IP Overview

Photovoltaic Thin Film Cells

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Thin Film Cells

Contents

List of Figures

List of Tables

Methodology

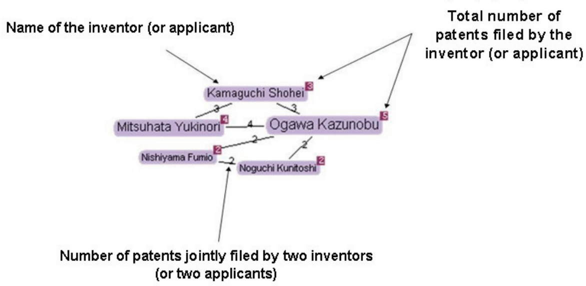
The various patents and patent applications have been extracted either from the FamPat (Questel), Espacenet and USPTO databases or other patent databases. Such databases group together patent applications into families of patents and cover all of the disciplines constituted by documents published by 77 patent offices.

The research methodology used for this study combines conventional Boolean operators (AND, OR and AND NOT) with more complex search operators such as word truncations (in the middle or at the end of the word), search for successions of words and search for several words in the same phrase or paragraph. Keyword searches may be carried out in the titles, summaries and main claims of patents.

The patent search may be limited not just by IPC or ECLA codes or the US classification but also by filing or priority dates.

The processing of raw data and overall statistics was performed using Intellixir software (www.intellixir.com).

Guide to reading diagrams of inventors or collaborations between applicants:



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Introduction

The economic situation and, in particular, the upward trend in the price of fossil energies and political pressure on the markets induced in part by public opinion and in part by geopolitical aims to loosen the ties of energy dependence has meant that considerable budgets have been allocated over many years to the development of alternative energy sources. The production of photovoltaic electricity is one promising avenue among these various types of “clean energies”.

Three main technological avenues exist for the photovoltaic energy production market: crystalline silicon cells (which represents in terms of patents nearly 3300 families since 1985), thin film cells (4300 families) and organic cells (a little less than 1900 families). This study, which focuses on thin film technology, represents the second part of a three-part analysis of the patent environment in the photovoltaics field.

Thin films constitute second generation photovoltaics technology. In this generation may be distinguished, in particular, amorphous silicon (a-Si), copper indium diselenide (CIS) and cadmium telluride (Cd-Te), to cite only a few.

At the moment, the maturity of thin film technology is lagging behind that of crystalline silicon. In fact, not all of the technological, ecological and economic stumbling blocks have been overcome yet and these cells, known as second generation cells, still only account for a small part of the photovoltaics market, namely around 10%, all technologies taken together. The companies that have based their strategies on this type of cell have invested heavily in research and development for more than 20 years to overcome these hitches and to protect their technical solutions so as to profit from what are assumed will be important spin-offs. In technological terms, the efficiency, around 6-7% for amorphous silicon technology (up to 14% in the laboratory and 40% with concentrators developed in particular by BOEING’s subsidiary, SPECTROLAB) and the deposition efficiency (slow or instead expensive) are the two principal limitations. In environmental terms, the toxicity of certain elements (cadmium) used in their manufacture also represents a brake to intensive exploitation and numerous recycling solutions have been proposed. Finally, in financial terms, this technology does not benefit as much from strong synergies with pre-existing industry to promote it, unlike silicon technology which relies on the semi-conductor industry and in particular the producers of silicon.

However, photovoltaic thin film cells have several undeniable advantages compared to crystalline silicon cells. Firstly, the process employed is very different to that of first generation cells and enables on-line industrial cell production, unlike silicon technology which requires the use of several different manufacturing techniques (production of the ingot, slicing, doping, etc.). Secondly, the production of this type of cell consumes less material than first generation cells, since less semi-conductor is used.

These two factors suggest that the cost of thin film cells may well, in the long run, be lower than that of cells based on crystalline silicon. Finally, on account of their specific characteristics (such as the possibility of being flexible and lighter or instead their high temperature resistance), they enable the needs of new markets to be met, which may turn out to be important in the future for building markets and in a sizeable chunk of specific niche markets (such as the military market, with photovoltaic tents).

Rather than from considering the strong and weak points of the technology, this study aims to establish a panorama of the industrial property in order to provide a clearer insight into the issues and challenges at stake and to position the different players involved in thin film technology in terms of technological choices and patent filing strategies by providing a complementary view to that provided by market studies. After an overall analysis of the photovoltaics field, aimed at assessing the technological weighting of each of the technologies involved (crystalline silicon, thin film and organic), we will analyse in greater detail herein patents and patent applications, filed between 1985 and mid 2007, that can be associated with thin film technology.

1. Brief outline of the photovoltaics market

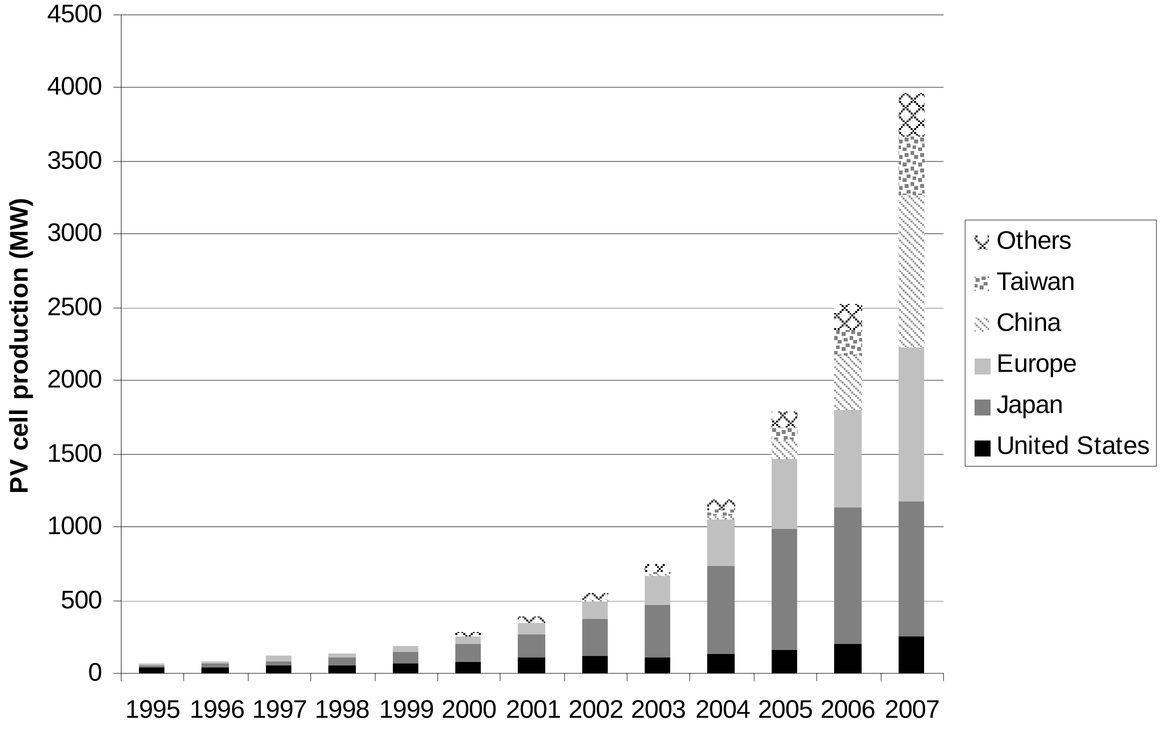


Figure 1 - Photovoltaic cell production (MW). Annual photovoltaic production by country, 1995-2007

The global production of photovoltaic installations is represented in the above figure. This figure is based on a combination of "Earth Policy Institute" data and our own data. The production of photovoltaic energy has experienced exponential growth over more than 10 years, with annual growth rates above 30%. Although the main areas of production have historically been centred in Japan and Europe (with increased production following market growth), 2005 saw the appearance and explosion of production in China and Taiwan. Thus, in 2007, production in China and Taiwan represented one third of the world production of photovoltaic cells.

It should be noted that data on the photovoltaics field can differ markedly, depending on the source of the data. For instance, EPIA (European Photovoltaic Industry Association) data points to a production of photovoltaic energy in 2007 of 2300 MW, well below the figures released by most other institutes.

Although the photovoltaics field has been a rapidly growing sector for almost the last 10 years, the contribution of photovoltaic energy to total electricity production remains marginal. Despite the very high growth rates over the last few years, it represents less than 0.1% of electricity production in Germany and in Japan. By way of comparison, the total worldwide power generated by photovoltaic installations (12 GW) remains, at the moment, around the generating capacity of wind farms in Spain (11 GW).

The development of this market is governed by non-technical considerations, such as the energy context (price of oil), policy (Kyoto Protocol, tax incentives, etc.) and environmental issues, which, depending on the countries, may act as a brake or a motor to the growth of the photovoltaics market.

These different players lead to a particular geographic breakdown, influenced to a large extent by government incentives and the propensity by the general public to use renewable energies. For instance, Germany and Japan alone now account for 63% of worldwide photovoltaic installations, as illustrated in figure 2. Europe, for its part, accounts for more than 50% of worldwide photovoltaic installations.

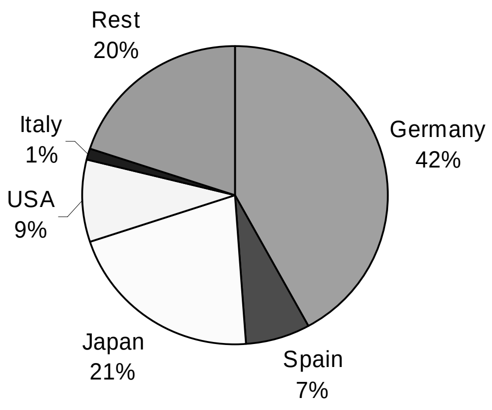


Figure 2 - World photovoltaics market (cumulative installations)

This breakdown should re-balance out in favour of the United States, China and Taiwan over the next few years. Thus, China, which does not appear in this graph, plans to install 10 GW photovoltaic generating capacity by 2020. To attain this objective, it will have to maintain its market growth of more than 40%. The United States should also become a more sizeable market with the installation of 3.5 GW over the coming years ("One Million Roofs" project). This project will impose internal growth of 30%.

Consequently, USA, China, Europe and Japan will represent the principal markets over the next ten years and will generate heavy growth in the sector in the medium term.

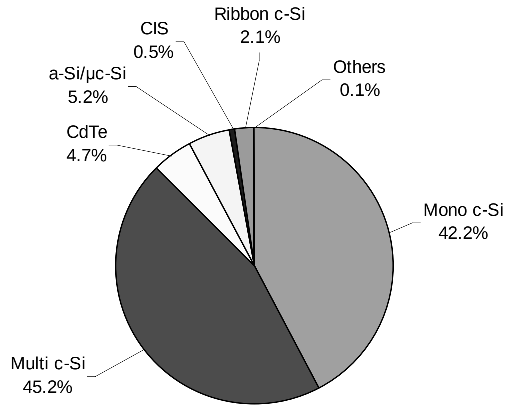


Figure 3 - Market segmentation by technology (Photon International, March 2006)

As regards the market share represented by crystalline silicon - monocrystalline, (mono c-Si), multicrystalline (multi c-Si) and ribbon c-Si - in all photovoltaic installations, current estimations vary between 85 and 95% of the global photovoltaics energy market. Thin film technologies - amorphous silicon (a-Si), microcrystalline silicon (µc-Si), cadmium telluride (Cd-Te) and copper indium selenide (CIS) - accounts for the remainder of the global market. The organic technologies are still extremely marginal. This breakdown is detailed in figure 3.

Finally, figure 4 shows the breakdown of the production of photovoltaic cells between the major players in this market. For the first time, Q-CELLS (a German firm that profits from the dynamism of its national market) has overtaken SHARP in terms of cell production (NB: SHARP's cell production dropped between 2006 and 2007). Producers of thin film cells, such as FIRST SOLAR, which commercialises Cd-Te cells, are now appearing among the major producers.

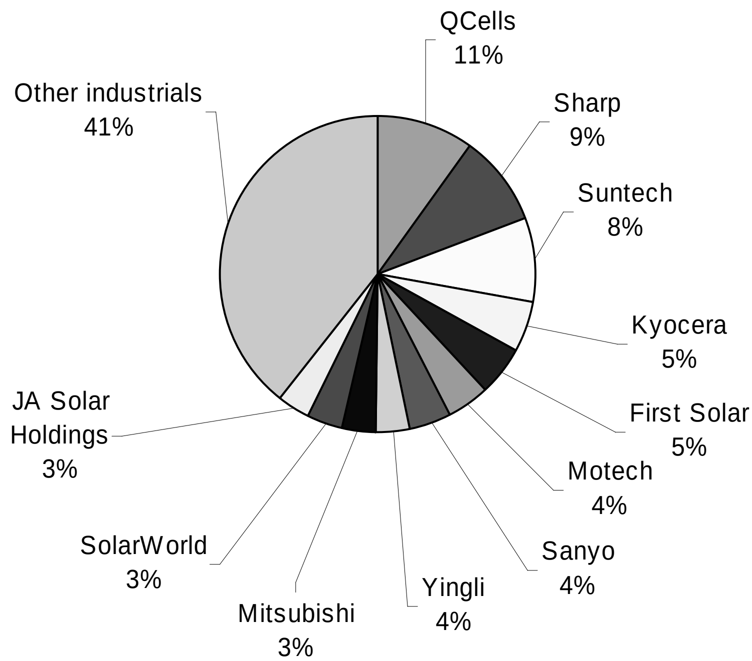


Figure 4 - Top cell manufacturers (Production MW, Photon International, 2007)

2. Global overview of photovoltaic patents

The aim of this section is to study the overall environment of the intellectual property concerning the photovoltaics field before focusing on thin film cells in the remainder of the document.

The “patents” search was conducted using a series of key words including: solar cells, solar modules, photovoltaic cells, photovoltaic modules and more specific terms used in photovoltaic technologies (cadmium telluride (Cd-Te), copper indium selenide (CIS), monocrystalline silicon (mono c-Si), etc.), and by searching for priority patent applications filed since 1985. This search was also limited by the use of IPC codes specific to the photovoltaics field, namely the following codes: H01L-031, H02N-006, E04D-013/18, H01L-021 and C30B. This search led to the extraction of around 22,100 patent applications published up to mid December 2008. An extraction at this date makes it possible to itemise all of the patent applications filed up to mid 2007, given the legal time lapse of 18 months before the publication of the filed patents.

Figure 5 thus represents the evolution over time of priority filings made in the photovoltaics field.

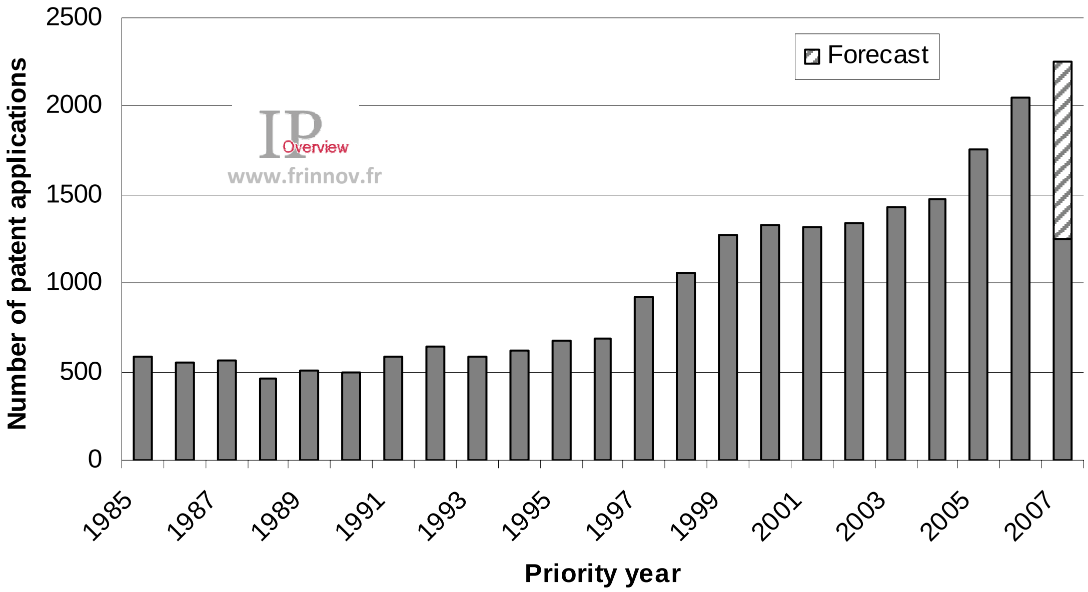


Figure 5 - Evolution in global patent filings

It should be noted that the dates given in this graph represent the priority dates of patent applications published to date (18 months prior to the publication of the applications). The data for 2007 is incomplete for the reasons explained previously.

The evolution over time of filings in the photovoltaics field shows a long history with patents that have already expired, a phenomenon consistent with the long time span since the photovoltaic effect was first discovered (in 1839) and with the first application for photovoltaic panels, which dates from 1960. Up to 1996, the number of filings remained stable at around 500-600 applications a year, followed by a rise in the number of filings, reaching a new level of around 1300 patent application filings a year. More recently, this already dynamic sector has surged further ahead, with more than 2000 patent applications in 2006 and, in all likelihood, 2007.

2.1. Technological segmentation

Taken together, these patents cover some very diverse technologies, namely, not only the different types of cells but also a considerable number of less specific patents and patent applications, whether they are uniquely application patents or instead connected technologies such as inverters or encapsulation, which do not fall within the main areas of expertise of cell producers.

The segmentation of the global portfolio of photovoltaic patents was conducted in the following manner:

- Patents clearly identifying "crystalline silicon cells"
- "Thin film cell" patents
- "Organic cells" (polymers, dye sensitized solar cells, etc.)
- Other patents that contain, as evoked previously, application patents and technologies complementary to photovoltaic cells

It should also be noted that it was decided to separate the CANON Company from the aforementioned technological segments due to the particular positioning of this company, which will be the subject of a specific analysis. In fact, the massive filings made by this company have had the effect of masking the trends of filings of the other players in this field, even though CANON does not at present sell any photovoltaic products.

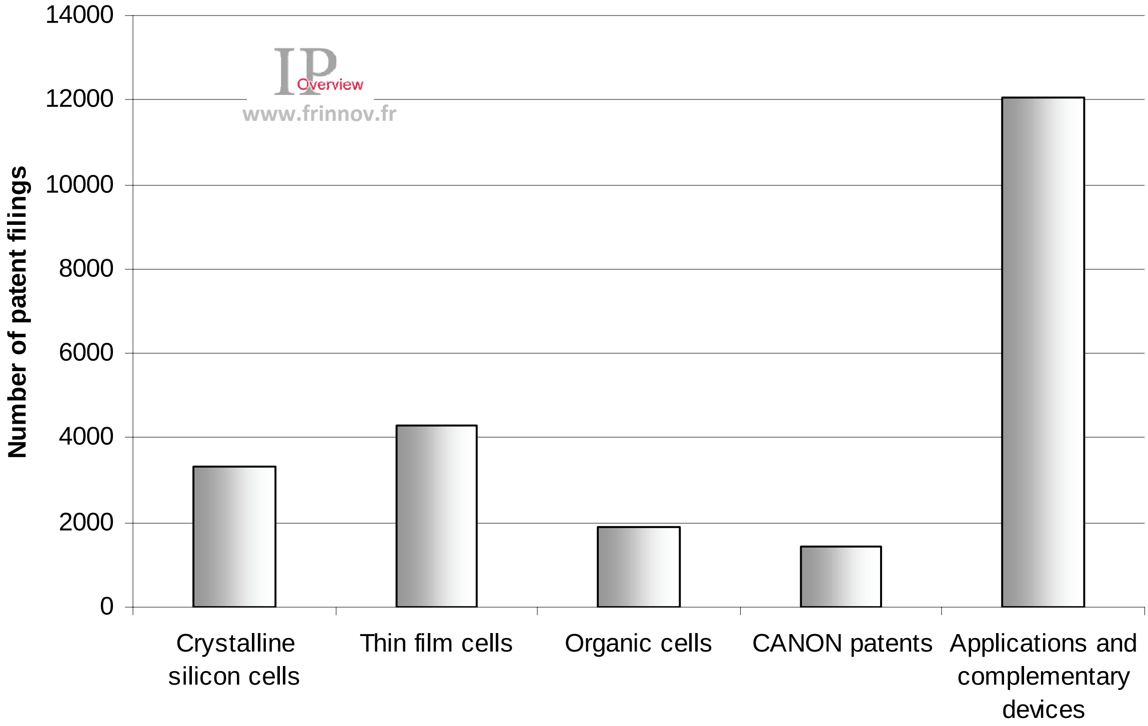


Figure 6 - Technological segmentation

Figure 6 shows the breakdown of patent applications filed in the photovoltaics field. It is important to note that the patents and patent applications that are classed in the technological categories (crystalline silicon cells, thin film cells or organic cells) are documents specifying the types of cells claimed.

As regards the patents in the photovoltaics field, which are classed in the segment "Applications and complementary devices", the type of technologies that have been patented but for which we will not give any precise segmentation are given below:

- Panel production: configuration of photovoltaic cells interconnected in series and in parallel, arranged on fixed or moving supports (solar tracking systems)
- Panel assemblies with specific voltages
- Charge controllers
- Energy storage batteries
- Current inverters (transformation of direct current into alternating current)
- Protection against overloads (circuit breakers or fuses)
- Measuring instruments

Concerning application patents, a segmentation is given in the following section.

2.2. Segmentation by application

This section gives an insight into the types of applications of photovoltaic devices.

It is important to keep in mind that the patent texts do not necessarily make clear a specific application. The segmentation by application herein makes it possible to highlight the key goals and market choices of certain companies but, for this reason, is not exhaustive.

The principal application, cited in the patents, is undoubtedly that relating to private or public buildings. The objective is to use the surface of roofs or building facades as a means of producing electrical energy for local purposes (for isolated habitats) or for re-injecting the current directly into the mains network. The patents protect in particular methods of integration with the existing installations or methods of installing solar panels.

Apart from these devices dedicated to building roofs and facades, it has been decided to highlight those adapted to the fields of aeronautics and space, vehicle and building windows, gadgets (such as, for example, watches or calculators), portable electronic equipment (PDA, laptop computers, etc.), sun shields, solar power plants, urban facilities, soundproofing walls, different types of water treatment (desalination, production of drinking water, etc.) and solar battery chargers. A very large number of other applications of photovoltaic systems also exist and the aim of this list is not to be exhaustive but to identify the companies that are involved in these specific market niches. The size of the circles (blue or red) is proportional to the number of patents linked to the topic. For reasons of clarity, we preferred to illustrate this point by two separate graphs that are not shown to the same scale.

