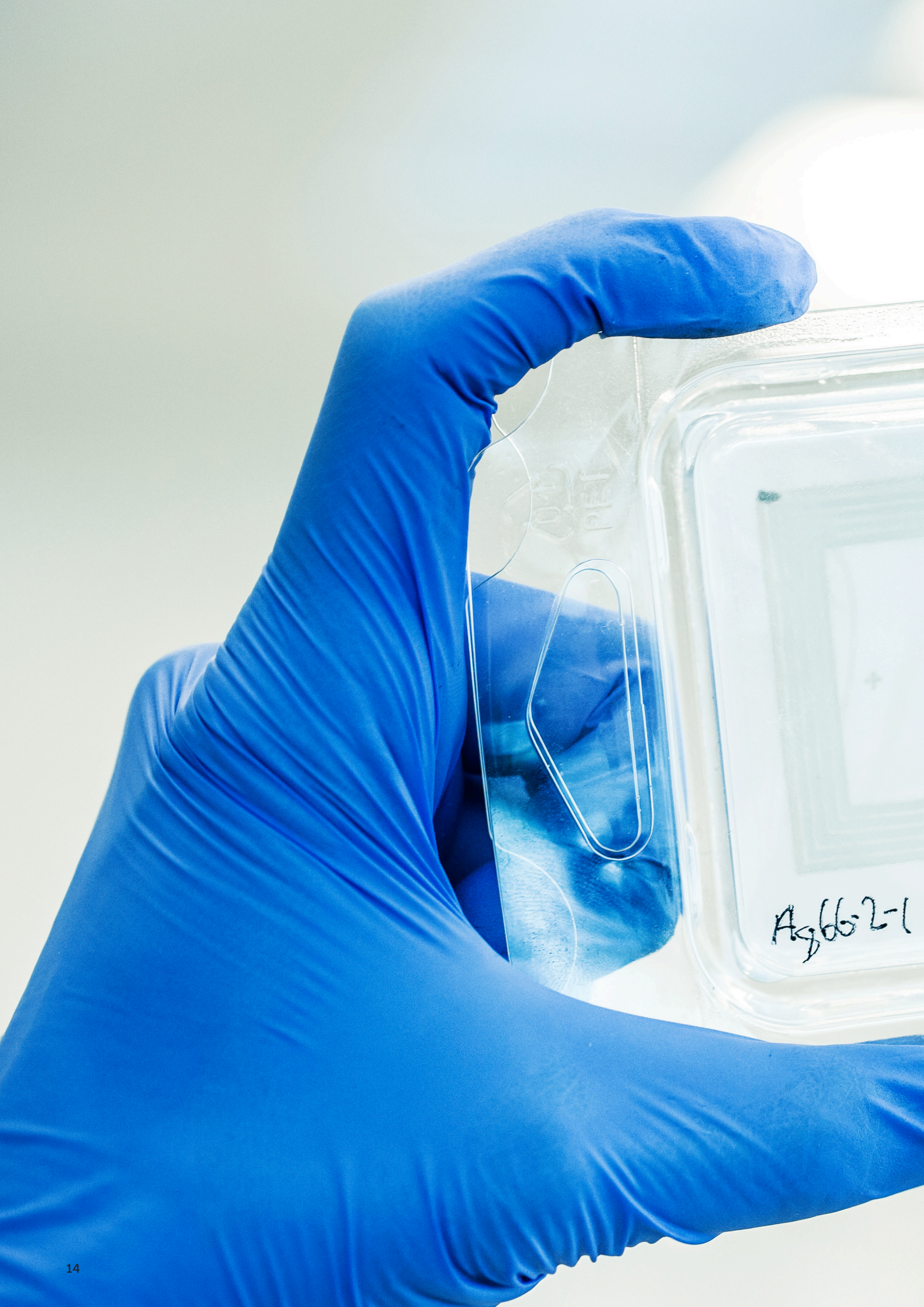
The second ranging country in 2020 was China with 466 published patents compared to the US with 1563 published patents in 2020. Regardless of the present differences between the US and China, China has experienced an upward curve since 2016 and the trend appears to continue. The third ranking county was South Korea where the number of patents fluctuated during the period and peaked at 187 patents in 2017.