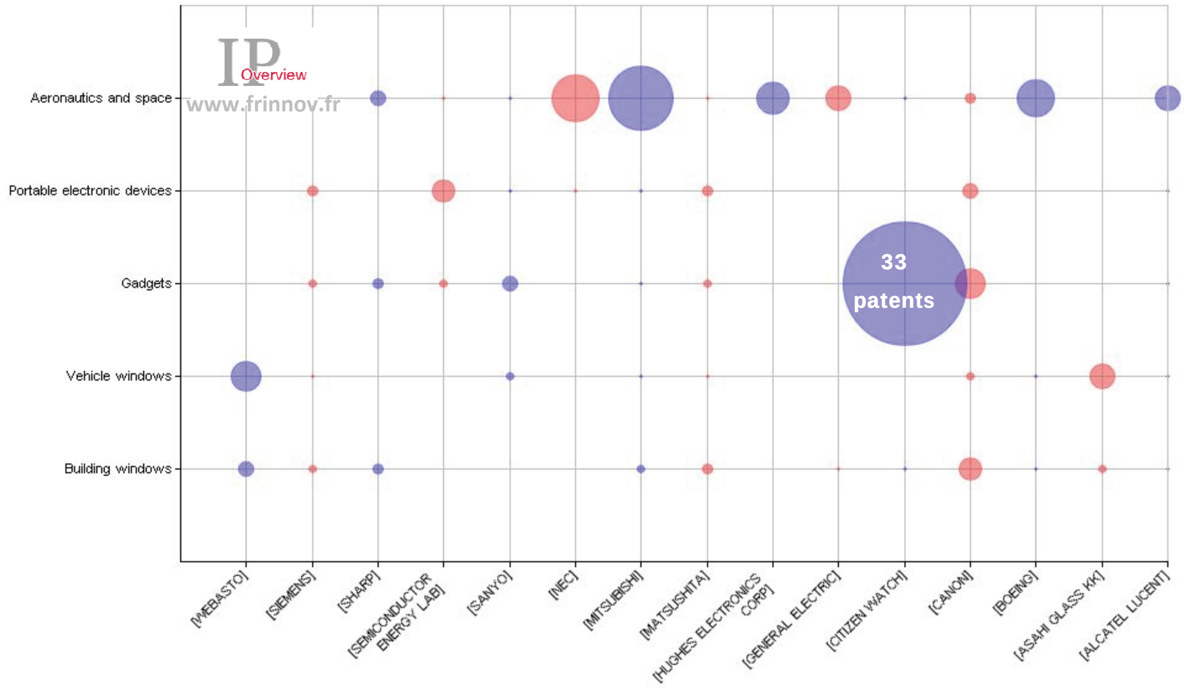


Figure 7 - Niche market by applicant – 1 / 2

This type of segmentation highlights the distinctive features specific to certain players. For instance, WEBASTO, which specialises in the design and production of automobile sun roofs, is leader in the production of solar sun roofs. Furthermore, the interest shown by this company in building windows stems from the existence of a subsidiary WEBASTO SOLAR, jointly owned by WEBASTO and SYSTAIC, a German company that sells solar equipment for buildings.

Certain companies are, on the other hand, positioned in the aeronautics and space industries (BOEING, HUGHES ELECTRONICS, MITSUBISHI).

Finally, this graph shows the interest shown by the CITIZEN WATCH Company in photovoltaic devices linked to its watch production plants.

Also worthy of note is the presence of SEL (SEMICONDUCTOR ENERGY LABORATORY), a private Japanese laboratory, whose activity is centred on research and development in the microelectronics sector but also to a lesser extent in the photovoltaics field. This Japanese laboratory is particularly active in terms of filing of patent applications (more than 9,000 priority patent applications). In the present case, the patent applications in the photovoltaics field filed by this company are mainly intended for portable applications.

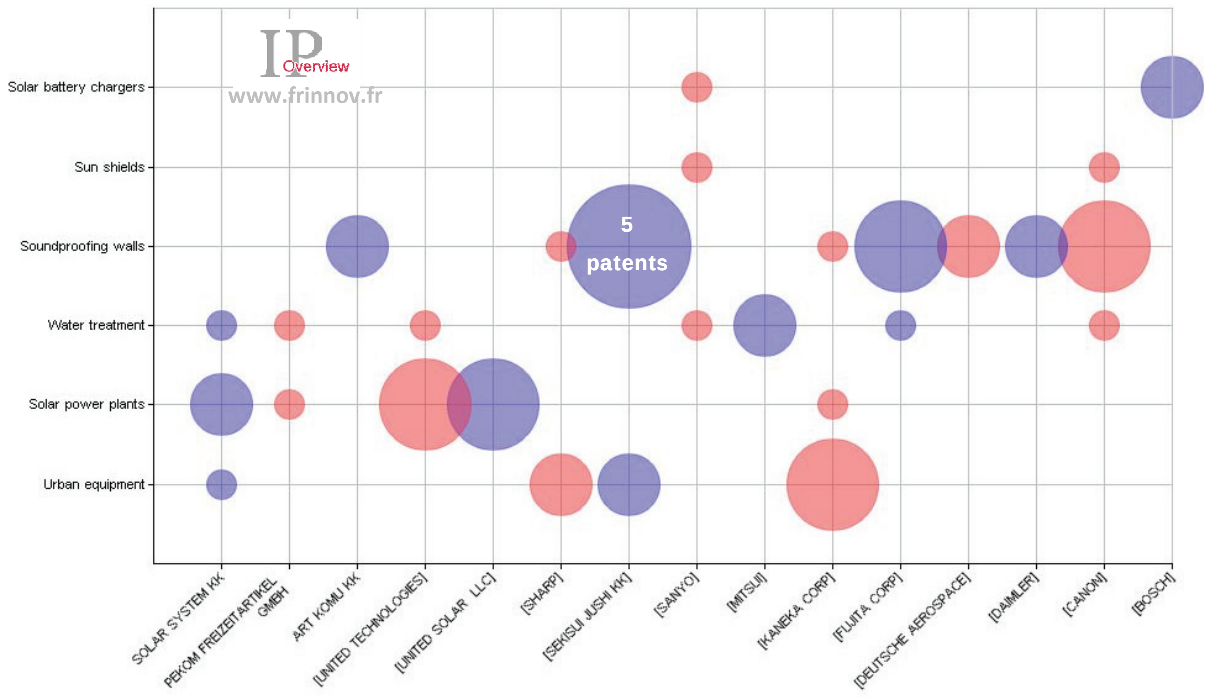


Figure 8 - Niche market by applicant – 2 / 2

Among the other applications in the photovoltaics field may be cited soundproofing walls, sun shields and also urban equipment. For instance, the KANEKA Company mainly targets the latter type of application, whereas SEKISUI mainly cites soundproofing type applications. The German company BOSCH has, for its part, patent applications relative to solar battery chargers.

2.3. Zoom on companies involved in the market

A list of companies that produce photovoltaic materials, gleaned from the "PV Status Report 2008", published by the Institute for Environment and Sustainability (Joint Research Centre - JRC, European Commission), and our own analysis, has been drawn up. Although this list is not exhaustive, it nevertheless identifies the 124 most characteristic companies of the sector. This list, available in Appendix 1, taken in conjunction with the results of the present patent search, makes it possible to compare the sizes of portfolios and to position them within their activity sectors. It should be recalled that the volumes indicated in this study are the volumes of patents filed and not the volumes of patents still active today.

Figure 9 illustrates the size of the patent portfolios of the identified firms. Nearly 40% of these companies did not file any patents in the field during the study period, namely from the 1st January 1985 to mid June 2007. Apart from these companies, the size of a conventional portfolio varies from 1 to 15 patents. In fact, nearly 40% of the companies have a portfolio of this magnitude. Only the Japanese industrial groups SHARP, SANYO, MITSUBISHI, MATSUSHITA (renamed PANASONIC since

October 2008), KYOCERA and FUJI ELECTRIC have patent portfolios very considerably above the average (more than 500 patent applications).

The world leader in terms of cell production (Q-CELLS) has, for its part, an average size portfolio of patents in the photovoltaics field, namely 9 patents.

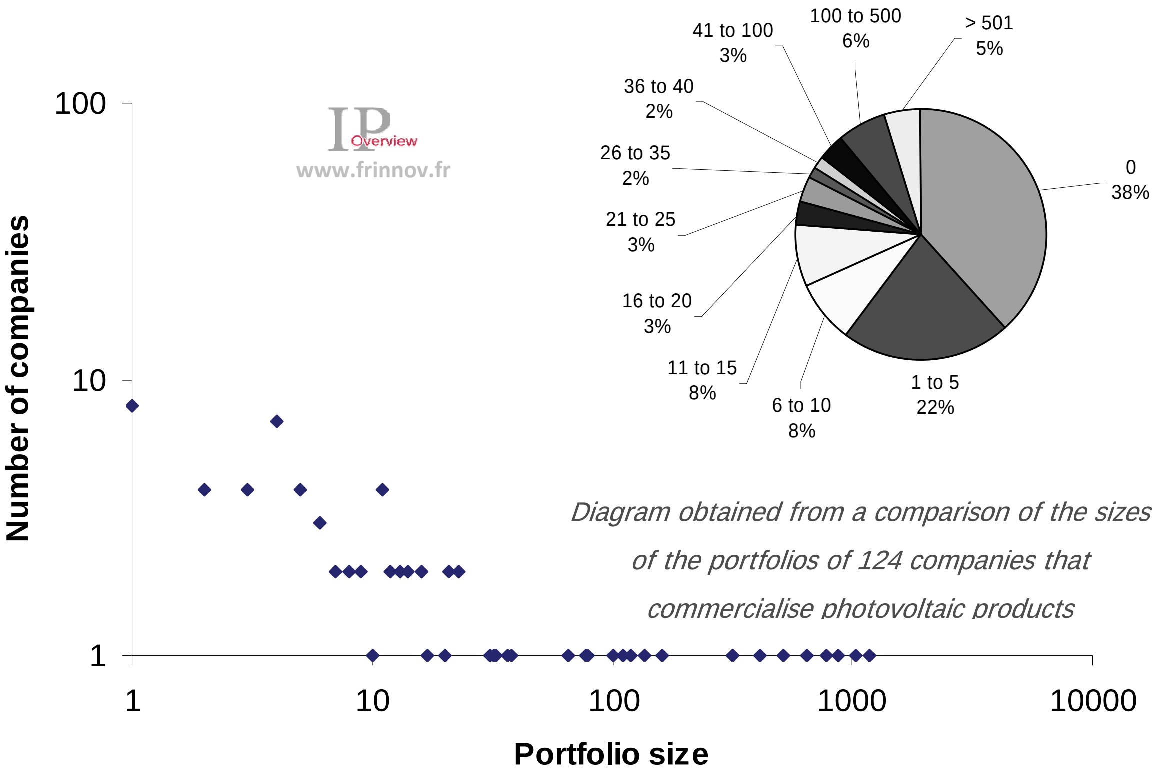


Figure 9 - **Topology of the patent portfolios of the identified companies**

This phenomenon reflects the fact that numerous photovoltaic technologies date from before 1985 and have therefore now (if they were in fact patented) fallen into the public domain. Today, although it is still therefore possible to produce photovoltaic cells without any particular protection, access to the most recent technologies is restricted. With the arrival of numerous industrial concerns in the sector, the companies currently positioned in the market have relied on an active policy of filing patents for around 5 years (Q-CELLS, SOLARFUN, NANOSOLAR, SOLARTEC, NEO SOLAR POWER, APOLLON SOLAR, SOLARWORLD and CONERGY). The table in Appendix 2 provides a view of the filings of these companies over time.

2.4. Zoom on CANON

The CANON Company has a surprising particularity: it appears as the leading applicant in the global photovoltaics field since 1985 with 1416 patent applications, well ahead of SHARP (1182 patents) even though it has very few links with the photovoltaics industry.

2.4.1. History of patent application filings and ambitions

In order to better understand this patent portfolio, we have listed the major known experiences of the group in the photovoltaics field:

- The application of amorphous silicon technologies of ENERGY CONVERSION DEVICES (ECD) for photocopier drums incited Canon to become, in 1987, a minority shareholder (7% holding) in ECD. These two companies later created a joint venture (50-50), UNITED SOLAR SYSTEMS (USS) in 1990, to manufacture photovoltaic cells. The products commercialised by this company were mainly focused on thin film technology. Finally, CANON sold its shares in USS to ECD in 2000.
- CANON got involved in the production of photovoltaic cells in 1996 and left it in 2005. It then opted for amorphous silicon technology. The low efficiency of their cells led them to abandon the project in 2005.
- The acquisition in 2005 of the company ANELVA, which is specialised in the production of thin film semiconductors and which has since been re-baptised CANON ANELVA, could be a foretaste of the willingness of the group to take a closer interest once again in the photovoltaics market. However the different press releases clearly refute this.

The following graph illustrates Canon's filing history in the sector.

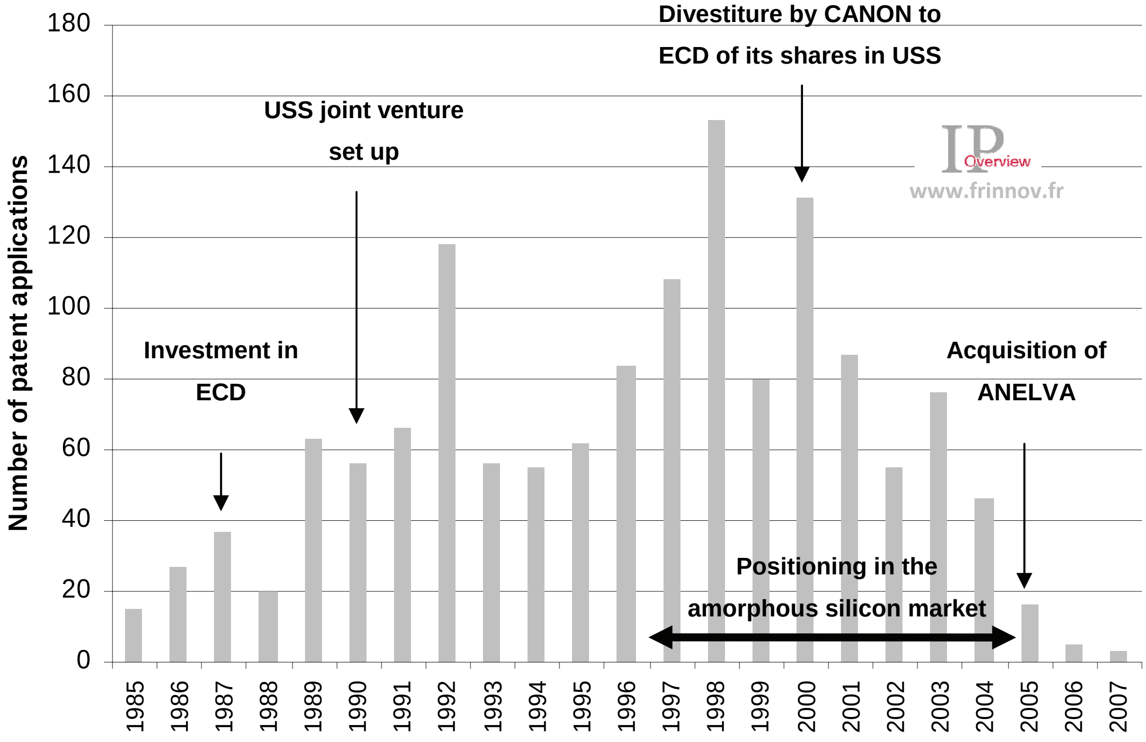


Figure 10 - Evolution in Canon's patent filings

The company began to file patent applications in the photovoltaics field at the start of the 1980s. The volume of applications has increased year by year in an impressive manner, reaching a peak in 1998 with more than 150 patent applications at the time when CANON was vying to position itself in the market for cells based on amorphous silicon. A significant decrease in the number of filings is apparent since 2000, which coincides with its withdrawal from UNITED SOLAR SYSTEMS. The abandonment of the production of amorphous silicon cells in 2005 then foreshadowed a stoppage in filings.

In the light of this history, the acquisition of ANELVA in 2005 certainly does not reflect the group's ambition to return to the solar cell market, but instead to exploit a connected segment of its photovoltaic patents portfolio, namely processes and devices for depositing thin films. This section is illustrated in figure 11 by the "Complementary device" and "Tools and apparatus" segments, which represent 16% of the overall portfolio.

2.4.2. Segmentation of the patent portfolio

CANON's patent application portfolio is a complex and comprehensive portfolio because it contains at one and the same time patents for devices for depositing semiconductor thin films (2%), manufacturing cells (59%), assembling and installing cells (8%), converters and inverters (6%), maintaining and dismantling cells (3%), patents directly linked to applications (6%), patents improving efficiency in an external manner (1%) and finally various complementary patents (15%).

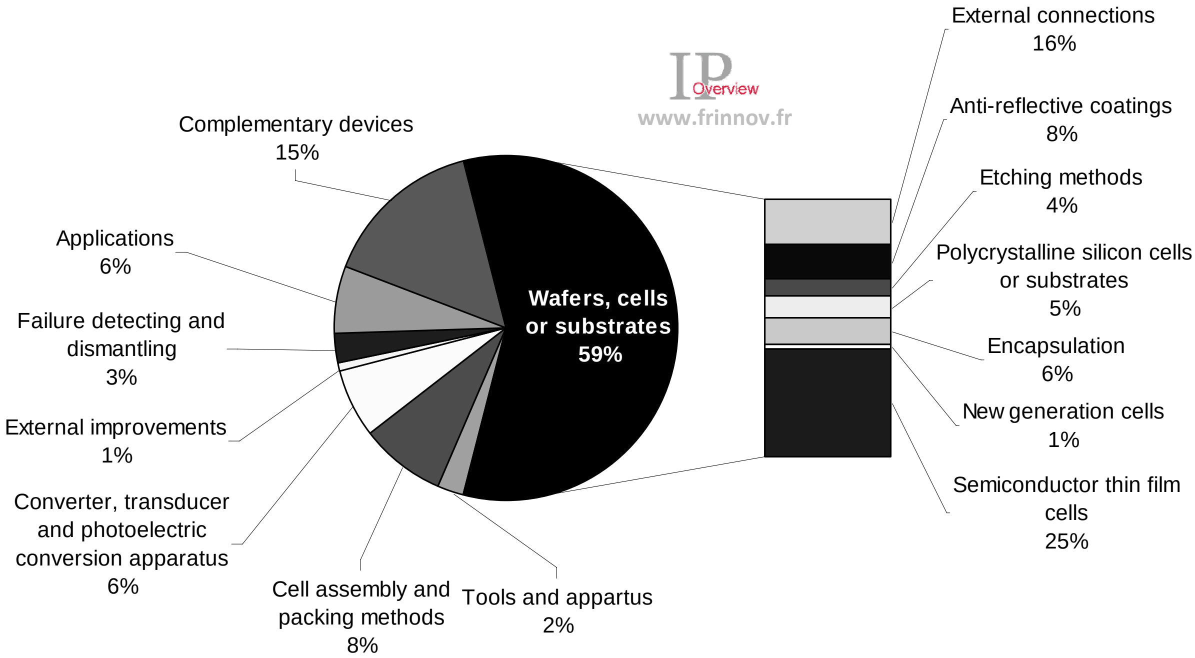


Figure 11 - Canon's portfolio segmentation

Comments:

- The segment "External improvements" represents in particular methods for cooling cells or concentrating light.
- The segment "Complementary devices" comprises in particular techniques for manufacturing solar panels or electronic components using photovoltaic associated technologies.

The most imposing segment of this portfolio concerns the manufacture of the cells themselves (59%) mainly based on thin film technologies (amorphous silicon and microcrystalline cells). However, CANON has pursued a policy of filing on all fronts in the photovoltaics sector, from crystalline silicon cells to organic cells and particularly DSSC (Dye Sensitized Solar Cells) technology.

2.4.3. Filing policy

CANON almost automatically (99%) makes a priority Japanese filing and then makes extensions if necessary and very rarely uses PCT (Patent Cooperation Treaty) filing.

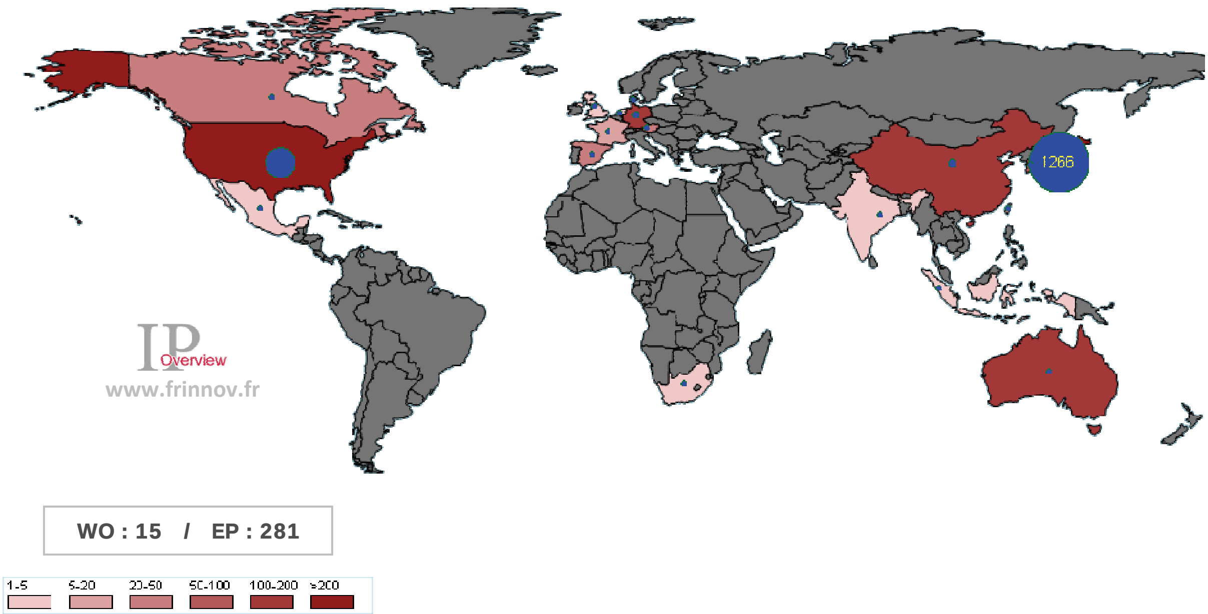


Figure 12 - Canon's patent extensions map

When there is an extension, the United States are generally designated, which is a traditional practice in this sector. In the case of more widespread extensions (other than uniquely the US), the combination of countries protected by CANON is usually "US, Europe and China".

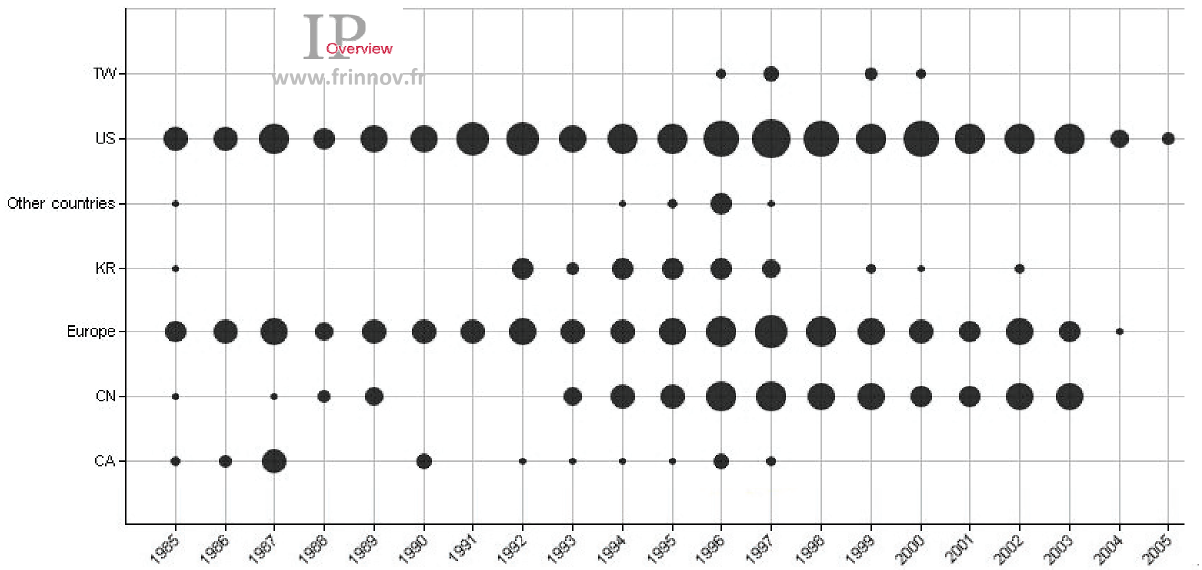


Figure 13 - Evolution in Canon's extensions

The dynamic of extensions (figure 13) shows the anticipation by CANON of the interest of protection in China (protected to the same level as Europe as of 1993 compared to 1997 for the majority of other companies).

2.4.4. Analysis of the patent portfolio

Although CANON is the principal applicant in the photovoltaics field as regards the volume of filings of patent applications, it is important to relativise its real impact.

Firstly, this portfolio has not been extended to a large extent outside of Japan (more than 50% of the patents are uniquely Japanese). Figure 14 shows the breakdown over time of the principal modes of extension employed by this company.

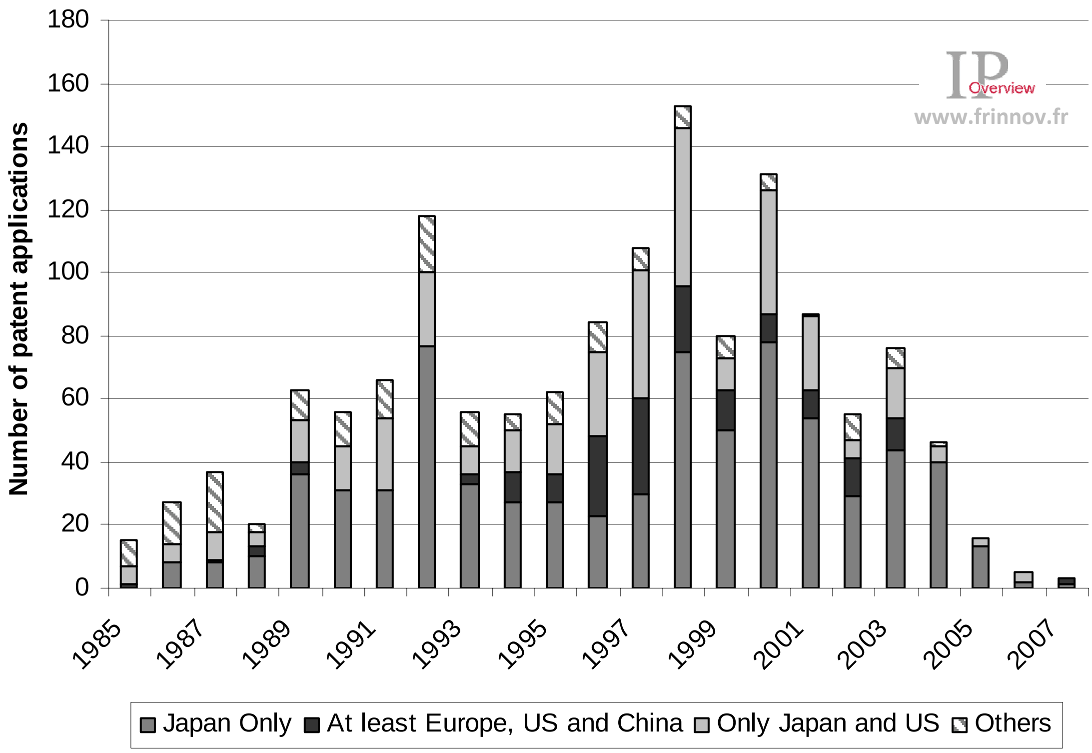


Figure 14 - Canon's extension mode over time

The period 1996-2004 was not only marked by a growth in filings but also by an increase in the number of families with a far more extensive geographic coverage than in CANON's historic practices. These practices, a sign of its wish to protect markets with a view to a commercial exploitation, corresponds to CANON's attempt to position itself for the production of photovoltaic cells.

Finally, the mode of filing patents in Japan is different to that of the US or Europe. Many patents are filed on the basis of one invention, but in the end only a few are granted. In the case of the CANON portfolio, it is important to note that only 36% (figure 15) of Japanese patents have been granted. This figure is moreover slightly above the average for the sector, which stands at 28%. The European and American granting averages are also slightly superior to the sector figures.

Figure 15 - Overview of Canon's granted patents

CANON's patents portfolio has certainly been little extended but the company has made efforts to obtain the granting of its patents when it has chosen to extend them. This shows the strategic interest of these filings for CANON. It was therefore decided to select and analyse these patents in particular in order to understand what topics are involved and gain further insights into the major inventors of the CANON Company. These patents mainly concern thin film solar cells, methods for assembling and installing solar modules for roof applications and finally encapsulation methods. Conversely, it is interesting to note that patents concerning organic solar cells have not been highlighted. The graph below shows the key teams of inventors and the associated topics in which they work.

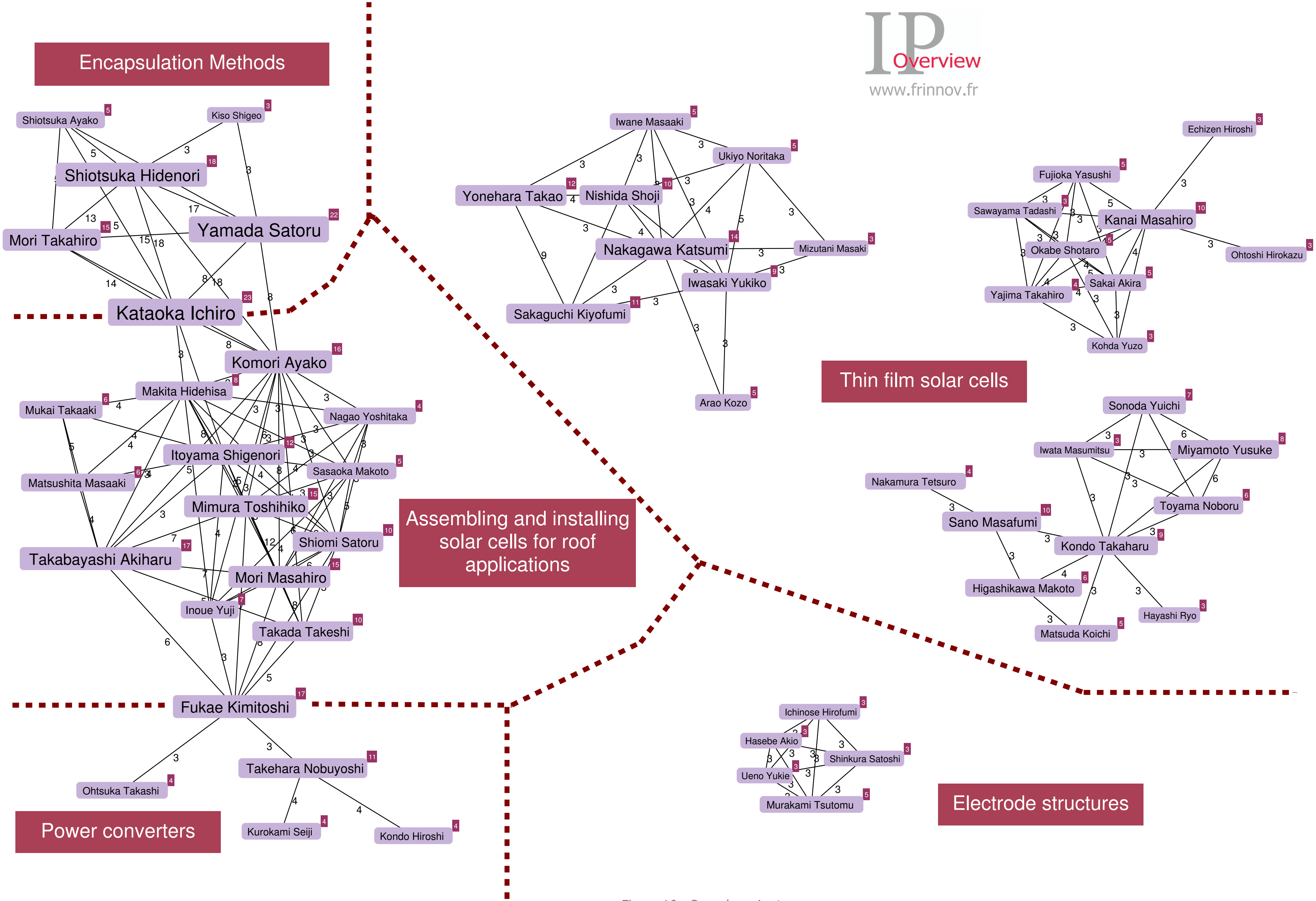


Figure 16 : Canon's major teams

3. Thin Film Cell patents - World analysis

Having completed the general overview of the photovoltaics sector, the remainder of the study will focus on an analysis of the patents and patent applications identified as belonging to the “thin film silicon cell" category.

Consequently, this section analyses on a worldwide level the 4285 families of patents specifically concerning thin film cells that have been filed since 1985 and published up to December 2008. The following sections will focus on the main geographic regions highly active in this field (Japan, Europe and the United States).

3.1. Protection strategies

3.1.1. Evolution of patent filings

The graph below illustrates the evolution over time of filings on photovoltaic thin film technologies.

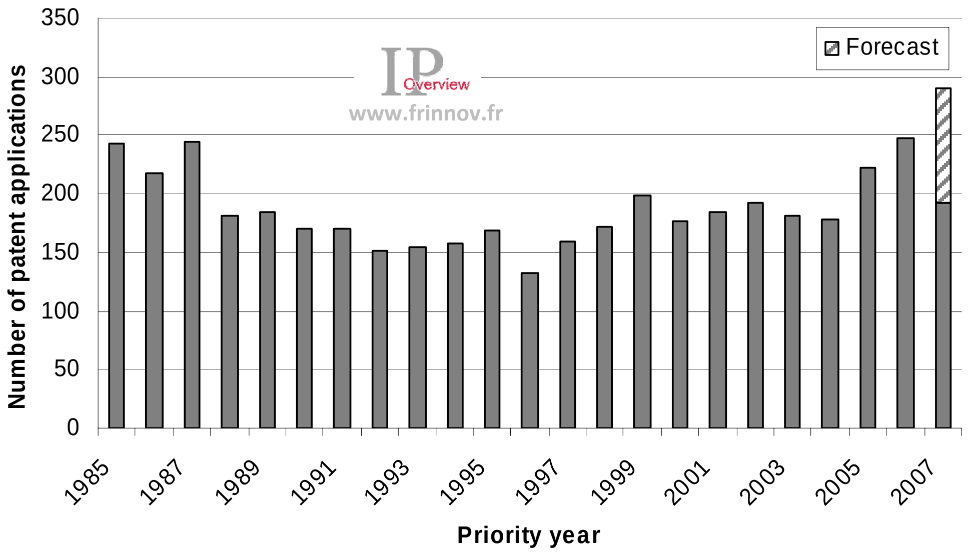
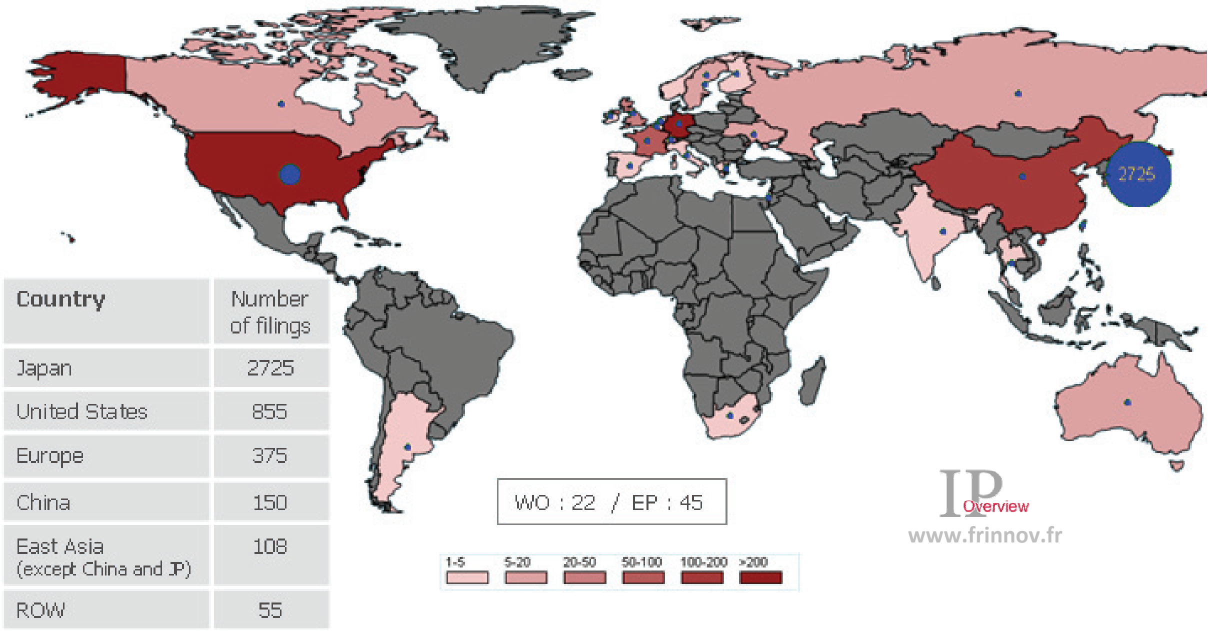


Figure 17 - Evolution of thin film cell patent filings

Despite a market that is still in its infancy, it may be observed that filings that concern photovoltaic technologies based on thin films are not a recent phenomenon. For instance, since 1985, between 150 and 200 filings have been made every year by the players involved in this sector. In recent years, a general increase in the annual number of filings up to around 250 patent applications a year may be noted, a potential sign of a new surge in interest for these technologies (since the data for 2007 is incomplete due to the 18 month delay in production, it has been extrapolated).

3.1.2. Priority filings

An analysis of the location of the filings of priority patent applications results in the map shown below.



Country	Number of filings
Japan	2725
United States	855
Europe	375
China	150
East Asia (except China and JP)	108
ROW	55

Figure 18 - Map of priority filings concerning thin film cells

In keeping with the geographic origin of a large number of players in this sector as well as the practice of priority filing most frequently in the country of origin of the applicant, it is Japan that is the country where the largest number of priority filings are made (2725 patent families). The overwhelming weight of priority filings in Japan since 1985 can also be explained by the fact that the Japanese patent office is traditionally tougher than other patent offices with regard to problems of the unity of invention. Japanese companies therefore file several patent applications with few claims in instances where an American or European company would only file one. The second is of an economic nature. In fact, the Japanese photovoltaics market has acted as a precursor and represents a high percentage of the global market. Moreover, Japanese firms are very well positioned in this field.

The major filing regions are then the United States (855 filings) and Germany (206 filings).

	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07
UKRAINE																		1	4	1	1	2	2
WORLD																	6	4	3	2	2		5
ITALY																	1		1	1	1		
TAIWAN															1		1			1	4	7	7
NETHERLANDS												2	1	1	2	1	2		1		1		
RUSSIAN FEDERATION										1							1		1	2	2		
SWITZERLAND									2			1			2	1							
SWEDEN							1			1				1					3	2			
SOUTH AFRICA					1														2				
AUSTRALIA				1			2			3		1	1	1	1	1	1					1	
ISRAEL			1							1		1							1			1	
CANADA		1					2		1			1						1		1	1	1	
FRANCE		1	1	1	1	1	3	2	1	3	1	3		2	2	4	4	7	4	1	5	3	1
UNITED KINGDOM		1	3				1				1	2			2		3	5	4	2	3	1	2
UNITED STATES	43	25	34	23	26	12	24	29	27	19	26	19	32	26	20	19	41	45	34	62	94	122	53
KOREA	3	1		7	4	3			1		1	2			2	3	9	6	5	4	11	15	7
JAPAN	189	180	202	143	148	147	126	110	113	120	134	95	116	125	137	127	101	96	96	73	71	45	31
CHINA	1									1	2		1	3	1		1	3	7	7	11	28	83
GERMANY	4	8	4	4	3	7	7	10	7	8	4	5	6	9	22	18	11	13	14	15	12	15	
EUROPE	2	1					3		1			1	1	3	5	3	3	9	2	4	2	4	1

Table 1 - Evolution of priority filings concerning thin film cells

The evolution over time of priority filings highlights a trend not shown up in the previous representation, namely that Japanese priority filings fell constantly over the studied period. Conversely, US, German and Chinese priority filings have risen sharply over recent years. Analyses of the industrial property focused respectively on Japan, Europe and the United States will be carried out in the following sections to study these phenomena in greater detail.

China, which still has a low volume of priority filings within its territory compared to all priority filings made since 1985, has now become an important motor for innovation in the sector. For instance, taking just 2007 as an example (for which the data is moreover incomplete), Chinese priority filings for that year were greater than the total number of all Chinese priority filings between 1985 and 2006. In fact, the Chinese government massively encourages the development of photovoltaic sourced energy, since it is faced with an ever increasing demand (4200 TWh forecast in 2020), which necessitates a diversification of supply.

Among Chinese applicants, it is interesting to note that numerous patent portfolios have been built up by academic institutions, such as that of the University of NANKAI (11 patent applications), the SHANGHAI Institute (8 filings), the University of SHANGHAI (6 patents) and the University of SICHUAN (5 patents).

The Chinese company that has the largest portfolio of Chinese priority patents in this sector is indexed in the patent data bases under the applicant BEIJING XINGZHE MULTIMEDIA TECH with 26 filings concerning thin film solar cells. Nevertheless, it is important to note that the identification of Chinese firms that file patents is particularly difficult due to problems in the automatic translation of the contents of Chinese documents. After verification, BEIJING XINGZHE MULTIMEDIA TECH is not involved in the photovoltaics sector, which is why in this study we have modified this applicant by the designation “unknown”.

Applicant	**Patent**
Unknown	26
UNIV. NANKAI	11
SHANGHAI INST.	8
UNIV. SHANGHAI	6
UNIV. SICHUAN	5
CHINESE ACAD. OF SCIENCE (CAS)	4
UNIV. JILIN	4
UNIV. TSINGHUA	4
ITRI (TW)	3
UNIV. BEIJING	3

3.2. Technological maturity factors

3.2.1. Analysis of the evolution of filings

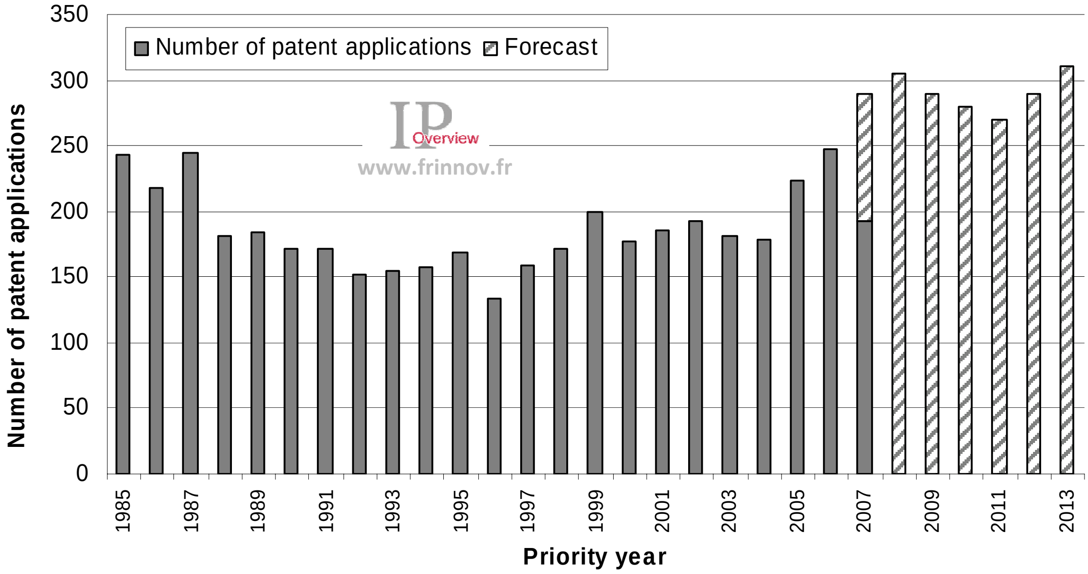


Figure 19 - Forecast of the number of filings

The above figure illustrates past filing trends as well as the forecasts for coming years. For instance, a slight downturn in the general increase in the number of filings may be expected in 2009 linked to the economic situation, which could lead to massive cuts in patent protection budgets. In addition, the probable cut in R&D budgets in 2009, which may also extend into 2010, is likely to make its effects felt on the volume of patent application filings over the following years. Nevertheless, in the longer term, this sector should experience renewed growth due to the energy context (upward trend in the price of fossil energies) and political context (incentives in favour of renewable energies, Kyoto protocol). Growth is envisaged, with a volume of filings of around 300 patent applications a year within the next 4 years.

3.2.2. Analysis of industrial filings over time

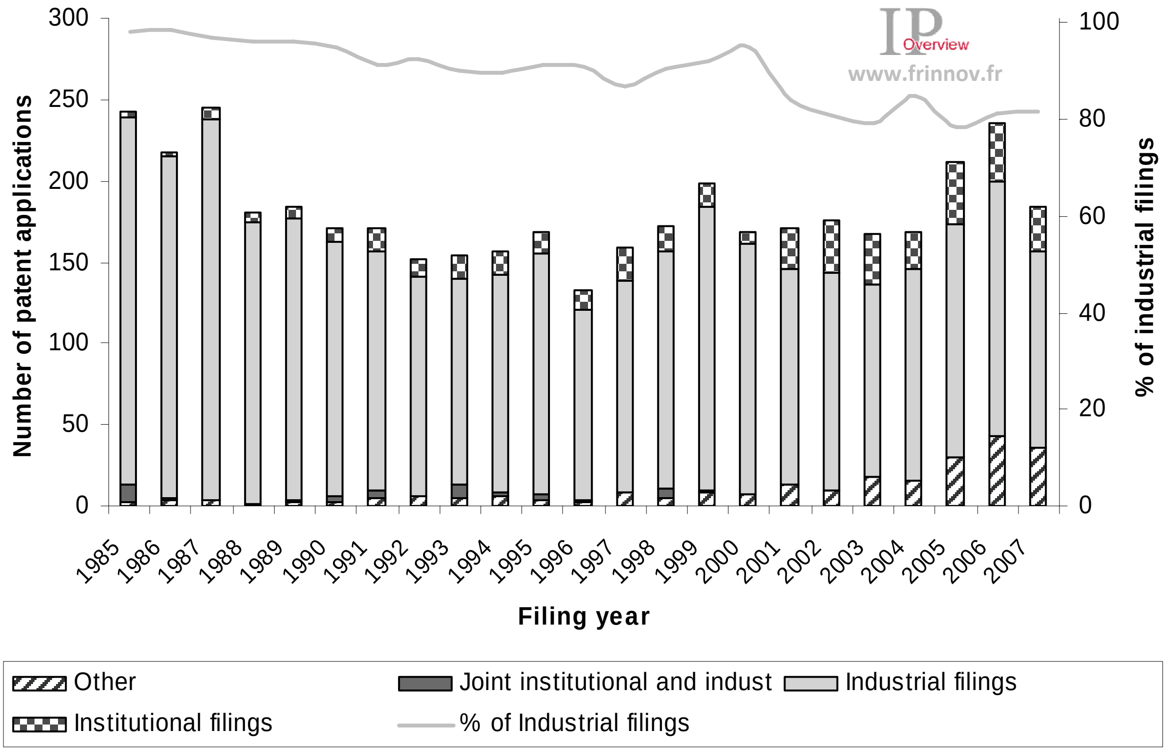


Figure 20 - Evolution of the breakdown of industrial patents concerning thin film cells

Figure 20 illustrates the proportion of filings made either by industrial concerns or by academic institutions or instead jointly filed by an institution and an industrial player. “Other” filings mainly correspond to filings made in the names of inventors (in particular in the case of US filings).