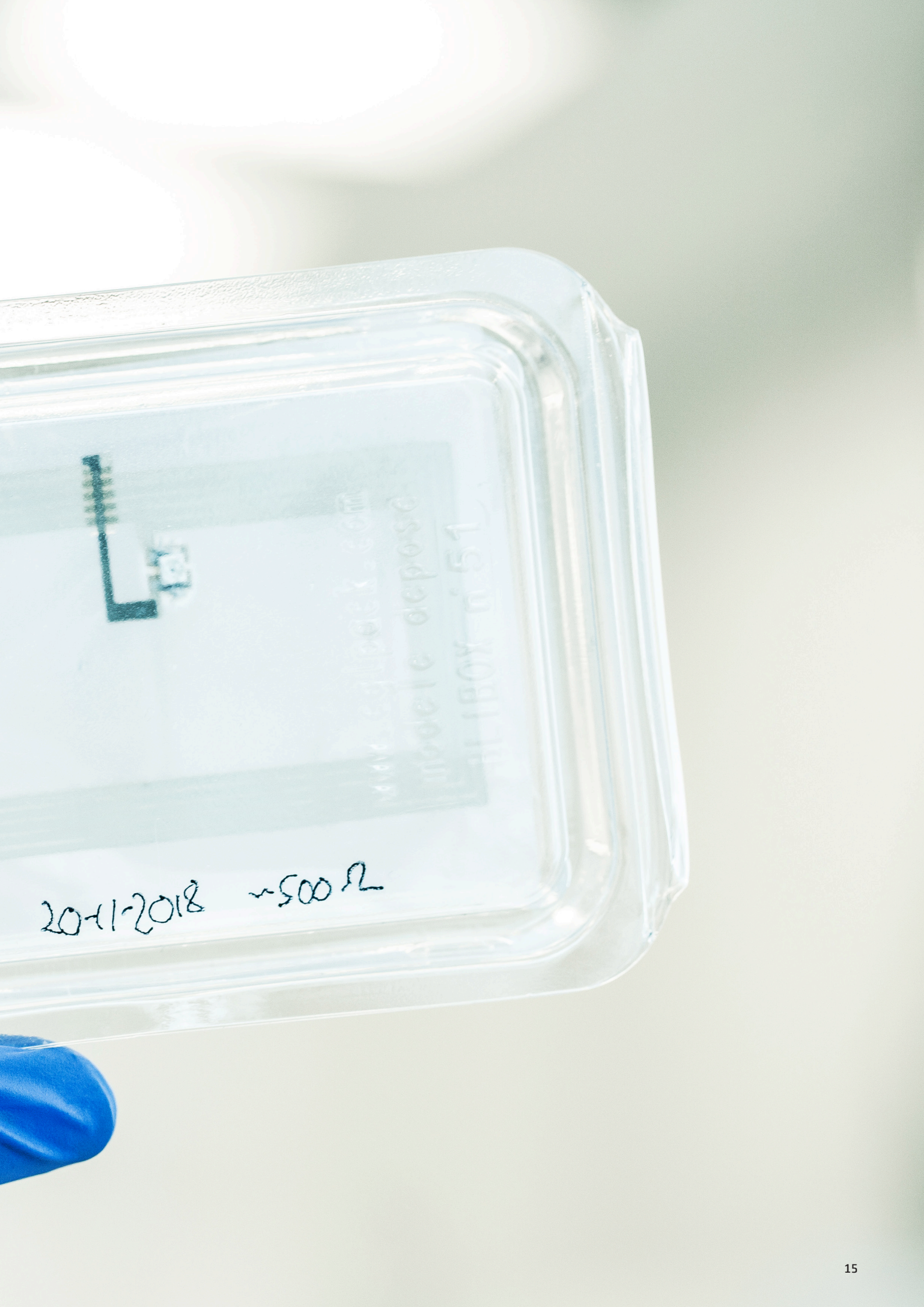
World Intellectual Property Organization (WIPO), European Patent Office (EPO), and patent offices in Germany, Japan, the UK and France are the least patented organisations on the top 9 list. Since 2000 these four counties and two organisations have not experienced a significant increase in the number of patents, and it does not look like they will do so in the years to come.