As in most market sectors in which the immediate application of the patents is clearly identified, the majority of filings are made by industrial applicants, unlike more fundamental subjects where the proportion of academic institutions can attain 40% of filings. It is moreover interesting to note that joint filings between industrial concerns and institutional bodies are not very widely practiced in the photovoltaics field.

Nevertheless, the significant increase in the proportion of institutional filings compared to industrial filings since 2001 is worthy of note. In order to illustrate this point, the following graph shows the evolution over time of the filings made by major institutional bodies.

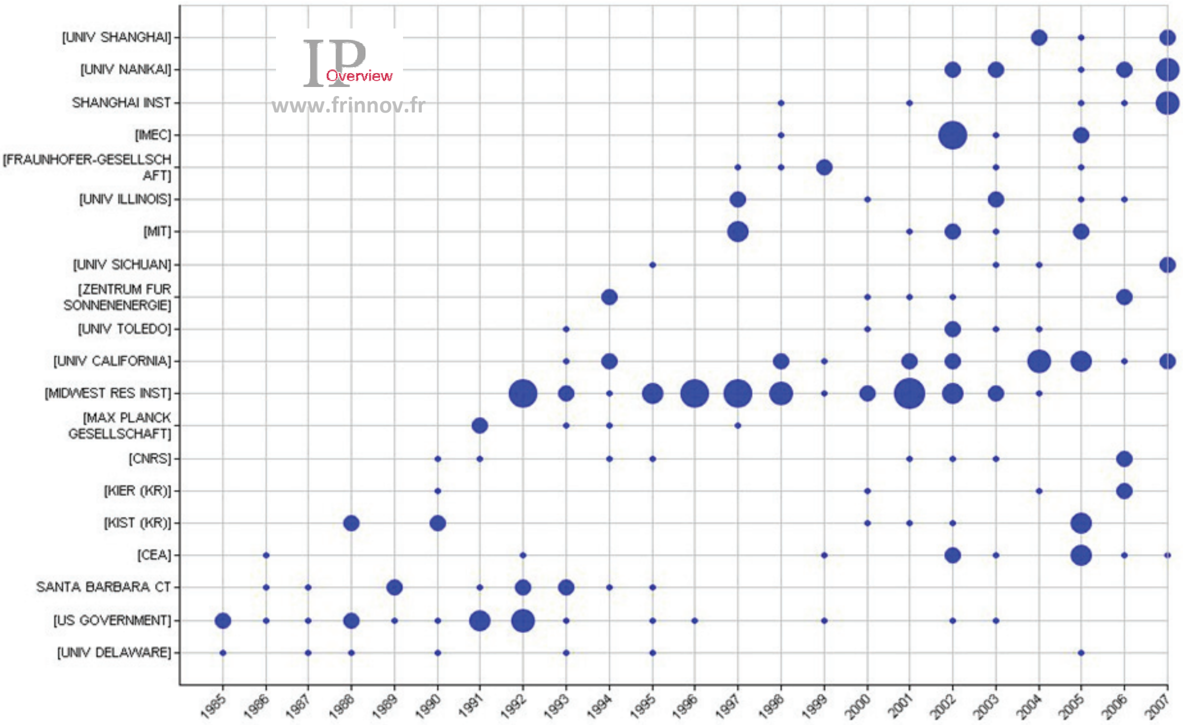


Figure 21 - **Evolution over time of filings made by academic institutions**

Such a representation clearly shows the increasing interest of Chinese and Korean institutions in this type of topic. Thus, over the last few years, the universities of NANKAI and SHANGHAI have filed in a sustained manner, as has KIST (Korea Institute of Science and Technology) and KIER (Korea Institute of Energy Research). The large number of filings made by the University of California should also be noted.

3.2.3. Topologies of portfolio sizes

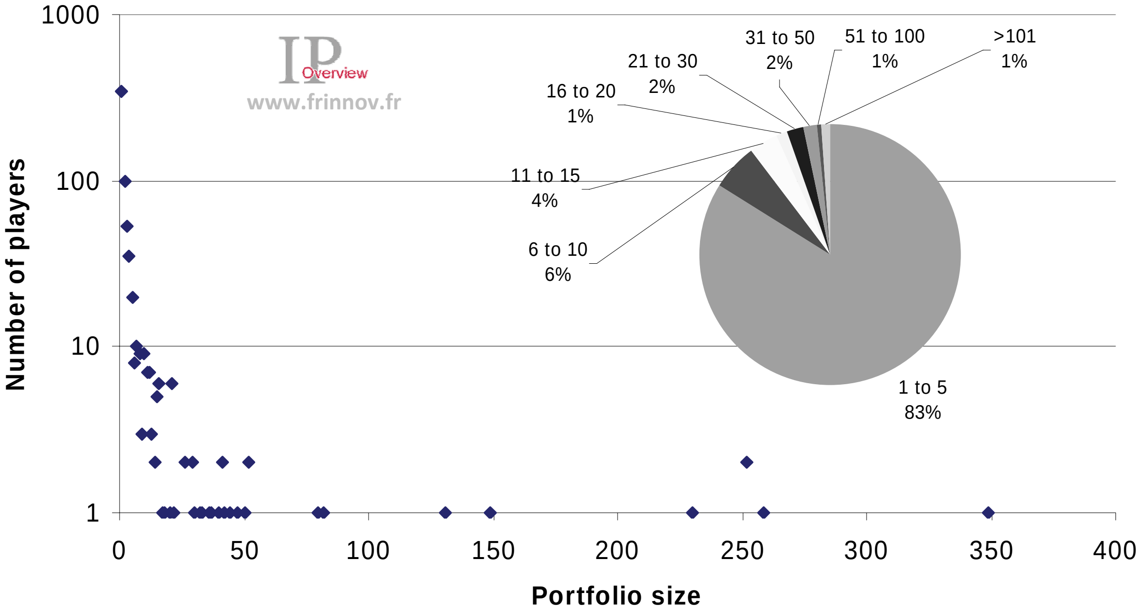


Figure 22 - Portfolio size vs. number of players

Figure 22 provides an insight into the composition of patent and patent application portfolios on photovoltaic thin film cells.

It appears that the majority of players (83%) have a portfolio of less than 5 patents and only 2% of patent portfolios contain more than 50 patents. A large number of players exist, including very small companies, universities and research centres, who file in the field without having a specific patent strategy.

3.2.4. Analysis of the granting of patents

Figure 23 - Overview of "thin film cell" granted patents

It is interesting to analyse the proportion of patents granted as a function of the number of filings made. This analysis may be performed on US, Japanese and European filings and finally gives an insight into the real patent protection at the time of the study. It should be noted that the ratio of US patents granted compared to US patents filed has no sense here and needs to be extrapolated. In fact, before November 2000, US patent applications were only published on the day of granting of the patent and applications that were not granted were never in fact published.

Thus, on the basis of the principle that the proportion of patents granted, filed before 2000, probably did not exceed 80% of the patents filed before this date, the US data may be extrapolated as illustrated in figure 23.

This figure shows that today, more patents have been granted in the United States than in Japan, which an analysis of the filings made previously could not predict.

In order to have a better understanding of granting phenomena, each item of data exposed above will be studied over time in the geographic focuses of this study.

3.2.5. Evolution in the number of applicants

The figure below shows the evolution in the number of applicants who appear in the patent applications for the year in question (darker curve). Thus, this curve does not represent the total number of players active in the filing of patent applications, since a player may very well not have made any filings over the course of a year. The lighter curve, for its part, represents the annual number of applicants who appear for the first time in a patent application.

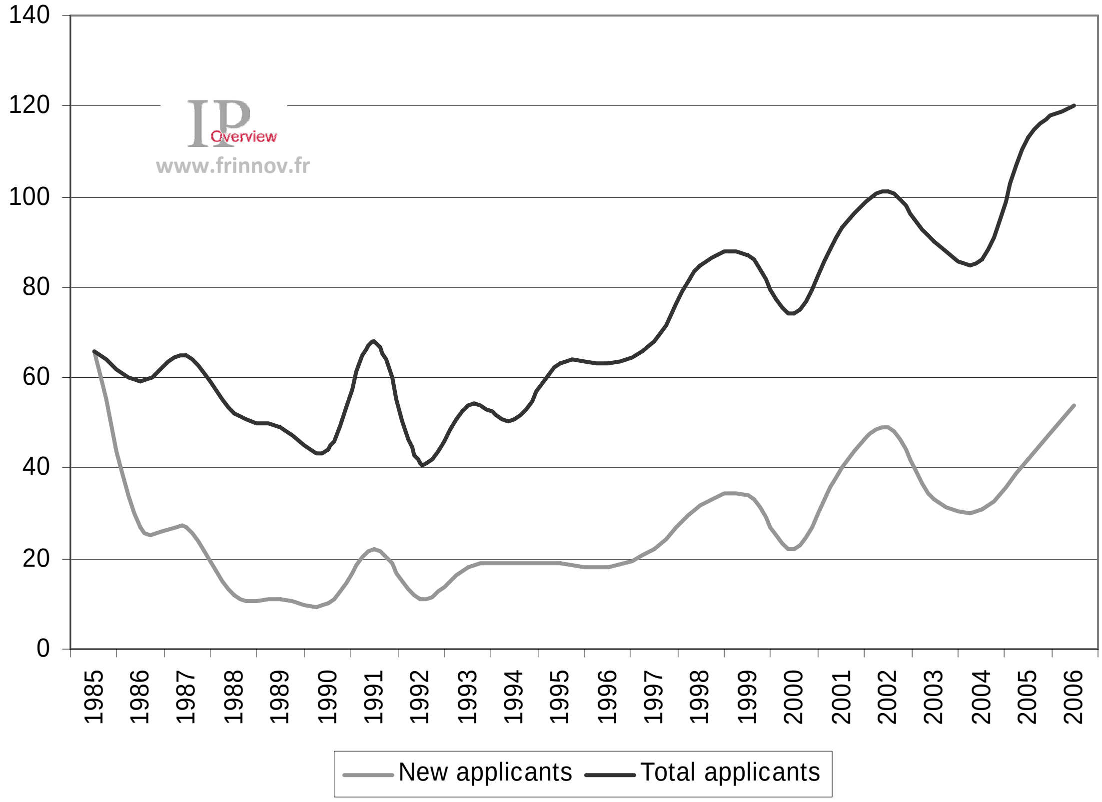


Figure 24 - Evolution of the number of applicants

An analysis of the above figure enables two principal trends to be identified:

- A first period from 1985 to 1997, during which the number of applicants oscillated between 40 and 70 every year, with the arrival of new applicants standing at about 20 newcomers a year.
- From 1997 onwards, a period of quite sustained growth in applicants up to 2006 may be observed, a sign of the increasing attractiveness of the sector, the number of new applicants also increasing overall.

Moreover, the data for 2006 provides a glimpse of a possible forthcoming surge in interest perhaps even more significant with nearly 55 newcomers in the sector for this year alone.

3.3. Applicants

3.3.1. Major applicants

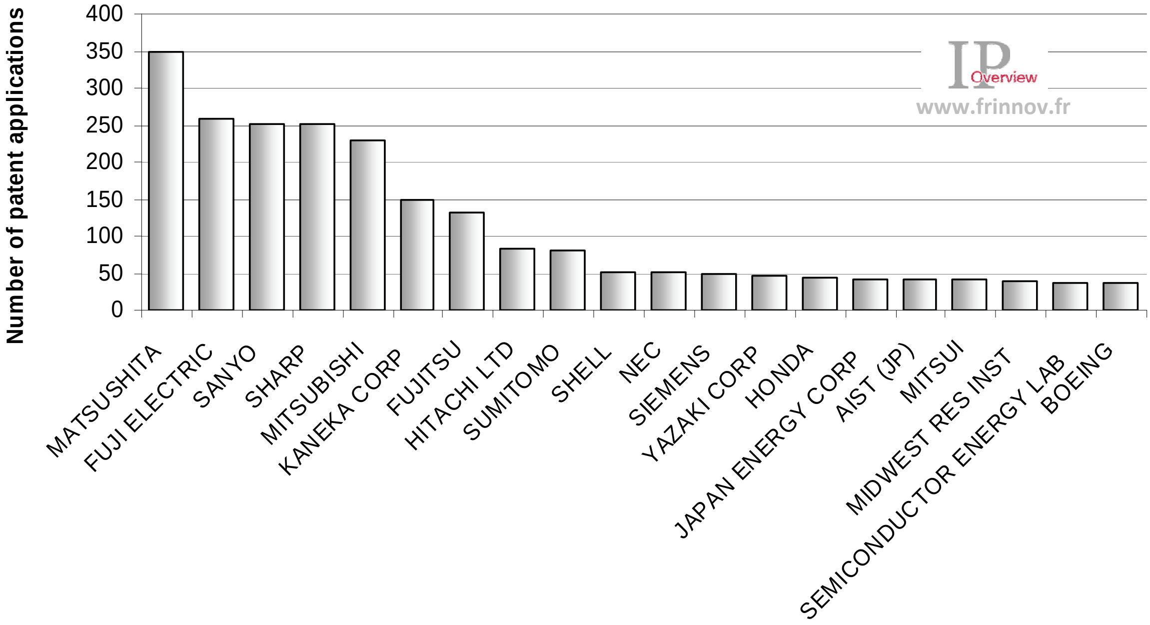


Figure 25 - Major applicants in the field

As traditionally observed in the photovoltaics field, the major applicants are Japanese players (16 out of 20), 15 of which are industrial players. Two academic institutions are nevertheless included in this list of major applicants, the AIST (Japan's leading public research centre) and the MIDWEST RESEARCH INSTITUTE. The MRI files in its own name patent applications stemming from the research work of the NREL (National Renewable Energy Laboratory) and also SolarTAC (Solar Technology Acceleration Center). MRI's filings are not focused on a unique type of thin film cell, which is in keeping with the research topics announced in particular by NREL, namely: amorphous silicon (a-Si), copper indium diselenide ($CuInSe_2$ or CIS) and related materials, cadmium telluride (Cd-Te), environment, safety, and health (ES&H), and module reliability.

The MATSUSHITA Group accounts for the largest number of filings, with in particular filings made by its different subsidiaries such as MATSUSHITA ELECTRIC, MATSUSHITA BATTERY and MATSUSHITA ECOLOGY. In fact, very early in the 1980s, MATSUSHITA positioned itself in thin film Cd-Te technologies (nearly half of the filings of MATSUSHITA concern this type of thin film) initially produced by screen printing and which generated thirty or so filings between 1985 and 1993. Subsequently, for the production of Cd-Te cells, MATSUSHITA turned towards close space sublimation techniques. In a more consequent manner, MATSUSHITA has also protected cells based on amorphous silicon (period between 1985 and 1990) before also focusing on the filing of patents concerning CIS cells (around 70 patent applications). Nevertheless, it should be noted that MATSUSHITA now only files a limited number of patent applications concerning photovoltaic thin film cells (around 3 to 4 applications a year since 2004) as illustrated in table 2 below.

FUJI ELECTRIC, whose patent and patent application portfolio exceeds 250 filings, began its research work in this sector in 1985 with filings initially focused on cells based on silicon, mainly deposited on glass substrates. Subsequently, several filings concerning CIS technology have been made by this company that do not seem to be focused on this type of technology. At present, in terms of commercialisation, FUJI ELECTRIC has concentrated its efforts on the production of lightweight photovoltaic modules manufactured by laminating a film-type amorphous solar cell on a steel plate. Nevertheless, a reduction in the filing quantity by this company since 2005 (5 a year maximum) may be observed.

The SANYO Company also has a portfolio of around 250 families of patents on photovoltaic thin film cells. Like numerous firms in the photovoltaics field, SANYO's early efforts were concentrated on amorphous technologies. Thus SANYO, whose research began in 1975, started the mass production of amorphous cells for the general public in 1980. Correlatively, there were a very large number of patent filings on this subject over the period 1985-1995. Subsequently (as of 1990), the main topics cited in SANYO's documents concern cells based on a layer of monocrystalline silicon coated with several thin films made of amorphous silicon (HIT technology - Heterojunction with Intrinsic Thin layer). The mass production of these cells started, for its part, in 1997. The current positioning of this company is thus a little different to that of other firms involved in the manufacture of thin film solar cells, since this type of cell favours high efficiency at low manufacturing costs.

The patent applications of the SHARP Company (around 250 filings) reflect its strategic orientation towards multijunction cells. In particular, SHARP works on cells of this type based on the semi-conductor InGaPAs (indium gallium phosphide arsenic) coupled to a concentrator. It has been possible to obtain a conversion efficiency of 40% for a cell of this type, with sides of 4.5 mm. The most recent patent applications are also turned towards multijunction cells comprising alternating amorphous silicon and microcrystalline silicon layers. The absence of filings made by SHARP concerning thin film CIS / CIGS cells may also be noted.

Although the 4th player in the market, the absence of the FIRST SOLAR company among the major applicants is noteworthy. This company, specialised in the production and the commercialisation of photovoltaic Cd-Te cells, only has in fact 8 patent applications on thin film cells listed in this study. Nevertheless, an analysis of press releases shows that it collaborates closely with NREL (laboratory of the MIDWEST RESEARCH INSTITUTE, 18th applicant in the field and the 1st American applicant in the Cd-Te field).

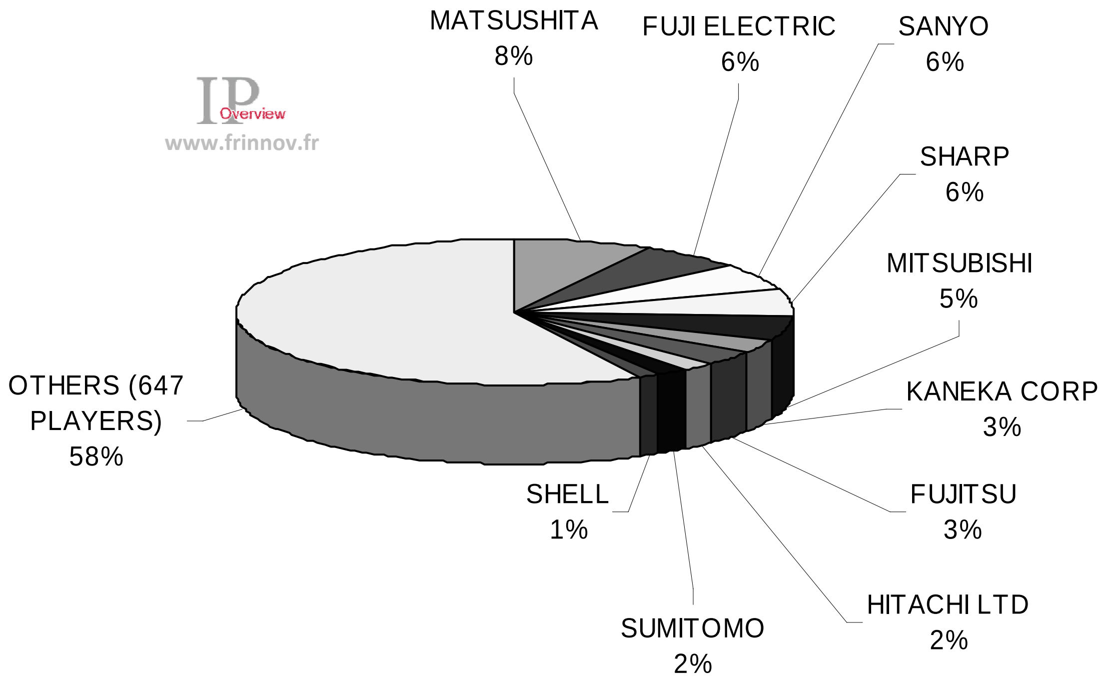


Figure 26 - Breakdown of patent portfolios by applicant

The above figure illustrates the percentage share represented by the 10 leading applicants. Thus 42% of patents are held by these 10 major players. Such an observation is typical of a sector in which patent portfolios are still being built up but in which the major players are already in place. In fact, it is classical to observe, in sectors that are very technologically mature, much higher concentration ratios of patents, namely that 5 major players can share around 80% of patent filings in a given field.

Nevertheless, in this field it is important to keep in mind that the filing dynamic of the major players (in particular Japanese) is falling, which may falsify such an analysis.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
BOEING	3	1		2	5	3	1	1			1				2	1	2	5	3	2	4		
FUJITSU	15	18	2	18	23	16	10	6	3	3	6	8		2			1						
HONDA		1					1	1						3		3	3	11		6	8	7	
MATSUSHITA	27	35	49	23	7	19	13	23	15	16	16	17	14	19	13	9	2	9	12	4	3	4	
MITSUBISHI	9	14	32	16	23	13	16	8	4	4	3	5	10	7	9	8	10	17	2	11	7	1	1
MITSUI		1	1	4	2	3	7	3	7	5	5	3											
NEC	6	8	3	5	4	6	3	2	4	5	3	1		1				1					
SANYO	17	12	9	5	28	27	16	16	12	7	14	5	8	6	7	7	8	4	17	7	8	5	7
SHARP	20	13	18	6	7	6	9	4	5	7	8	8	9	18	20	25	24	8	11	11	9	3	3
SHELL			1			2	3	2	3	1	4	4	1		5		1	1	1	5	6	5	7
SIEMENS	6	5	6	6	1	2	2	7	4	2	1	2		1	4				1				
YAZAKI CORP		3				1			6	10	8	4	8	7									
FUJI ELECTRIC CO LTD	10	10	25	14	16	8	15	15	11	22	16	5	5	3	20	18	9	17	9	5	5		1
JAPAN ENERGY CORP								5	6	11	10	1	3	3	3								
SUMITOMO	12	8	14	10	2	6	3	3	6		4	3	2	1			1	2	1			2	
HITACHI LTD	10	6	5	7	2	10	1	1	3	8	2	2	2	2	1	2	6	1	5	2	2	2	
AIST (JP)	7				1	1	1		1			1		3		2	4	6	8	2	1	3	
MIDWEST RES INST								5	2	1	3	5	5	4	1	2	6	3	2	1			
SEMICONDUCTOR ENERGY LAB	7	3		1		3		2	1	1	7	1	3	1	1	2		1			1		2
KANEKA CORP	4	5	7	3	4	2	1	9		5	9	1	5	8	33	20	10		7	6	7	2	1

Table 2 - Filings of the major players over time concerning thin film cells

3.3.2. Emerging applicants

The following table shows the companies or institutions that are starting to file, which we consider as "emerging applicants". The emergence factor, which enables these applicants to be identified, corresponds to the growth in terms of patent filings over the period 2004, 2005, 2006 and 2007.

Applicant	N° of patents (2004-2007)
NANOSOLAR INC	19
APPLIED MATERIALS INC	15
GENERAL ELECTRIC	15
KONARKA TECHNOLOGIES INC	14
SOLYNDRA INC	10
GUARDIAN IND	10
CORNING INC	10
DU PONT	7
PALO ALTO INST INC	5
AGENCY SCIENCE TECH RES	4
ATOMIC ENERGY COUNCIL	4
BANPIL PHOTONICS INC	4
MILLENIUM COMM LTD	4
ITN ENERGY SYSTEM INC	4
HIGHER WAY ELECTRONIC	4

Table 3 - Emerging applicants

The NANOSOLAR Company was created in 2002 by two former students of STANFORD University. This company, which began to file patents in the photovoltaics field in 2002, is that which has shown the largest growth over the period 2004-2007. Its patent positioning ties in with its commercial announcements; in fact, out of the 21 patent applications, 15 explicitly concern CIGS cells. The characteristic of this company mainly resides in the deposition method that it uses, which is similar to newspaper printing techniques and has the advantage of taking place in a continuous manner on a flexible metal strip. At present, NANOSOLAR has two plants, one located in San José in California and the other near to Berlin in Germany, which represent an annual production capacity of 1GW.

APPLIED MATERIALS, with 15 filings between 2004 and 2007, is the second most dynamic company in the field in terms of recent filings. Unlike the companies previously described in this study, APPLIED MATERIALS does not however commercialise photovoltaic cells since the products of this company are exclusively aimed at equipment for photovoltaic thin film cell production lines. In particular, APPLIED MATERIALS has patents protecting multi-junction cells alternating thin films made of amorphous silicon with layers of microcrystalline silicon as well as the corresponding production equipment and processes. They have also protected through a patent a process and the related equipment enabling continuous deposition by electroplating on flexible substrates (US2008128013).

The GE Company has pursued a dynamic filing policy in the photovoltaics sector from 2004 onwards, a period that was particularly marked by the takeover of ASTROPOWER, the photovoltaic equipment manufacturer, by the GE ENERGY branch. GE’s filing policy in the field began for its part in 2005 with 4 filings, followed by 7 in 2006 and at least 4 in 2007 (the delay in publication of the data prevents greater precision). The company has specially invested in "silicon nano-wire based" cells. Two key inventors of "GE's solar platform", Tsakalakos LOUCAS and Korevaar BASTIAAN, appear as emerging inventors in the US focus section (part 6).

KONARKA TECHNOLOGIES, a company based in Lowell, Massachusetts, was created in 2001. It is mainly focused on photovoltaic ink jet printing solutions on all types of substrate (plastic, fibres, etc.). This type of solution is dealt with in more detail in the report "Photovoltaics III - Organic Solar Cells". This company is very dynamic in terms of patent filings over the last few years (it has a portfolio of around 70 patent families). However, the ten or so patents that appear in this study dedicated to thin films mainly concern CIGS cells.

SOLYNDRA, based in Fremont, California, was created in 2005 by Chris Gronet, who is still the company’s CEO. The company designs and manufactures photovoltaic systems composed of assembly panels and equipment for the commercial roofs market. It has in particular developed and protected, with ten or so patents, cylindrical modules and the technology of depositing suitable CIGS thin films. SOLYNDRA systems are designed to offer minimum installation costs for each system combined with maximum solar energy efficiency, mainly for roof applications. SOLYNDRA is a company in full economic and technological development. However, it should be noted that although Chris Gronet is the main inventor of SOLYNDRA patents, two key inventors left the company in 2008: Benyamin Buller for FIRST SOLAR (inventor in 4 SOLYNDRA patent applications filed in 2006, WO2008019066, WO2008060315, WO2007117442 and WO2008051275) and Ratson Morad for DAYSTAR TECHNOLOGIES (inventor of a SOLYNDRA patent filed in 2006, WO2008060315).

3.3.3. Major collaborations

In order to analyse the co-filings network (figure 27), it is important to note that only players that have filed more than 2 patents with a partner are shown on this map.

There are different explanations to co-filings; they may in fact involve filings stemming from a collaboration between two separate companies, a collaboration between a company and an academic player, or instead the link up may stem from a relation between a parent company with its subsidiary, which jointly file together.

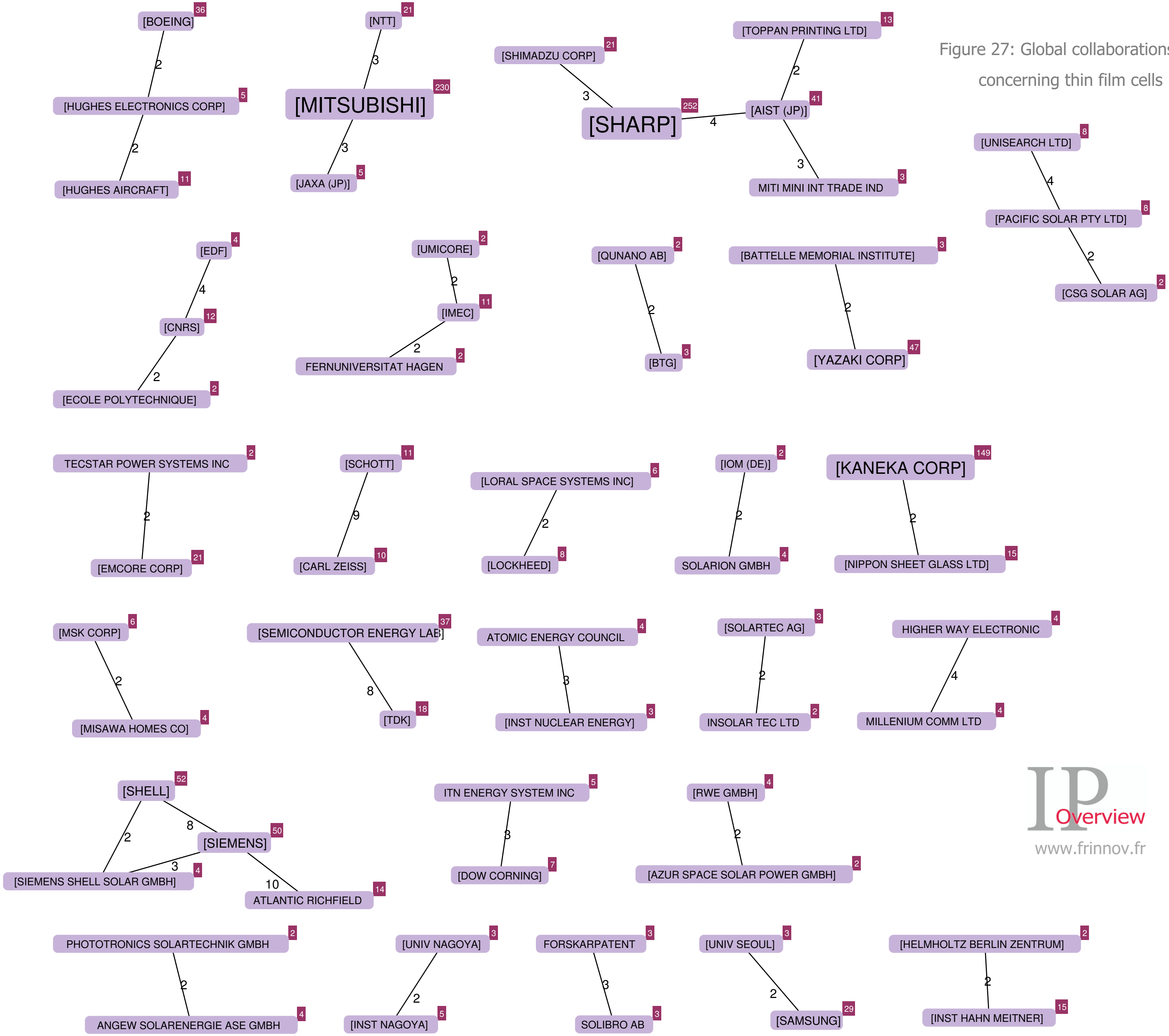
For instance, the link up that has generated the largest amount of co-filings is that between SIEMENS and ATLANTIC RICHFIELD COMPANY (ARCO). All of these co-filings took place between 1985 and 1988 before the take over by SIEMENS of ARCO Solar in 1989 (the Californian subsidiary of ATLANTIC RICHFIELD OIL COMPANY). This takeover by SIEMENS allowed ARCO to become one of the main producers in the photovoltaics field at the time. The co-filings between these two companies mainly concerned CIS thin film cells. The other most important collaboration in this sector is linked to the 8 co-filings of the TDK Company with the SEMICONDUCTOR ENERGY LAB, a Japanese private research laboratory.

Several co-filings between industrials correspond to jointly owned filings between a subsidiary and its parent company or instead a joint venture set up with a parent company, such as:

- SCHOTT with CARL ZEISS: both companies are 100% subsidiaries of the CARL ZEISS Foundation. The 9 co-filings between these two companies are mainly focused on aluminoborosilicate glasses.
- SIEMENS SHELL SOLAR with SHELL and SIEMENS: the majority of co-filings between SIEMENS, SHELL and their joint venture SIEMENS SHELL SOLAR relate to CIS thin film cells and took place between 1993 and 1999.

Concerning the links between industrial players and institutions, SHARP's filings with AIST are worth underlining, in particular with regard to thin film cells integrating microcrystalline silicon deposition. The other noteworthy industrial/institutional collaboration concerns the link up between EDF and CNRS, which has led to a joint research laboratory (CISEL) being set up on CIS thin film cells.

Figure 27: Global collaborations map concerning thin film cells



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3.4. *Topology of patents in the sector*

3.4.1. Segmentation of patents by technologies

The patent portfolios of photovoltaic technologies based on thin films is segmented in the following manner: the different types of cells as well as 3 categories that do not concern the type of cells, external connections, encapsulation and anti-reflective coatings, so as to identify the different positions taken by the players in the field.

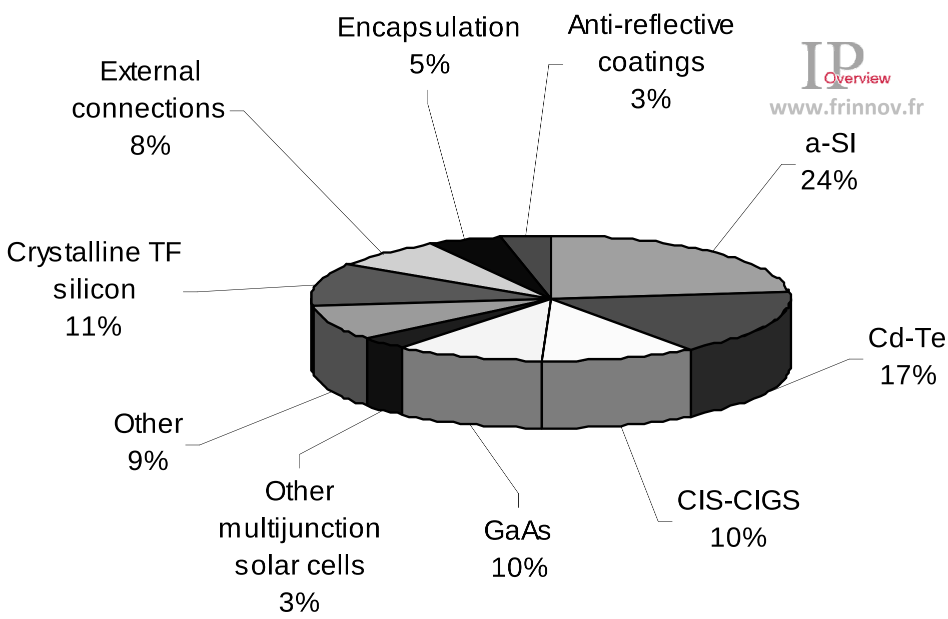


Figure 28 - Segmentation of thin film photovoltaic cells patents portfolio

This representation shows that the type of thin film cells that have generated the most filings since 1985 are amorphous silicon cells, which account for nearly 1/4 of filings, followed by Cd-Te cells. Then come patents on solar cells based on micro- or nano-crystalline silicon thin films deposited on substrates, and CIS-CIGS and Ga-As multijunction solar cells, which each account for 10% of filings.

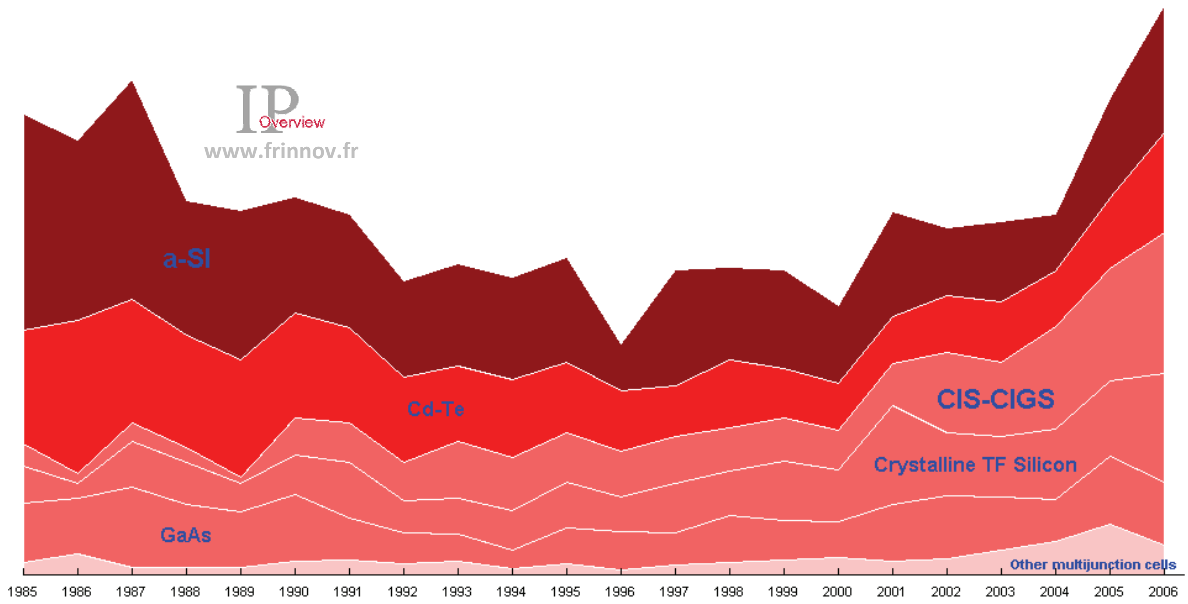


Figure 29 - Segmentation of photovoltaic thin film cell patent portfolios over time

It is nevertheless important to observe these results over time so as not to have a biased view of the segmentation of filings by technology. In fact, although amorphous silicon thin film cells have been researched for many years and have generated numerous filings, the production of patents concerning them has seen a fall over the last 20 years, the main drawback with these cells being their low efficiency. The same type of downward trend in terms of filings may also be observed in the case of Cd-Te cells, mainly for environmental concerns due to the fact that they contain cadmium.

Conversely, the number of patents concerning CIS-CIGS cells or even micro- or nano-crystalline silicon solar cells deposited on substrates has risen sharply over the last few years. Filings relating to multi-junction cells are, for their part, increasing overall.

3.4.2. Types of cells protected by the major players

The following representation (figure 30) enables the positions taken by different players that file patents on photovoltaic thin film cells to be identified. Thus, some players have taken up exclusive or virtually exclusive positions on one type of thin film cell, such as FUJITSU, NEC, JAPAN ENERGY CORP and NIPPON MINING for Cd-Te technologies. In the same way, YAZAKI CORP, HONDA, SHELL and NANOSOLAR are mainly focused on CIS/CIGS technologies. Other firms, such as FUJI ELECTRIC, KANEKA, MISTUBISHI and SHARP have patents that protect practically all types of thin film cells.

Graphs illustrating the positioning (types of thin films, types of filings and types of substrates) of the major Japanese, European and US companies and the major academic players are available in Appendices 4 to 15.

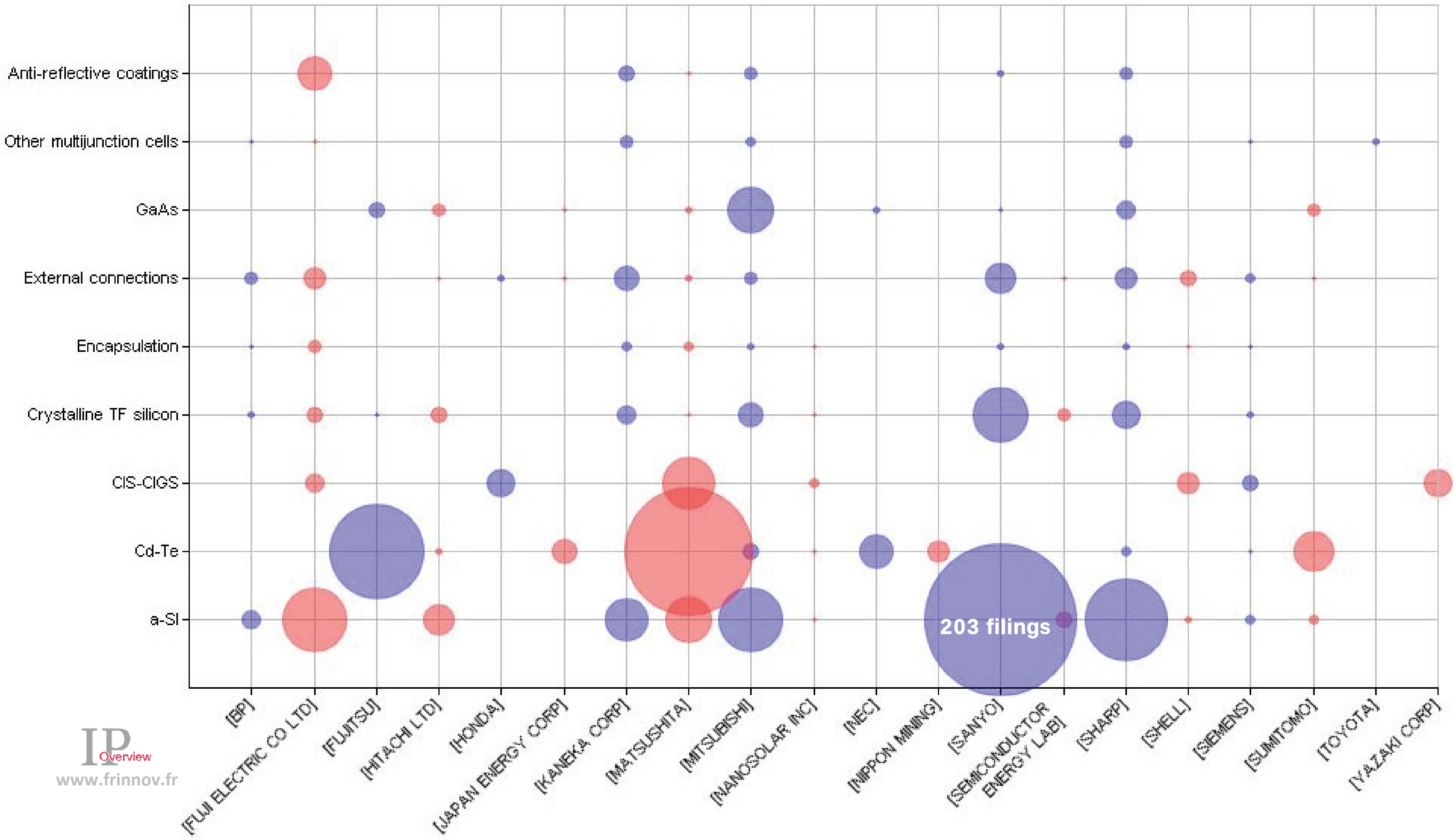


Figure 30 - Topics of the major players

3.4.3. Segmentation of patents by IPC code

We have highlighted the IPC codes that are the most represented in the patent applications filed since 1985. This segmentation is given in the figure below.

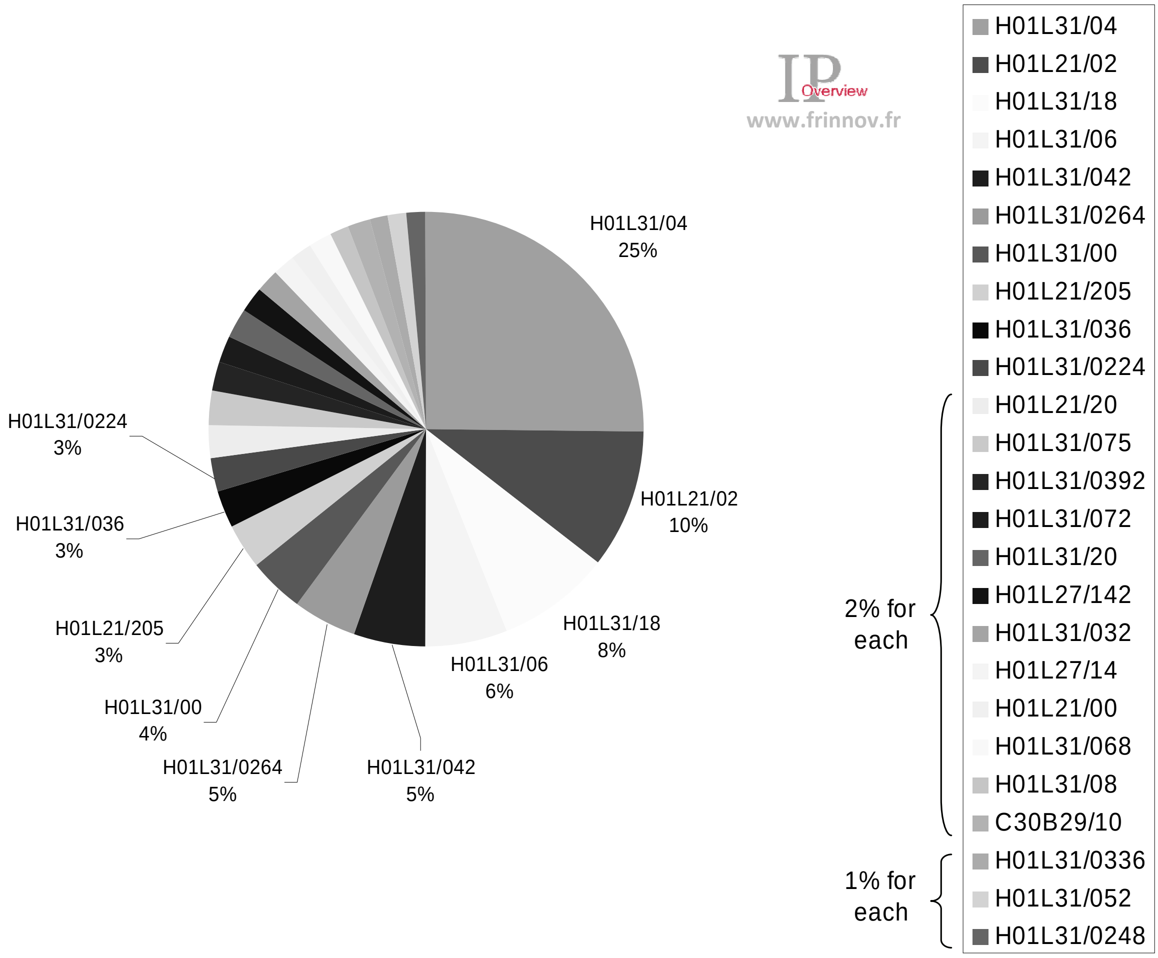


Figure 31 - Breakdown of the main IPC codes appearing in patent applications

The main IPC codes are stable over time and are particularly representative of the sector without however giving an insight into principal applications and emerging applications (see the signification of the most represented codes below).