FIGURE 6: GRANTED PATENTS BY THE LOCATION (COUNTRY) OF THE PATENT OFFICE, 2000-2018



Note: Extract 5. May 2021. N: 18980 patent families. Source: PatSnap, processed by Danish Technological Institute




20-1-2018 ~500 Ω

The global company hotspots

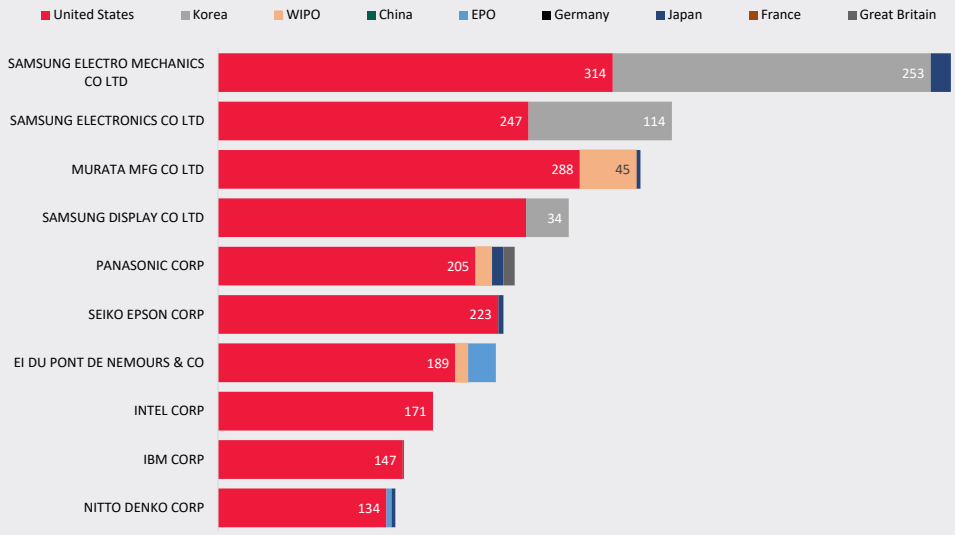
The top global companies[5] are the companies with the most printed electronics related patents. Samsung Group stands out as three of the company's subsidiary companies are represented in the top ten, see Figure 7. Samsung Group has focused on printed electronics for a long time and it has even developed their own copper ink by 2011[6]. The company released the Samsung Galaxy Fold Phone in the spring of 2019, which is an example of one of their products using printed electronics[7].

The Japan-based company Murata Manufacturing is the third most patented company, follow by Samsung Display Co., Panasonic and Seiko Epson..

DuPont is the seventh non-Asia-based and first non-electronics company on the list. DuPont is an US company that produces conductive inks for printed electronics applications. Intel is the only other US company on the top ten list, where no European companies are represented. Most of the top ten companies are based in Japan. However, it is interesting that most of the patents are granted by US patent authorities and are applicable for the US market.

[4] Standardisied current assignee (Current assignee name has been standardised by PatSnap. Current assignee is the person or entity to which this patent is currently assigned).
[6] Raghu Das (2011) Printed electronics progress at Samsung. Printed Electronics World. www.printedelectronicsworld.com/articles/3103/printed-electronics-progress-at-samsung
[7] www.inverse.com/article/56034-samsung-galaxy-fold-flexible-tech-why-it-didn-t-work-but-how-it-could

FIGURE 7: TOTAL NUMBER OF PATENTS BY TOP 10 GLOBAL COMPANIES WITH PRINTED ELECTRONIC-RELATED PATENTS



Note: Extract 5. May 2021. N: 18980 patent families across all companies.
Source: PatSnap, processed by Danish Technological Institute