IPC code	Description
H01L31/04	Semiconductor devices sensitive to infra-red radiation, light, electromagnetic radiation of shorter wavelength, or corpuscular radiation and specially adapted either for the conversion of the energy of such radiation into electrical energy or for the control of electrical energy by such radiation, adapted as conversion devices

IPC code	Description
H01L21/02	Processes or apparatus specially adapted for the manufacture or treatment of semiconductor or solid state devices or of parts thereof. Manufacture or treatment of semiconductor devices or of parts thereof
H01L31/18	Semiconductor devices sensitive to infra-red radiation, light, electromagnetic radiation of shorter wavelength, or corpuscular radiation and specially adapted either for the conversion of the energy of such radiation into electrical energy or for the control of electrical energy by such radiation. Processes or apparatus specially adapted for the manufacture or treatment of these devices or of parts thereof
H01L31/06	Semiconductor devices sensitive to infra-red radiation, light, electromagnetic radiation of shorter wavelength, or corpuscular radiation and specially adapted either for the conversion of the energy of such radiation into electrical energy or for the control of electrical energy by such radiation, adapted as conversion devices, characterised by at least one potential-jump barrier or surface barrier
H01L31/042	Semiconductor devices sensitive to infra-red radiation, light, electromagnetic radiation of shorter wavelength, or corpuscular radiation and specially adapted either for the conversion of the energy of such radiation into electrical energy or for the control of electrical energy by such radiation, adapted as conversion devices, including a panel or array of photoelectric cells, e.g. solar cells
H01L31/0264	Semiconductor devices sensitive to infra-red radiation, light, electromagnetic radiation of shorter wavelength, or corpuscular radiation and specially adapted either for the conversion of the energy of such radiation into electrical energy or for the control of electrical energy by such radiation, characterised by their semiconductor bodies, characterised by the material. Inorganic materials
H01L31/00	Semiconductor devices sensitive to infra-red radiation, light, electromagnetic radiation of shorter wavelength, or corpuscular radiation and specially adapted either for the conversion of the energy of such radiation into electrical energy or for the control of electrical energy by such radiation
H01L21/205	Processes or apparatus specially adapted for the manufacture or treatment of semiconductor or solid state devices or of parts thereof. Manufacture or treatment of semiconductor devices or of parts thereof, the devices having at least one potential-jump barrier or surface barrier, e.g. PN junction, depletion layer, carrier concentration layer, the devices having semiconductor bodies comprising elements of the fourth group of the Periodic System or AIIIBV compounds with or without impurities, e.g. doping materials. Deposition of semiconductor materials on a substrate, e.g. epitaxial growth, using reduction or decomposition of a gaseous compound yielding a solid condensate, i.e. chemical deposition

IPC code	Description
H01L31/036	Semiconductor devices sensitive to infra-red radiation, light, electromagnetic radiation of shorter wavelength, or corpuscular radiation and specially adapted either for the conversion of the energy of such radiation into electrical energy or for the control of electrical energy by such radiation, characterised by their semiconductor bodies, characterised by their crystalline structure or particular orientation of the crystalline planes
H01L31/0224	Semiconductor devices sensitive to infra-red radiation, light, electromagnetic radiation of shorter wavelength, or corpuscular radiation and specially adapted either for the conversion of the energy of such radiation into electrical energy or for the control of electrical energy by such radiation. Details. Electrodes

These emerging applications could potentially be detected by a more detailed analysis of the appearance of new IPC codes over time. The following table lists the new IPC codes that have appeared since 2004.

Year of first appearance	IPC Code	Description of the IPC Code	N° of patents	Patent information
2004	H01B1/02	Conductors or conductive bodies characterised by the conductive materials, mainly consisting of metals or alloys	3	DU PONT (US2005P725348) NANOSOLAR (US20040943657, US20040782017)
	H01L51/46	Solid state devices using organic materials as the active part, or using a combination of organic materials with other materials as the active part, specially adapted for sensing infra-red radiation, light, electromagnetic radiation of shorter wavelength, or corpuscular radiation. Selection of materials.	3	Unknown (US2005P641766) KONARKA TECHNOLOGIES (US2004P637843) NORFOLK STATE UNIV. (US2005P749429)
	B05C11/00	Component parts, details or accessories not specifically provided for in groups	2	Unknown (US20070695495) SOLIBRO (SE20040000582)

Year of first appearance	IPC Code	Description of the IPC Code	N° of patents	Patent information
	B32B38/10	Ancillary operations in connection with laminating processes. Removing layers, or parts of layers, mechanically or chemically	2	SHOWA SHELL SEKIYU (JP20040370332) SILICON CHINA (US2006P825261)
	B41F31/00	Inking arrangements or devices	2	NANOSOLAR (US20040943657, US20040782017)
	H01B1/24	Conductors or conductive bodies characterised by the conductive materials. Conductive material dispersed in non-conductive organic material, the conductive material comprising carbon-silicon compounds, carbon, or silicon	2	TOIN GAKUEN (JP20040013711) DU PONT (US2005P725348)
2005	C09K13/00	Etching, surface-brightening or pickling compositions	2	MERCK PATENT GMBH (DE200510033724, DE200510001343)
	G01N13/10	Investigating surface or boundary effects, e.g. wetting power. Investigating or analysing surface structures in atomic ranges using scanning-probe techniques	2	MATSUSHITA ELECTRIC IND CO LTD (JP20050008480) MITSUBISHI HEAVY IND. LTD (JP20050218002)

Year of first appearance	IPC Code	Description of the IPC Code	N° of patents	Patent information
2007	B23K20/10	Non-electric welding by applying impact or other pressure, with or without the application of heat, e.g. cladding or plating, making use of vibrations, e.g. ultrasonic welding	2	Unknown (CN101110458 , CN201075394)
	B23K20/24	Non-electric welding by applying impact or other pressure, with or without the application of heat, e.g. cladding or plating, Preliminary treatment	2	

Table 4 - IPC appearance

This table makes it possible to highlight patents involving emerging technologies. For instance, the B41F31/00 code, normally associated with inks, first appeared in the photovoltaics field in 2004. In fact, the NANOSOLAR Company has protected a new deposition technique (US20040943657 and US20040782017), which consists in producing absorbent CIGS layers by means of encapsulated semi-conductor nanoparticles or quantum dots then dispersing them in a binder such as an ink, paste or paint. This technique has, moreover, been highly publicised.

This table also highlights a patent of the SOLIBRO Company (SE20040000582), which protects an on-line production method by co-evaporation and a method of controlling the copper, indium, gallium and diselenide (CIGS) composition of the solar cell.

3.4.4. Breakdown of the major IPC codes of the major players

The following graph gives the most represented IPC codes for the ten major applicants in the sector. The breakdown of these IPC codes ties in with the positioning of these players. A difference in the positioning of the patents of the FUJITSU Company may be noted compared to the others because it is the only player for which the H01L21/02 and H01L31/0264 codes predominate rather than the H01L31/04 code.

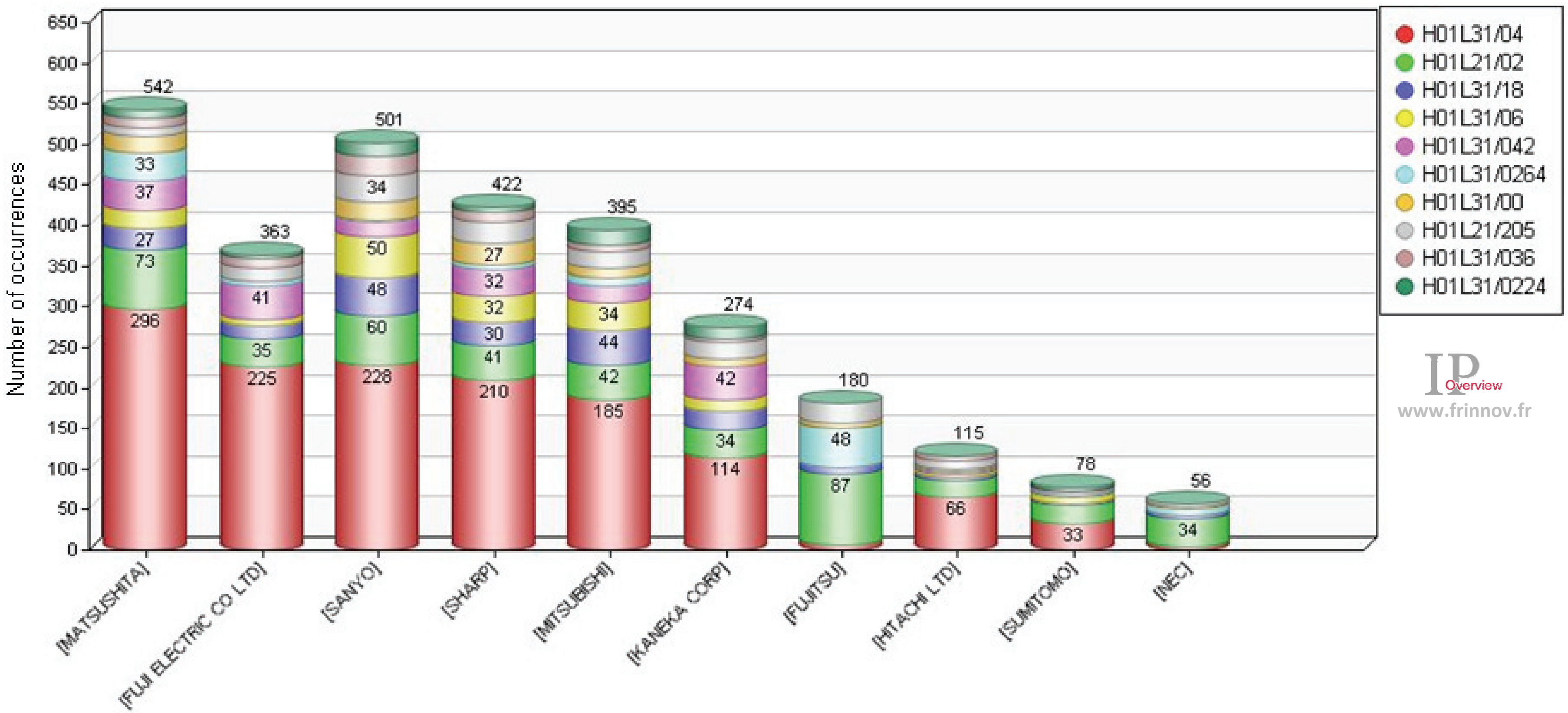


Figure 32 - Breakdown of the major IPC codes of the majors players

4. Thin Film Cell patents - Japan focus

4.1. Overall data

The portfolio of patents and patent applications concerning photovoltaic thin film cells comprises around 2725 Japanese priority applications, not counting the CANON patents that are dealt with separately, which represents around 60% of all the priority filings in this field.

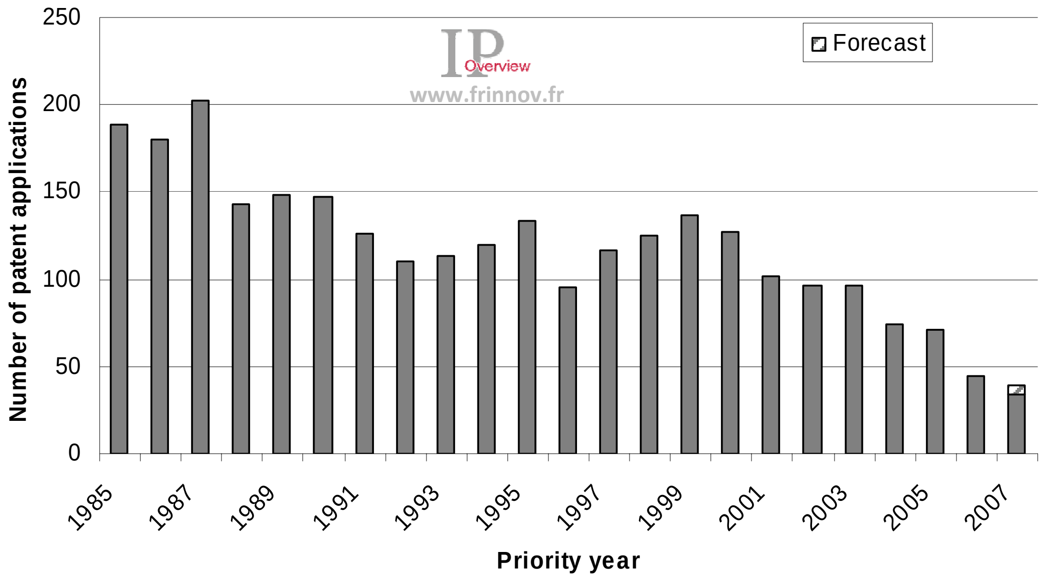


Figure 33 - Evolution in the number of Japanese priority filings

Figure 33 gives the evolution over time of these Japanese priority filings. The highly sustained rate of filing between 1985 and 1987 (nearly 200 filings a year) has since shown a sharp downward trend, and their number dropped below the 50 filings mark in 2006. In a context where the photovoltaics market and the perspectives announced for thin film technologies are particularly promising, such a contrast is quite disconcerting. The aim of the following graph is to provide some explanations for such a phenomenon.

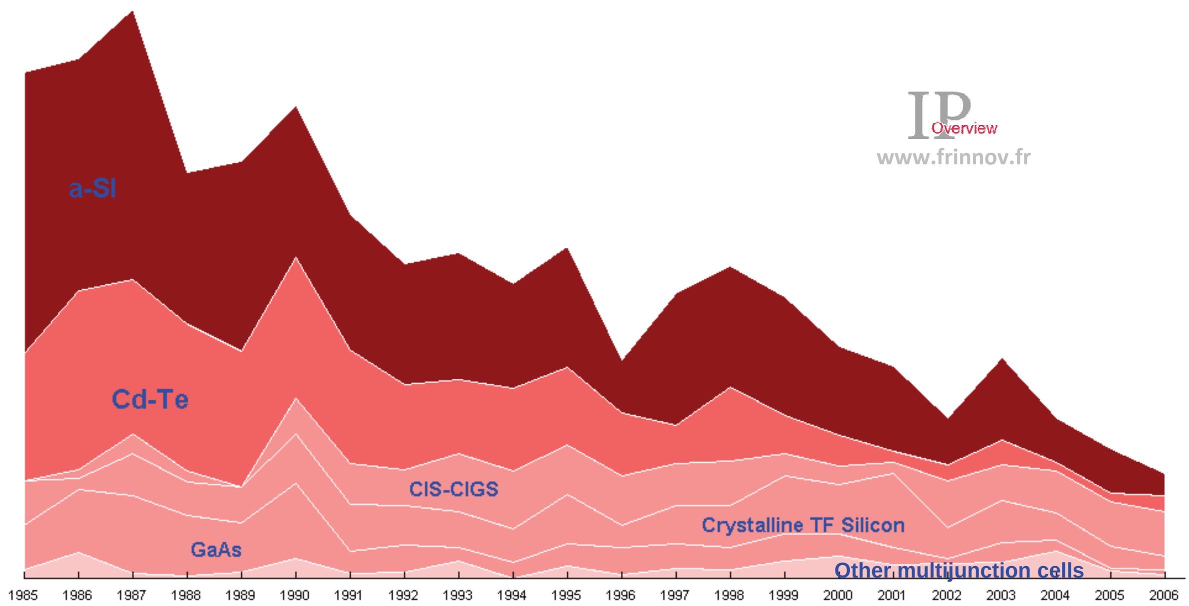


Figure 34 - Evolution in Japanese filings by technology

The phenomenon of the reduction in the number of filings for amorphous silicon cells and for Cd-Te cells identified beforehand in the “Overall” section is even more flagrant when one notes the Japanese priority filings. On the other hand, the other technologies seem to be stable in terms of the number of filings over the studied period. This reduction in filings with regard to these two topics seems to be correlated with major Japanese players backing out, at least in terms of filings of patents. For instance, MATSUSHITA, which at the start of the studied period filed nearly 50 patent applications a year (in 1987), in 2006 only filed 4 patent applications concerning photovoltaic thin film cells. A similar observation may be made for the companies FUJI, SANYO and SHARP.

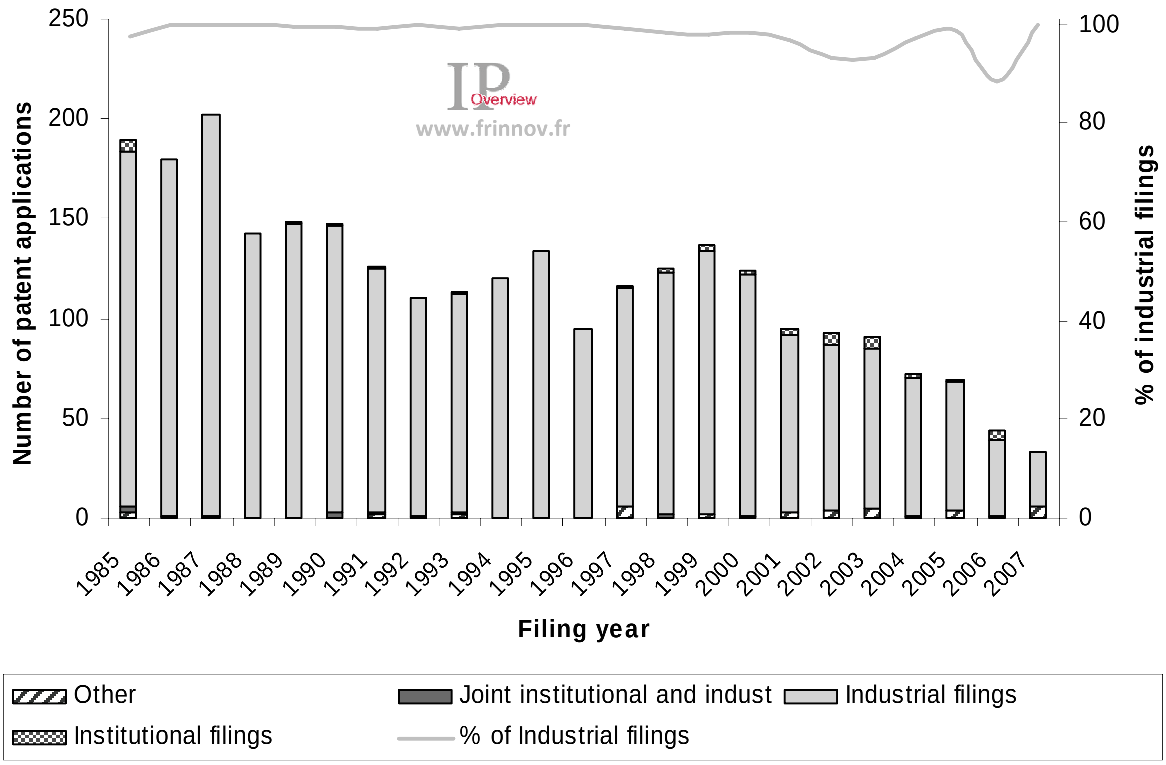
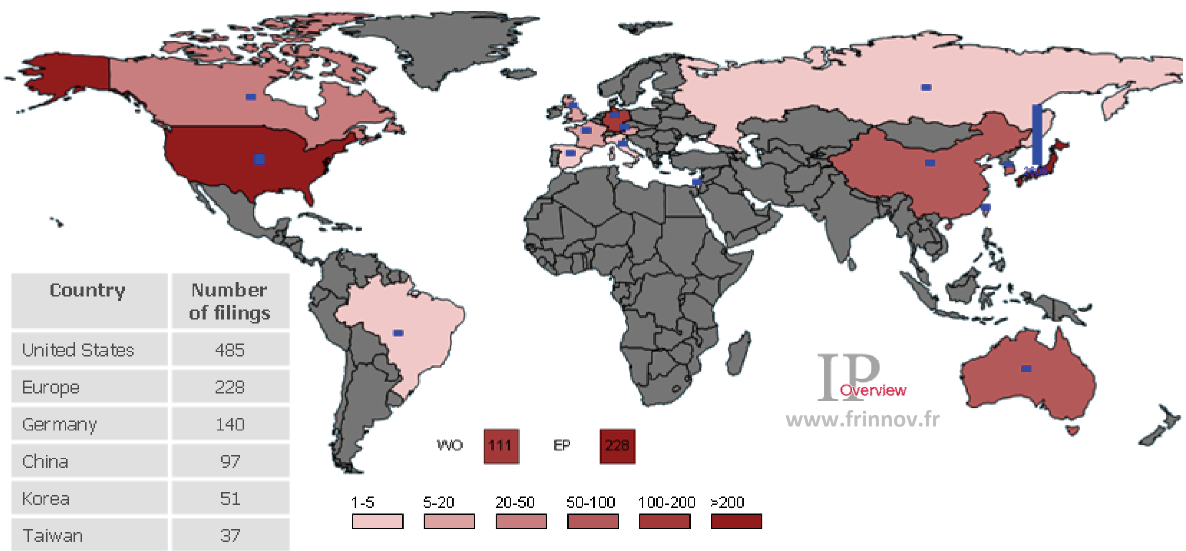


Figure 35 - Evolution in Japanese filings and breakdown of industrial patents

The aim of figure 35 is to highlight the proportion of filings stemming from academic institutions compared to filings from industrial research. In this case, the findings are very clear; Japanese priority filings concerning photovoltaic thin film cells are exclusively made by industrial players apart from several co-filings with academic players, but which only account for a very small proportion. The institutional filings correspond, for their part, almost exclusively to filings made by the AIST.



Country	Number of filings
United States	485
Europe	228
Germany	140
China	97
Korea	51
Taiwan	37

Figure 36 - Map of extensions (Japanese priority)

The above map provides an illustration of the countries protected by the players that file Japanese priority applications. The extensions chosen by these applicants tie in with the locations of the principal markets such as the United States, Europe and especially Germany. As identified in the general analysis, the other countries the most protected recently are then China, South Korea and Taiwan (cf. figure 37).