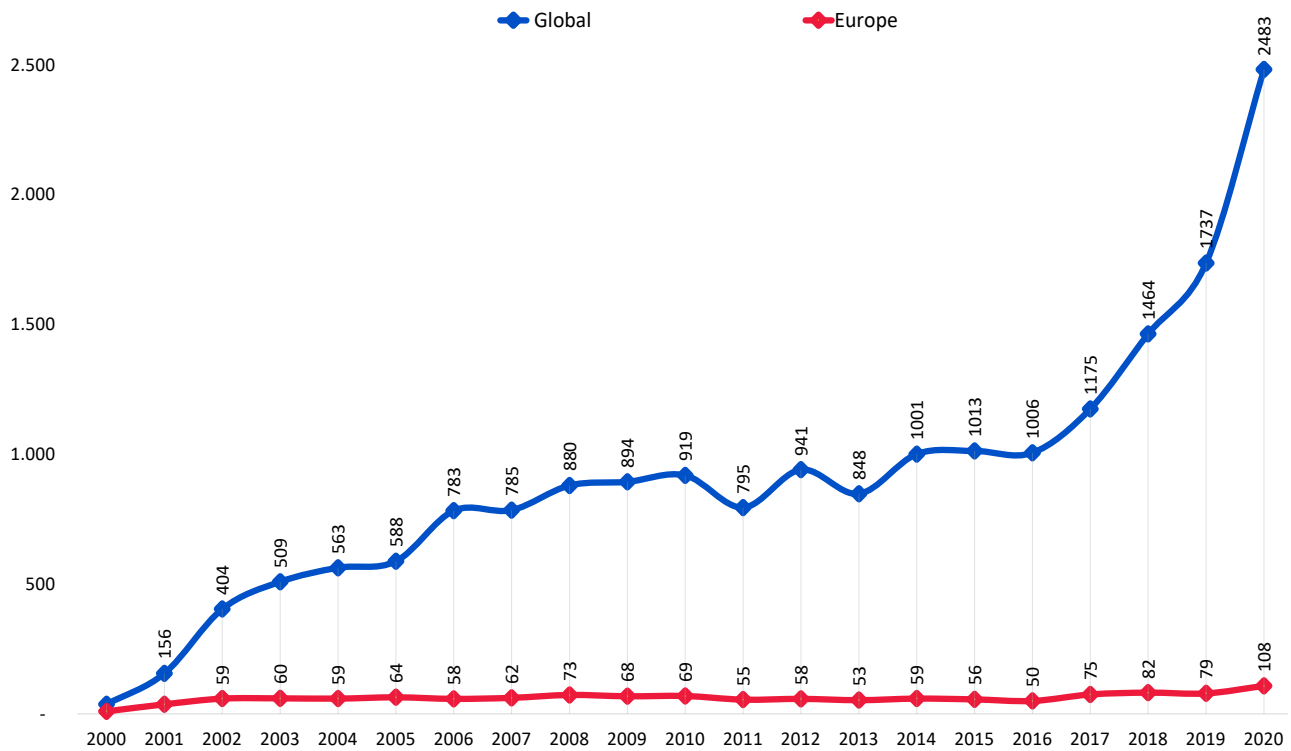
European hotspots

From a European perspective, Europe is among the world regions within printed electronics, but obviously without holding a dominating position regarding publishing patents. In this section, we examine how Europe including Norway, Switzerland, and Iceland are positioned in a global context. We also focus on internal differences.