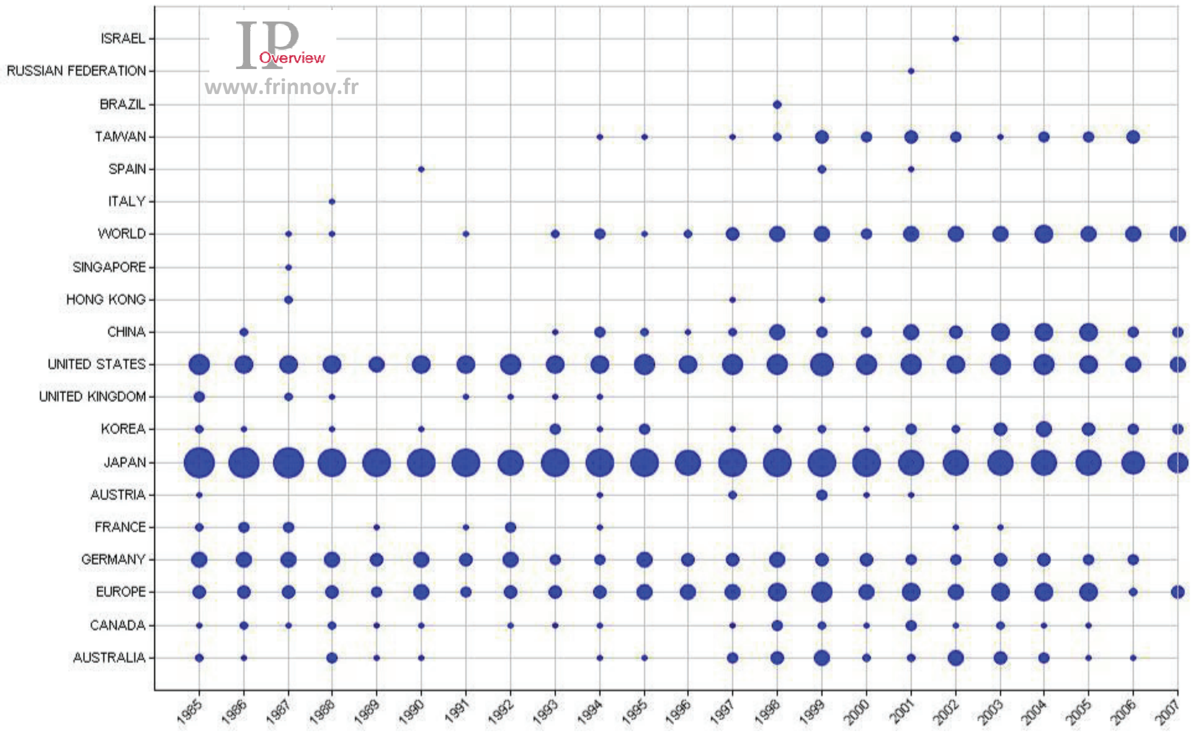


Figure 37 - Evolution in extensions (Japanese priority)

An observation of the grant rate per country over time makes it possible to highlight trends such as a toughening of the granting conditions or instead a propensity to abandon the maintenance of patent applications before they are granted.

An analysis of the grant rate over time cannot however be de-correlated from the evolution in the grant time. This grant time evolves and makes it possible to determine up to what date the grant rate may be taken into account.

To date, nearly 3300 filings of Japanese patent applications have been made (priority + extensions) and around 880 have been granted. The figure below illustrates the average grant time observed for the Japanese patents that have been granted.

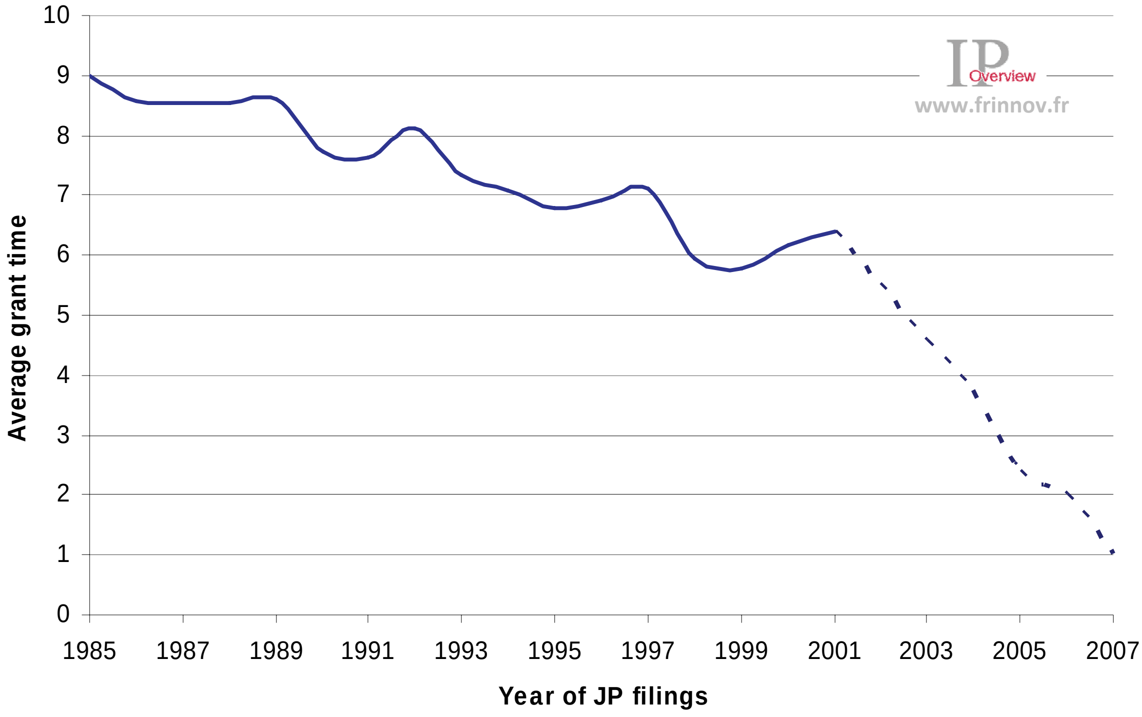


Figure 38 - Evolution of the grant time of Japanese patents

This curve representing the average grant time only makes sense up to 2001. In fact, after this date, the average time observed corresponds to the difference between the filing date and the current date and cannot therefore be taken into account, since the only patents granted cannot in fact have taken more time to be granted.

Between 1985 and 2001, the average grant time thus dropped overall, going from 9 years for applications that were filed in 1985 to around 6 years for applications that were filed after 1997. It is nevertheless important to relativise this time period (compared to the time periods observed in Europe or the US) in so far as the time lapse between the filing and the starting point of examination by the Japanese patent office has changed over time (7 years for filings made before 2001, which has now been reduced to 3 years).

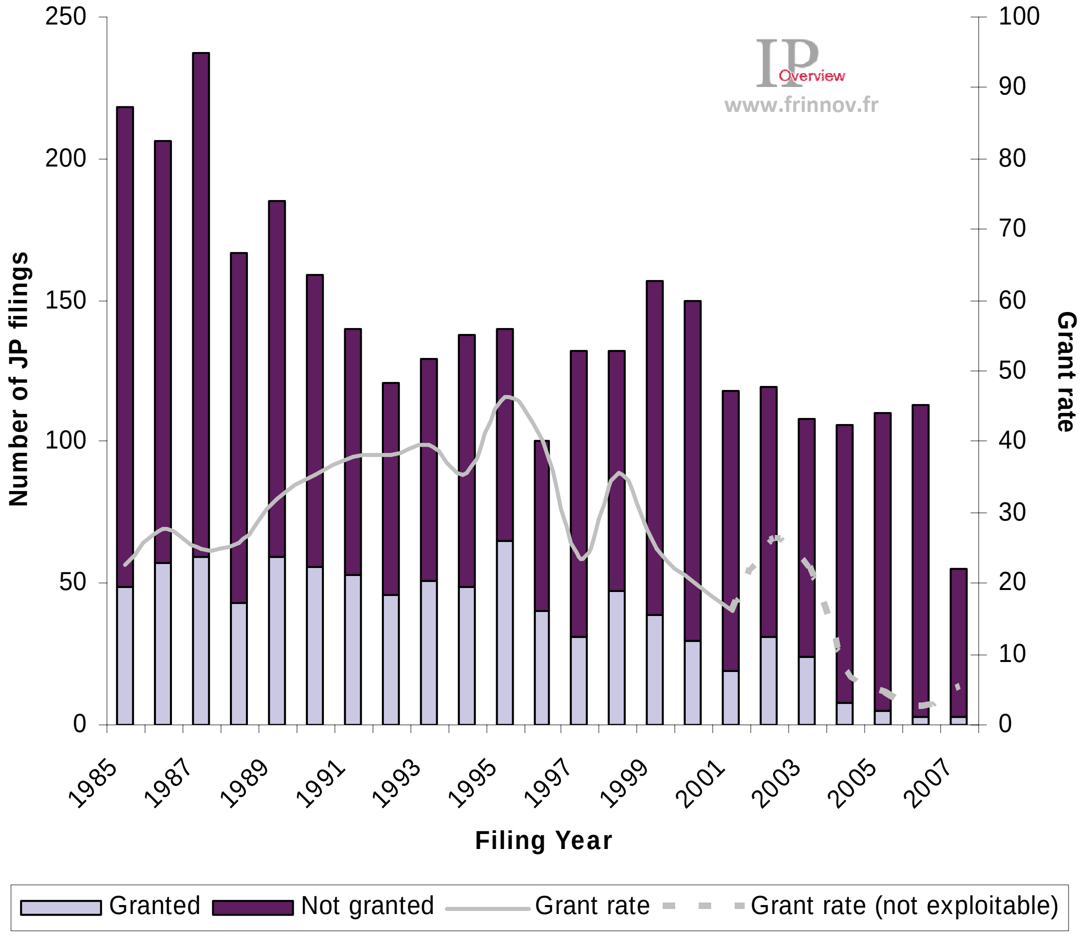


Figure 39 - Evolution of the granting of Japanese patents

As explained above, the grant rate for Japanese patents is only exploitable up to 2001. Generally speaking, this rate increased from 1985 (rate around 25%) up to 1995, reaching a grant rate of nearly 46%. Since this date, the grant rate has decreased and barely 16% of patent applications filed in 2001 are granted today.

4.2. Applicants

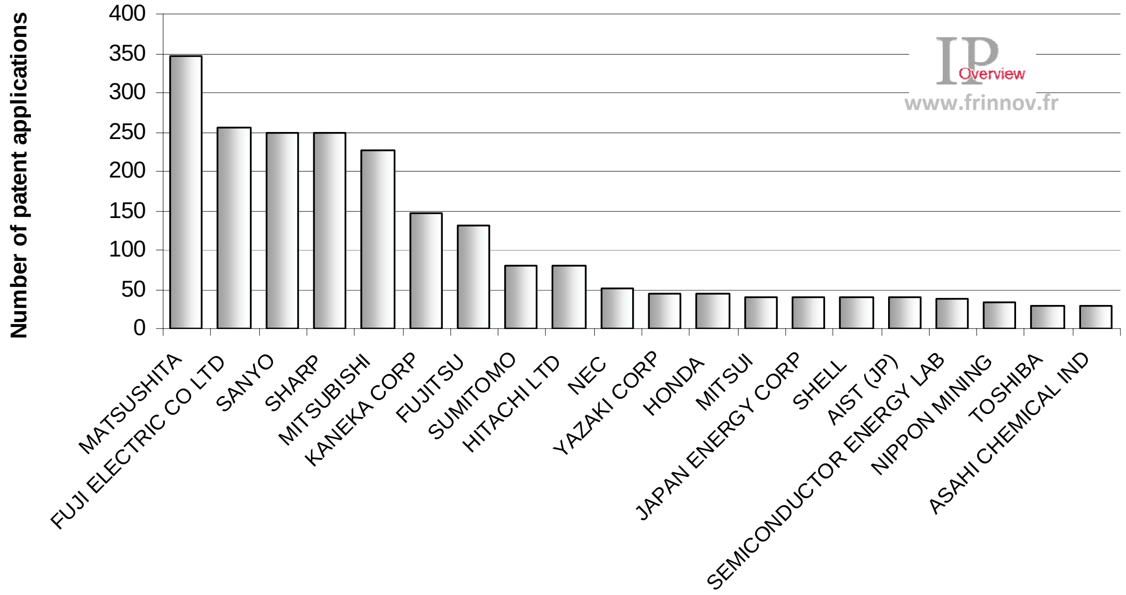


Figure 40 - Major applicants in the field (Japanese priority)

The major applicants of Japanese priority applications are the same as those on a worldwide level, Japan being the country where the most priority filings in this field are made. The applicants studied previously in the “Overall” section will therefore not be described again in this section.

The MITSUBISHI Company pursued a very strong patent filing policy over the period 1985-1991 mainly concerning Ga-As multijunction cells, but also Cd-Te and amorphous silicon cells and depositions of crystalline silicon in thin films. Subsequently, filings on Ga-As cells have dropped especially and MITSUBISHI has mainly filed patents on thin film amorphous or crystalline silicon cells. For this latter technology, MITSUBISHI ELECTRIC has claimed a conversion efficiency of 18.9%, obtained by improving the infrared absorption by texturing the cell. MITSUBISHI envisages the launch of mass production of these modules for 2011.

Unlike the other major Japanese applicants, the KANEKA Company pursued a moderate filing policy with regard to photovoltaic thin film cells up to 1998 (between 5 and 10 applications a year), attaining a peak in filing in 1999 with 33 patent applications. The company’s filings then dropped at the same pace as during the previous period. The principal topic of KANEKA concerns amorphous silicon cells.

YAZAKI CORP, whose portfolio is more modest than the players described previously with 47 patent applications, mainly filed between 1993 and 1998, is for its part focused on CIS/CIGS thin film cells. This company has however no longer filed since 1998.

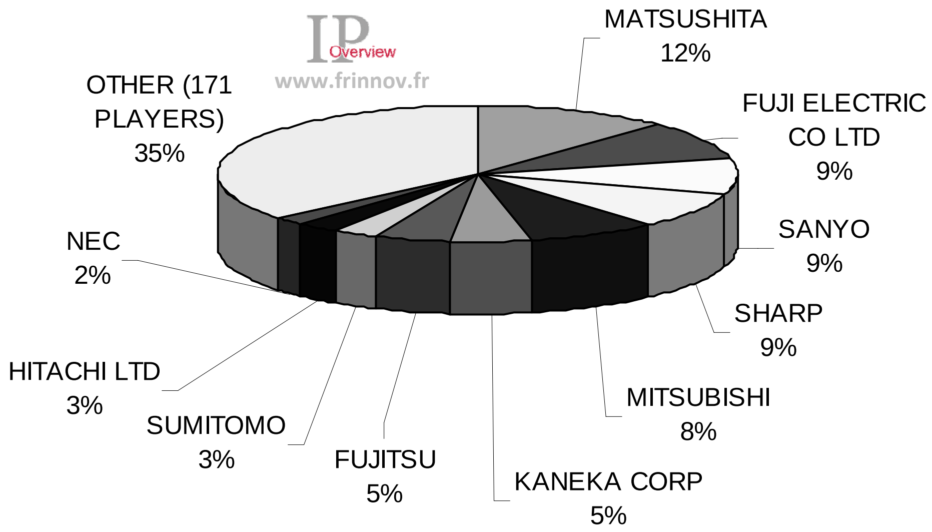


Figure 41 - Breakdown of patent portfolios by applicant (Japanese priority)

The above figure illustrates the percentage share represented by the 10 leading applicants. Thus, nearly 2/3 of Japanese priority applications are held by these 10 major players. Such a configuration reflects the concentration of Japanese industrial players, which may signify increasingly higher entry barriers for potential newcomers to the Japanese market.

Nevertheless, the following table shows the evolution over time of the filings made by the principal applicants described previously and makes it possible to highlight the considerable slow down in the number of filings made by these players. Thus, the companies FUJITSU, MITSUI, NEC, TOSHIBA, YAZAKI, JAPAN ENERGY CORP and ASAHI CHEMICAL seem to have ceased their research activity in this sector, since none of these companies has made any filings since 2002.

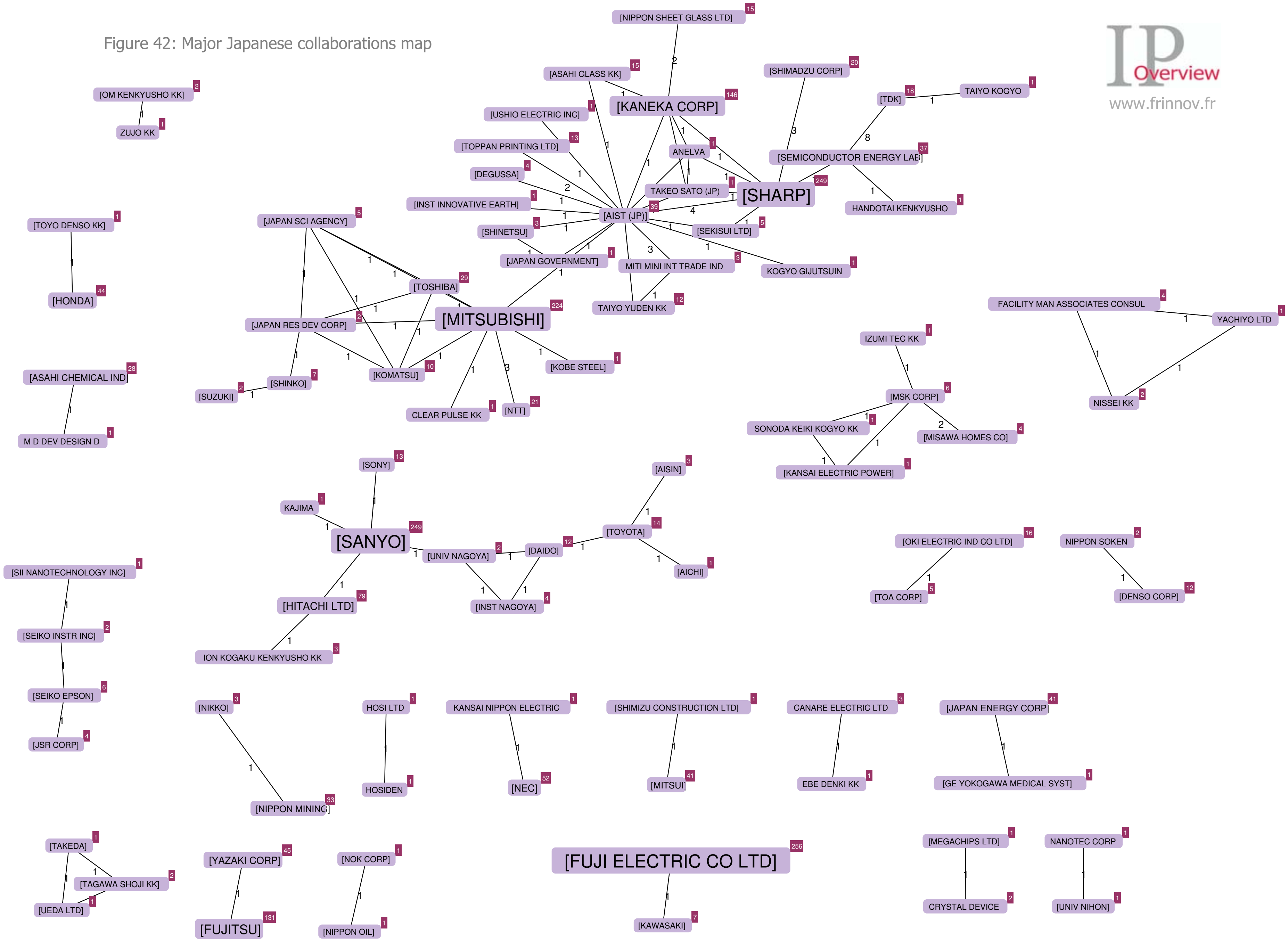
In this respect, several companies stand out nevertheless by their dynamism over recent years, namely HONDA, SHELL and SANYO.

HONDA (with the creation of its subsidiary HONDA SOLTEC) began its R&D work on photovoltaics in 1997, which allowed this company to obtain in 1999 a laboratory conversion efficiency of 18.1% on a 0.5 x 0.5 cm^2 substrate for CIGS cells. Following this success, HONDA has focused on increasing the size of the substrate with a view to commercialising cells of this type. After significant progress in terms of conversion efficiency and size of substrate, the average conversion efficiency of photovoltaic cells commercialised (always less than the results obtained in the laboratory) since 2007 by Honda is 11.1%.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
FUJITSU	15	18	2	18	23	16	10	6	3	3	6	8		2			1						
HONDA		1					1	1						3		3	3	11		6	8	7	
MATSUSHITA	27	35	49	23	7	19	13	23	15	16	16	17	13	19	13	9	2	7	12	4	3	4	
MITSUBISHI	9	14	32	16	23	13	16	8	4	4	3	5	9	6	8	8	10	17	2	11	7	1	1
MITSUI		1	1	4	2	3	7	3	7	5	5	3											
NEC	6	8	3	5	4	6	3	2	4	5	3	1		1				1					
NIPPON MINING	2	8	2	3	5	6	5											1				1	
SANYO	17	12	8	5	27	27	16	16	12	7	14	5	8	6	7	7	8	4	16	7	8	5	7
SHARP	20	13	18	6	7	6	9	4	5	7	8	7	9	18	20	25	24	8	11	11	8	2	3
SHELL						2	3	2			4	3	1				1	1	1	5	5	5	7
TOSHIBA	4	4	3	4		2	1			1	1	4	2	2	1								
YAZAKI CORP		3							5	10	8	4	8	7									
FUJI ELECTRIC	10	10	25	14	16	8	15	15	9	22	15	5	5	3	20	18	9	17	9	5	5		1
JAPAN ENERGY CORP								5	5	11	10	1	3	3	3								
SUMITOMO	12	8	14	10	2	6	3	3	6		4	3	2	1			1	2	1			2	
ASAHI CHEMICAL				1			1		7	4	3	1	7	3	1								
HITACHI LTD	10	6	5	7	2	10	1	1	3	8	2	2	2	2	1	2	3	1	5	2	2	2	
AIST (JP)	7					1	1		1					3		2	4	6	8	2	1	3	
SEL (JP)	7	3		1		3		2	1	1	7	1	3	1	1	2		1			1		2
KANEKA CORP	3	5	7	3	3	2	1	9		5	9	1	5	8	32	20	10		7	6	7	2	1

Table 5 - Evolution in the patent filings of major players (Japanese priority)

Figure 42: Major Japanese collaborations map



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The Japanese collaborative environment, which has led to the co-filing of patents, is shown in figure 42. A first observation is that R&D on photovoltaic cells seems to be clearly borne by industry and not by academic research. In fact, as may be seen in figure 35, the proportion of patent applications stemming from public research is extremely low, as are joint industrial-institutional co-filings. The presence should nevertheless be noted of AIST, the leading Japanese research body, which has filed with numerous industrial players such as SHARP, DEGUSSA, TOPPAN PRINTING and KANEKA. Given the consequent number of Japanese patent applications, the overall number of co-filings is proportionally very low.

4.3. Inventors

The inventors identified in Japanese priority applications have been classified into three separate classes:

- Firstly, **the most prolific** inventors in terms of filings. The five leading inventors are Klaus Murozono Mikio (MATSUSHITA, cited as inventor in 100 patents), Negami Takayuki (MATSUSHITA, 69 patents), Hanabusa Aki (MATSUSHITA, 63 patents), Sannomiya Hitoshi (SHARP, 55 patents) and Nishitani Mikihiko (MATSUSHITA, 51 patents).
- Secondly, the inventors **considered as experts**. The expertise factor is calculated by multiplying the number of patents in which the inventor is cited by the number of different co-inventors. The following names stand out in particular: Arita Takashi (MATSUSHITA, 47 patents), Wada Takahiro (MATSUSHITA, 50 patents), Yamagishi Hideo (KANEKA CORP, 39 patents), Omura Kuniyoshi (MATSUSHITA, 38 patents) and Nomoto Katsuhiko (SHARP, 30 patents).
- Finally, **emerging inventors**. The emergence factor represents the increase in patent filings, calculated over the period 2004, 2005, 2006 and 2007. The five leading emerging inventors are as follows: Goto Hiroyuki (HONDA), Kuriyagawa Satoru (SHELL), Sasagawa Eishiro (MITSUBISHI), Tanaka Yoshiaki (SHELL) and Yamashita Nobuki (MITSUBISHI).