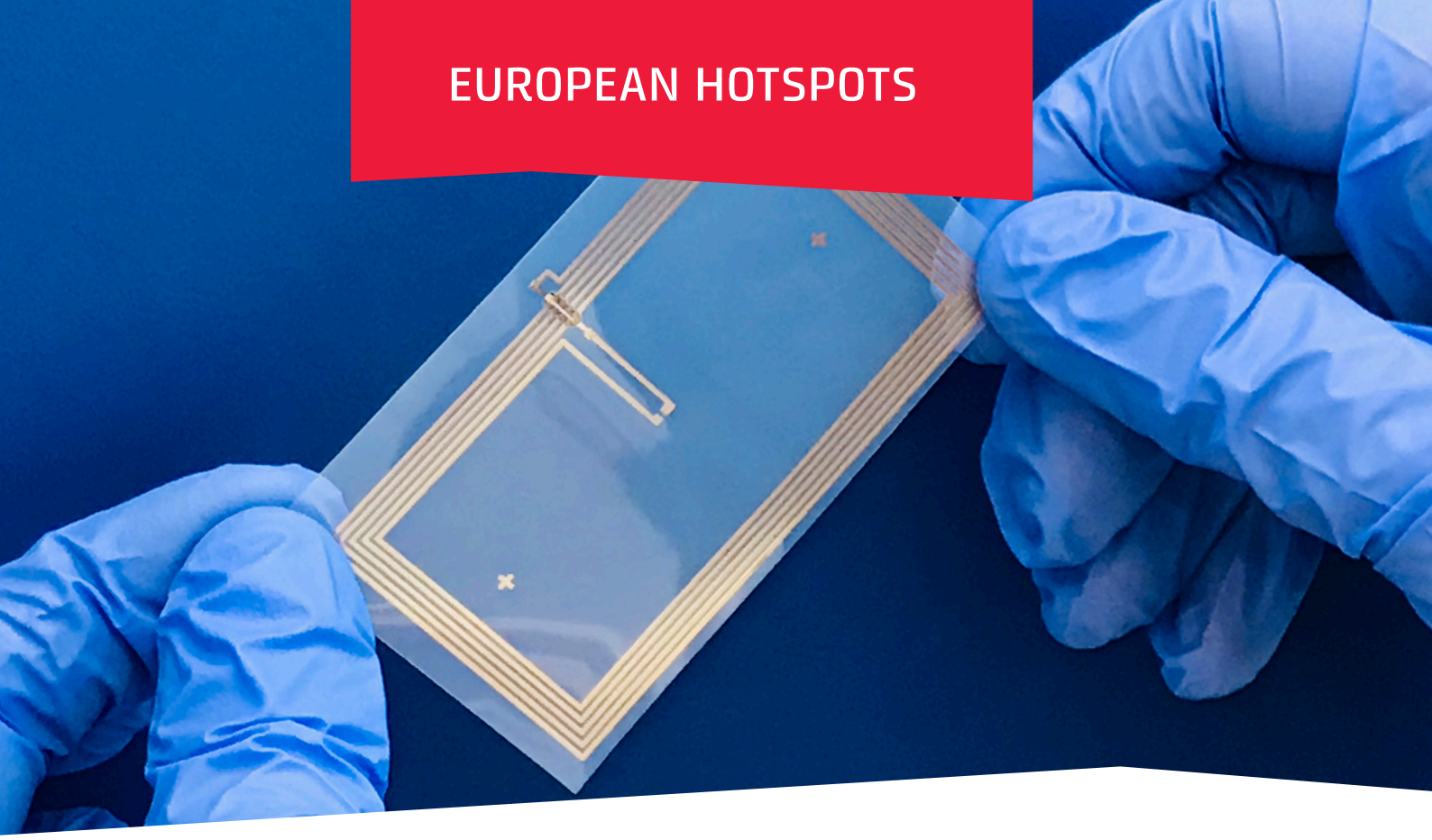
The European share of the patens related to printed electronics

From 2000 and onwards, we observe a slightly increase in the number of patents granted in Europe to assignees. However, in the same period, Europe experienced a declining share of all global patents going from 27% in 2000 to 4% in 2020, see Figure 8.

FIGURE 8: PATENTS IN EUROPE GRANTED TO EUROPEAN ASSIGNEES COMPARED TO THE TOTAL NUMBER OF PATENTS WORLDWIDE



Note: Extract 5. May 2021. N: 18980 patent families. Source: PatSnap, processed by Danish Technological Institute



Highly industrialised countries more active within printed electronics

Within printed electronics the technological developments expressed by the number of patents granted to European assignees are concentrated in a broad area from Southern Germany/Switzerland over France and Benelux to the UK, see Figure 9. Some minor hotspots can also be found in the Nordic countries.

In a regional perspective, the technological developments have mainly taken place in the European urban corridor for decades. This region is characterised by an agglomeration of the main European industries and research organisations investing heavily in technical R&D and hereby they dominate the general technological and economic development in Europe. Technological developments within printed electronics also seem to occur in this region.

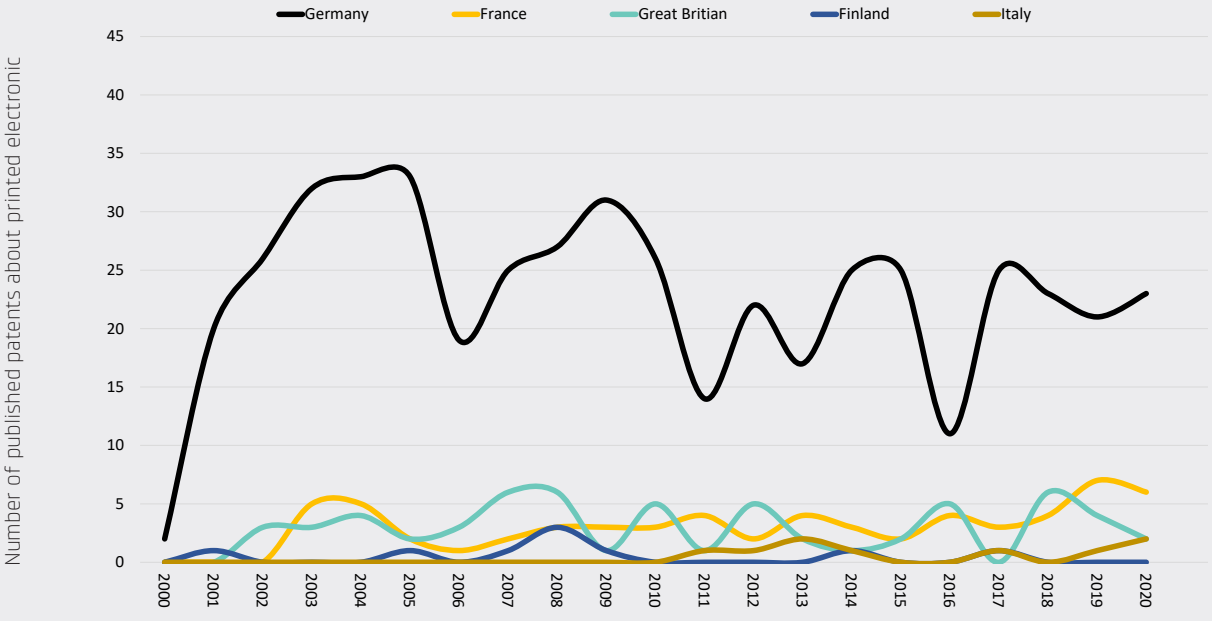
In Europe, patenting within printed electronics has mainly taken place in Germany since 2000. Each year, German assignees have been granted more patents than any other European countries, see Figure 10. Globally, the total number of patents have increased significantly since 2015 (cf. Figure 8).

However, the rapid global technological developments since 2015 cannot be seen in Europe. In other European countries, such as the UK, France, the Netherlands, and Switzerland, a rather low number of patents has been granted per year since 2000 and only a marginal increase has been seen since 2015.

FIGURE 9: GEOGRAPHICAL DISTRIBUTION OF PATENTS GRANTED TO EUROPEAN ASSIGNEES WHERE THE PATENTS ARE REFERRED TO THE LOCATION OF THE ASSIGNEES.

Note. The figure does indicate in which regions the patent is valid
Source: PatSnap, processed by Danish Technological Institute

FIGURE 10. PATENTS PER YEAR GRANTED TO EUROPEAN COMPANIES BY LOCATION OF THE COMPANIES



Note. Extract 5. May 2021. N: 622 patent families. Source: PatSnap, processed by Danish Technological Institute

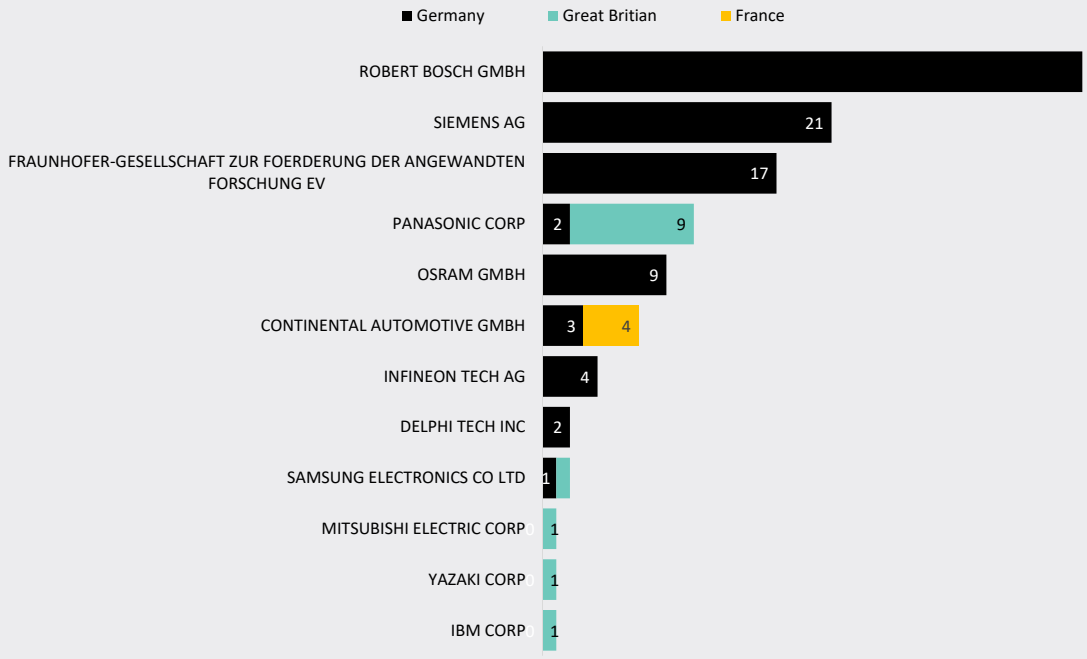
Top European patenting companies within printed electronics

In Europe, we have identified the top 12 companies that hold published patents, see Figure 11. Compared to the number of patents held by the dominating global companies, the European companies hold relative few patents, and even Bosch with the highest number of patents in Europe holds fewer patents than the company that is number 10 on the global top 10 list (cf. Figure 7).

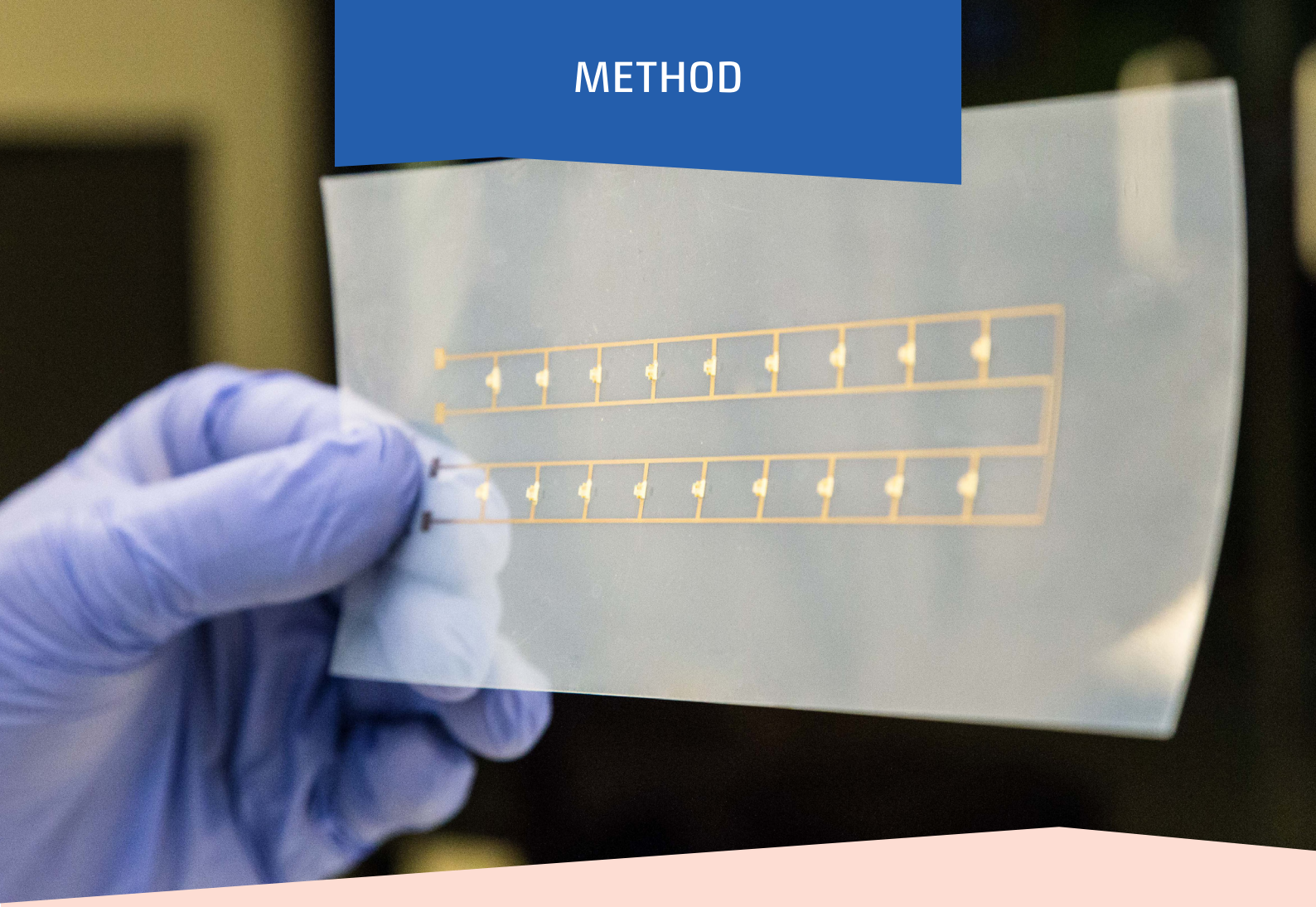
In Europe, five of the top 12 companies are from Germany, holding approx. four out of four patents granted to European companies. The remaining companies are from the UK and France.

According to the industrial sectors that the companies represent, printed electronics mainly appears to be of relevance to the electronics and automotive industries.

FIGURE 11: THE MOST PATENTING EUROPEAN COMPANIES BY NUMBER OF PATENTS, 2000-2018



Note. Extract 5. May 2021. N: 199 patent families. Source: PatSnap, processed by Danish Technological Institute



Method

The patent authorities attach technology codes to the patents. The technical classifications system CPC (Cooperative Patent Classification) applies more than 250,000 unique codes. When doing patent mapping targeting printed electronics, a key task is to identify the most relevant CPC-codes regarding printed electronics and to limit the number of irrelevant patents.

The search strategy has been to identify a core set of patents with high relevance to the technology 'printed electronics' through CPC-codes. The codes identified and included in this study are presented in Table 1.

METHOD

The search strategy has been to identify a core set of patents with high relevance to the technology 'printed electronics' through CPC-codes. Our patent search identified 18,890 patent families from 2010-2020 of high technological relevance to this study.

We have captured the group of patent families by using CPC-codes because it is a more precise search for patents rather than using keywords such as 'printed electronics'. The challenge when using key words in the patent search is that printed electronics is an all-encompassing term for the printing meth-od. Given that printed electronics is a method and patents rarely mention the specific method in the patent description, it is not a satisfactory way of searching for printed electronics related products. Moreover, printed electronics technologies have different names such as flexible printed circuits and stretchable printed circuits. There are no conventions that can be followed, and some patents may be relevant to printed electronics but without mentioning related words. Thus, it is not enough just to search for printed electronics. Therefore, we have used CPC-codes to identify the most relevant patents that include technologies related to printed electronics.

However, the wheel of innovation indicates that the identified patents represent technologies that are all related to printed electronics, see Figure 12. 'Printed circuits' and 'electrical conductivity' are the two most frequent keywords when it comes to printed electronics patents, each with a number of keywords, including applications and specifications attached to them. 'Flexible printed circuit board' is the most frequently used keyword in the second tier of the wheel and 'Metal Layer' and 'printed circuit' are keywords that occur under many of the first tiers of the wheel indicating a strong relationship between the key words in the first layer.

Overall, we assume and are confident that our patent search related to printed electronics is providing us with solid data. Through validating the search in the wheel of innovation we believe that the group of patents is sufficient to make an overall strategy analysis of the technological developments within printed electronics. The data base can also be used as a point of departure for more focused patent searches within more specific technological areas.

FIGURE 12: WHEEL OF INNOVATION, KEY TECHNOLOGIES WITHIN PRINTED ELECTRONICS

Source: PatSnap, processed by Danish Technological Institute

The Circle Chart categorizes the most frequent keywords in identified patents into a 2-tier hierarchy of within the most recent 10,000 Simple Families in the technology field.

In this report, Danish Technological Institute dives into global databases with patent data to gain a better understanding of the potential of the printed electronics. This kind of patent mapping provides insight into identifying trends and patterns in the data. The purpose of the report is to use the data to gain strategic insight into technologies, actors, and markets.

By carrying out a patent mapping focused at printed electronics, we offer companies a global strategic overview of trends within printed electronic. The patent mapping gives an indication of the key technological areas and the leading knowledge centres (companies/research institutes and their geographical distribution). Such a global patent mapping can only provide companies with overall strategy business information. If a company initiates innovation within a specific technological field of printed electronics, we recommend that they request a focused patent mapping which can provide them with more relevant information and an indication of 'license to operate' with respect to existing patents.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 814485.

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