Figures 43, 44 and table 6 below outline the specific research topics and their teams (since 2003) and provides a quick summary, in volume terms, of their filings. We have provided details of some of these inventors hereafter:

Murozono Mikio is the leading Japanese inventor with around one hundred patents and patent applications concerning photovoltaic thin film cells to his credit, filed on behalf of MATSUSHITA from 1986 to 1998. Since 1986, he has filed patents in the photovoltaics field and more precisely on Cd-Te cells. The deposition techniques claimed in the patents of this inventor correspond well with MATSUSHITA's positioning, namely first of all the "screen printing" techniques and then the "close space sublimation" technique. Without necessarily having left the photovoltaics field, this inventor is now President of CLEAN VENTURE 21, a Japanese company created in 2001 and specialised in spherical silicon cells.

Omura Kuniyoshi (PV Research & Development Center, MATSUSHITA) has 38 patent applications to his credit filed between 1985 and 2000 in collaboration in particular with Murozono Mikio on Cd-Te cells.

Negami Takayuki, also an inventor for MATSUSHITA (69 filings between 1991 and 2006), is for his part specialised in photovoltaic thin film CIS cells.

Wada Takahiro (50 patent applications) has mainly filed patents concerning CIGS cells (40 documents) and several patents on Cd-Te cells. He filed these patents up to 1998 on behalf of MATSUSHITA and who now works at the University of Ryukoku in the Materials Chemistry Department, in particular on the preparation of CIGS cells by Non-vacuum Particles-based Techniques. **Nishitani Mikihiko** has mainly worked with Negami Takayuki and Wada Takahiro on the same subjects, he has in fact co-filed 40 of these 63 patent applications with Wada Takahiro.

Hanabusa Akira (also an inventor on behalf of MATSUSHITA) filed these initial patents on amorphous silicon based cells then on Cd-Te techniques. He has in particular collaborated with Murozono Mikio on Cd-Te patents and with **Arita Takashi** for amorphous silicon technology.

Sannomiya Hitoshi and **Nomoto Katsuhiko** of the SHARP Company work on amorphous silicon cells and their filings are spread out practically over the whole period studied.

Yamagishi Hideo (PV Business Development Department, KANEKA CORP) is specialised in amorphous silicon based cells.

The emerging inventors described hereafter possess a lower number of patent applications filed, but these are more recent. For instance, Goto Hiroyuki (HONDA) is the inventor of a portfolio of 4 patent applications concerning thin film CIGS cells, Sasagawa Eishiro (Mitsubishi) and Yamashita Nobuki (Advanced Technology Research Center, Mitsubishi) have respectively filed 4 and 5 patent applications on amorphous silicon cells and deposition techniques, in particular of microcrystalline silicon. Finally Kuriyagawa Satoru and Tanaka Yoshiaki (Showa Shell Sekiyu K.K.) have filed patent applications on photovoltaic CIS cells.

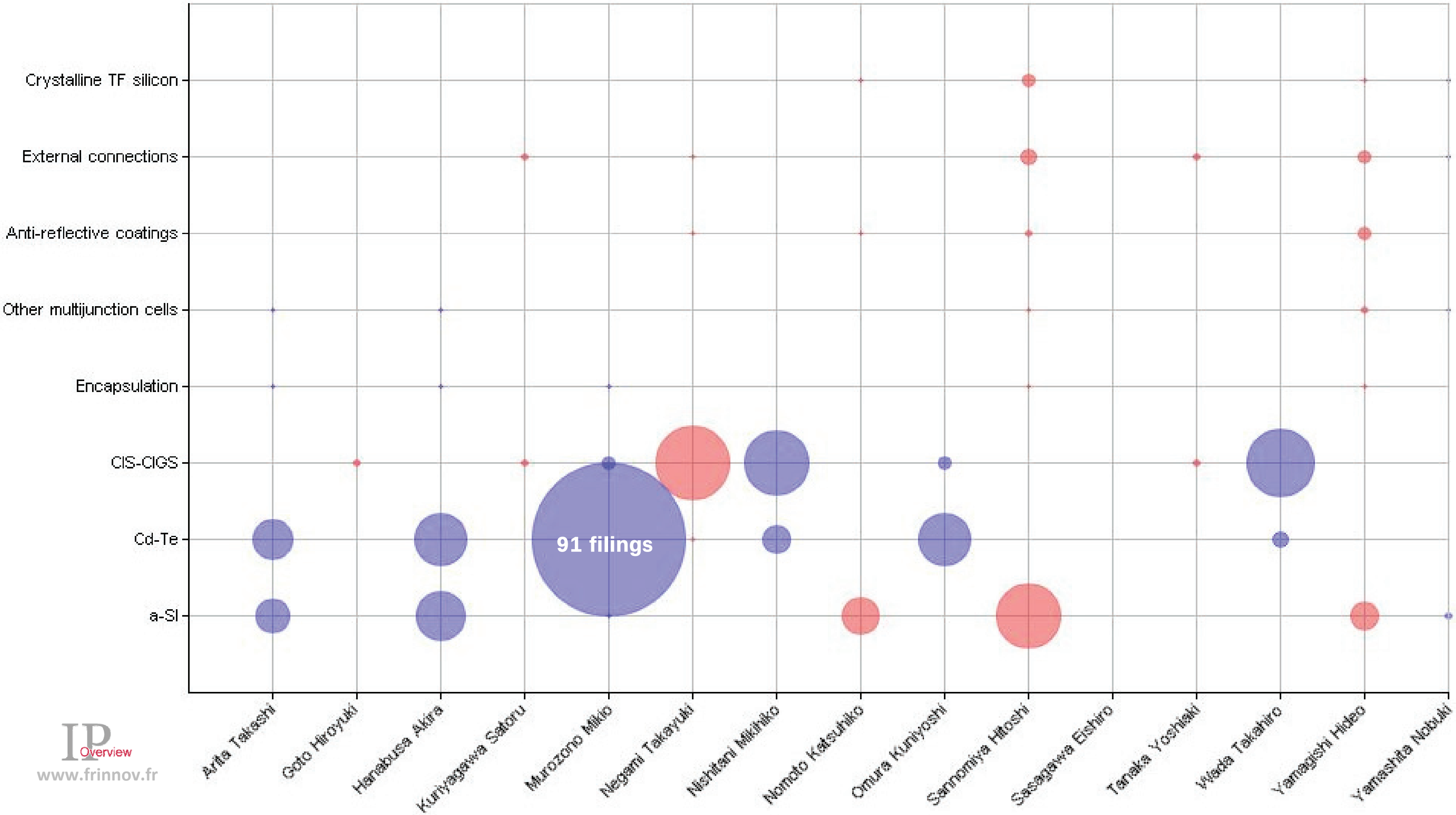

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Figure 43 - Topics of the Major Japanese inventors

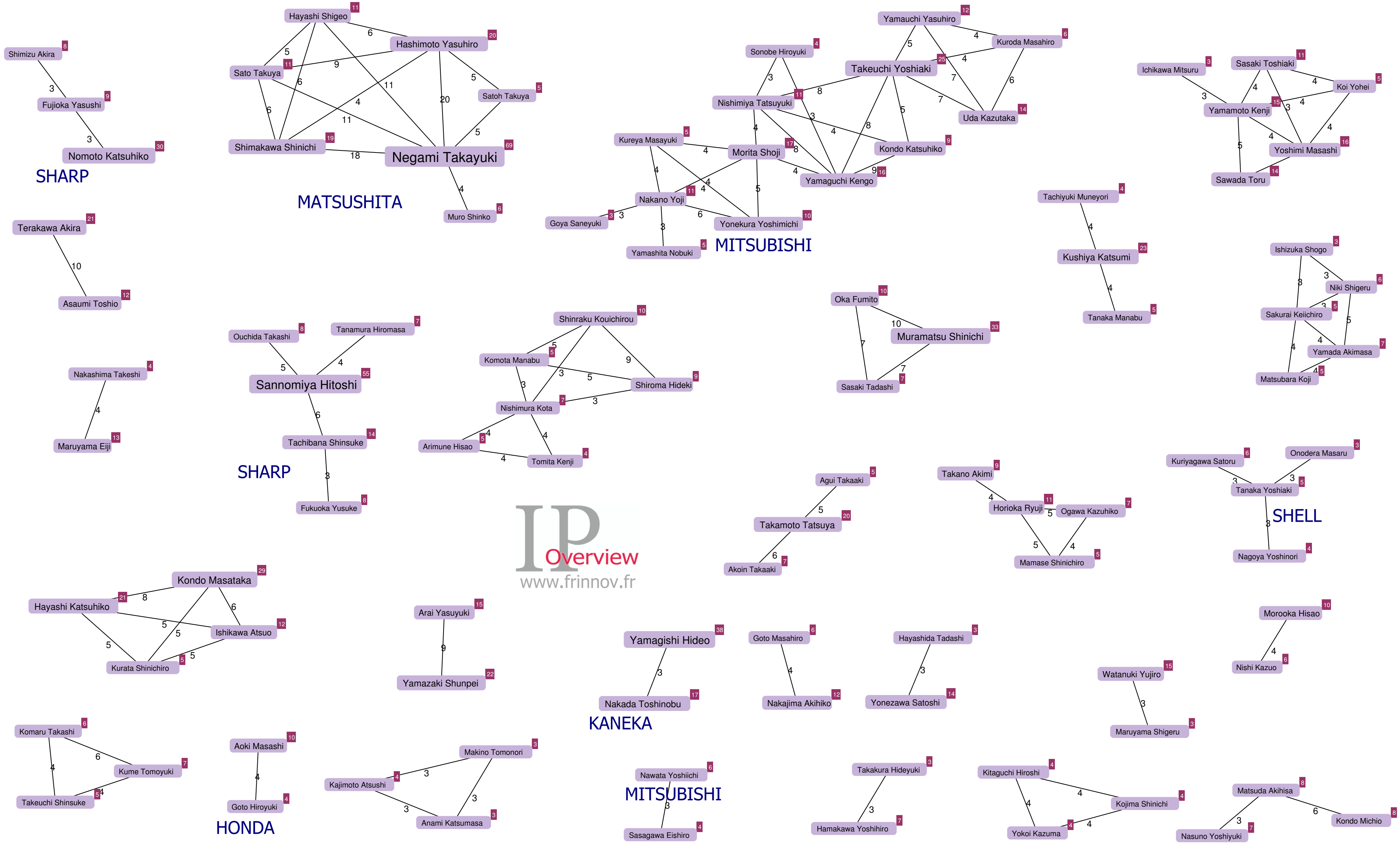


Figure 44: Emerging Japanese inventor teams (since 2003)

	Most prolific Japanese inventors					Japanese experts					Emerging Japanese inventors				
	Murozono Mikio	Negami Takayuki	Hanabusa Akira	Sannomiya Hitoshi	Nishitani Mikihiko	Arita Takashi	Wada Takahiro	Yamagishi Hideo	Omura Kuniyoshi	Nomoto Katsuhiko	Goto Hiroyuki	Kuriyagawa Satoru	Sasagawa Eishiro	Tanaka Yoshiaki	Yamashita Nobuki
1985			6	1		5									
1986	12		14	1	1	10		3	4	1					
1987	20		11	2	1	7		2	14	3					
1988	7					2		1	2	1					
1989				3				3		1					
1990	2			3	4			1		1					
1991	2	2	1	7	5	1	2			7		1			
1992	12	5	4	4	8	9	8	2		2					
1993	3	8	3		9	1	10		1	1					
1994	5	6	2	5	7	3	8	2	2	2					
1995	3	5	1	4	8		9	3	2	1					
1996	9	6	6	2	6	6	8	1	4						
1997	9	2	6	3	1	3	2	2		1					
1998	14	4	6	5			3	4	4	4					
1999		3	2	3				6	2	1					
2000		3	1	2				2							1
2001		2		1						2					
2002		5		2	1										
2003	2	10		4				4		2					
2004		2		1								3	3	4	3
2005		2		2				1					1	1	1
2006		4									4	2			
2007								1							

Table 6 - Evolution in patent application filings by inventor (Japanese priority)

5. Thin Film Cell patents - European focus

5.1. Overall data

A little less than 400 priority patents have been filed in a European country or via the European procedure since 1985. 2007 is not completely representative on account of the 18 month delay in publication, and only patents filed up to June 2007 are listed in this study.

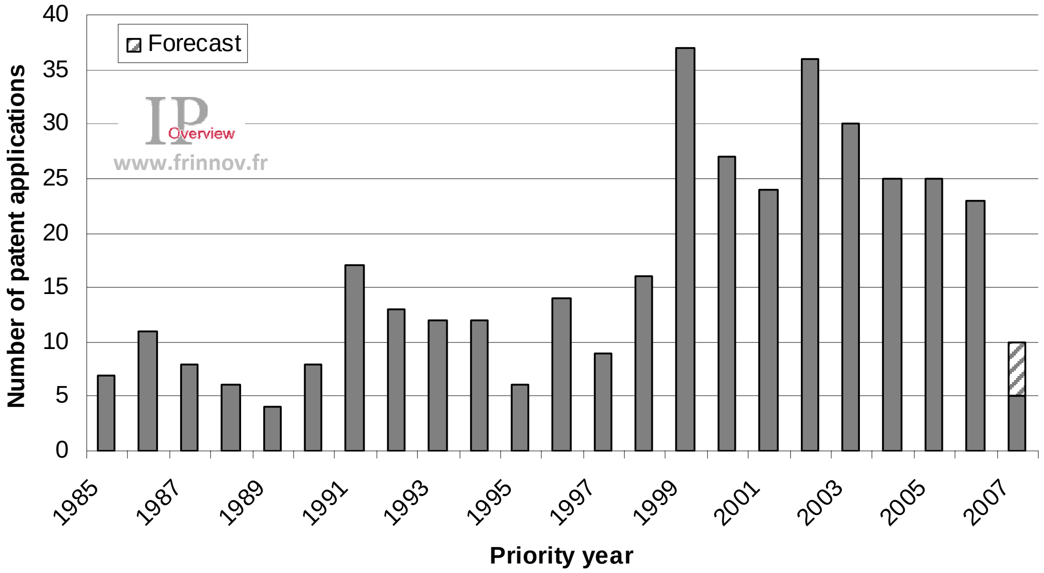


Figure 45 - Evolution in the number of filings (European priority)

In volume terms, the number of filings doubled from 1999 then stabilised at around 25 filings a year. The United States (with more than 100 patents in 2005 and 2006) and Japan (around 50 in 2005 and 2006) are well ahead of Europe in this respect.

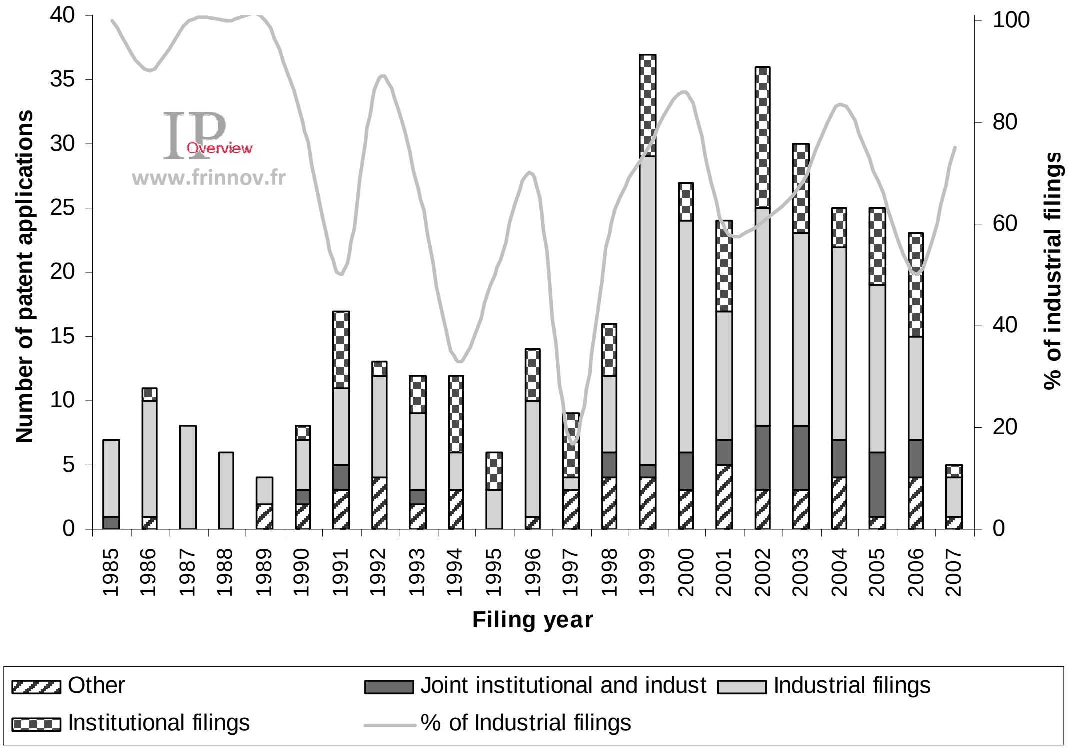


Figure 46 - Evolution in European filings and breakdown of industrial patents

Europe stands out by the important percentage represented by academic patents (around 35% over recent years) and by the considerable number of co-filings between industrial and academic players. This latter phenomenon has increased sharply over recent years.

The following map (figure 47) makes it possible to highlight in more detail the geographic breakdown of priority filings in Europe in volume terms whereas figure 48, for its part, provides an insight into the dynamic of European filings.

NB: For reasons of clarity, the countries in which the number of priority patents is not significant have been removed from the graph, namely Ireland, Greece, Norway, and Belgium.

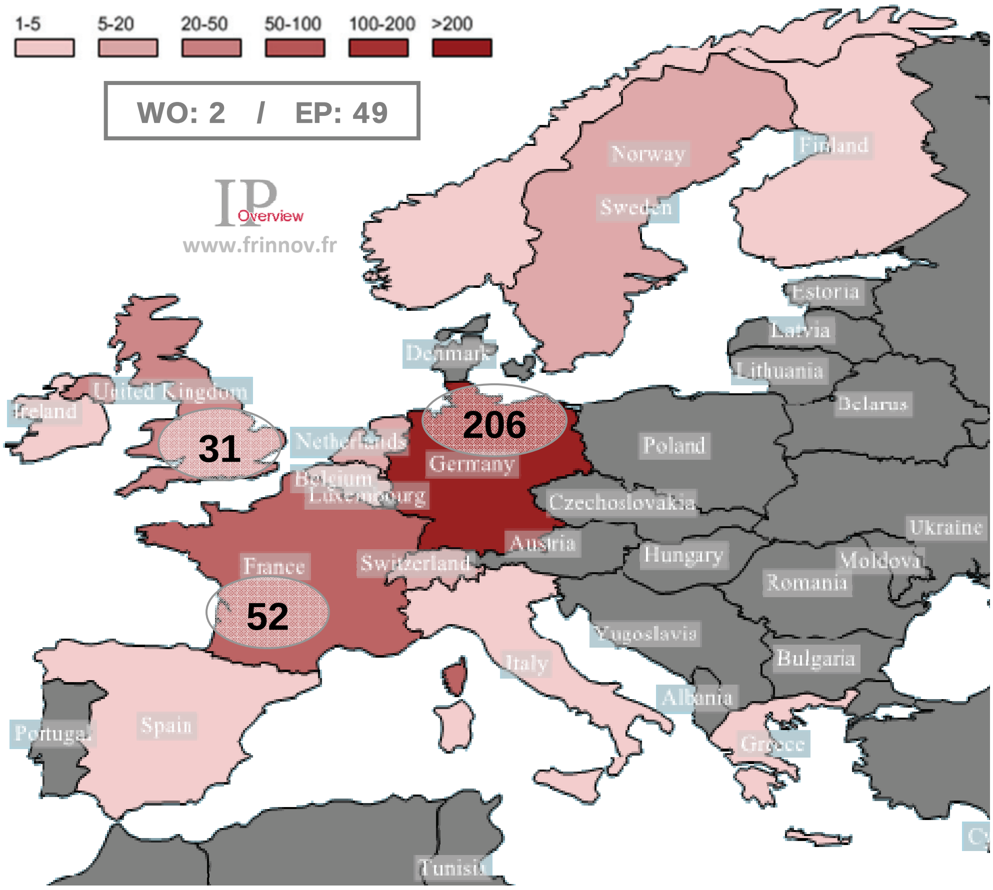


Figure 47 - **Map of priority filings / Zoom on Europe**

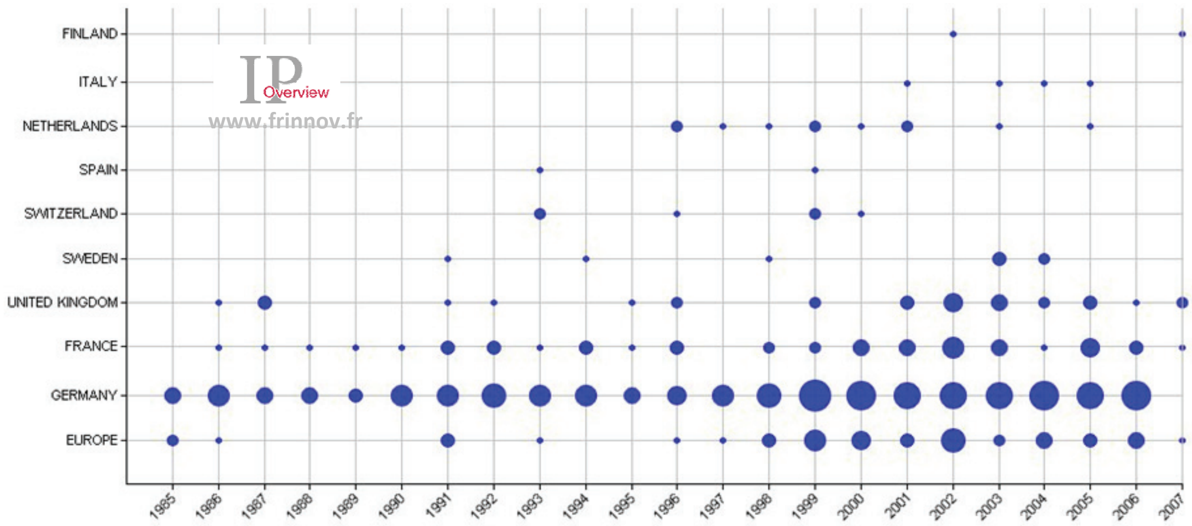


Figure 48 - **Evolution in European filing by country**

Germany, France and the United Kingdom are the three main countries where the most priority patents are filed, and this has been the case for the longest period. Italy and the Netherlands are also beginning to see significant activity in terms of filings over the last few years. The absence of Spanish priority filings is somewhat surprising when compared to the dynamism of its internal market, which was the second European market in 2005 and 2006.

The following map makes it possible to highlight the geographic breakdown of patent extensions chosen by European players to protect their inventions.

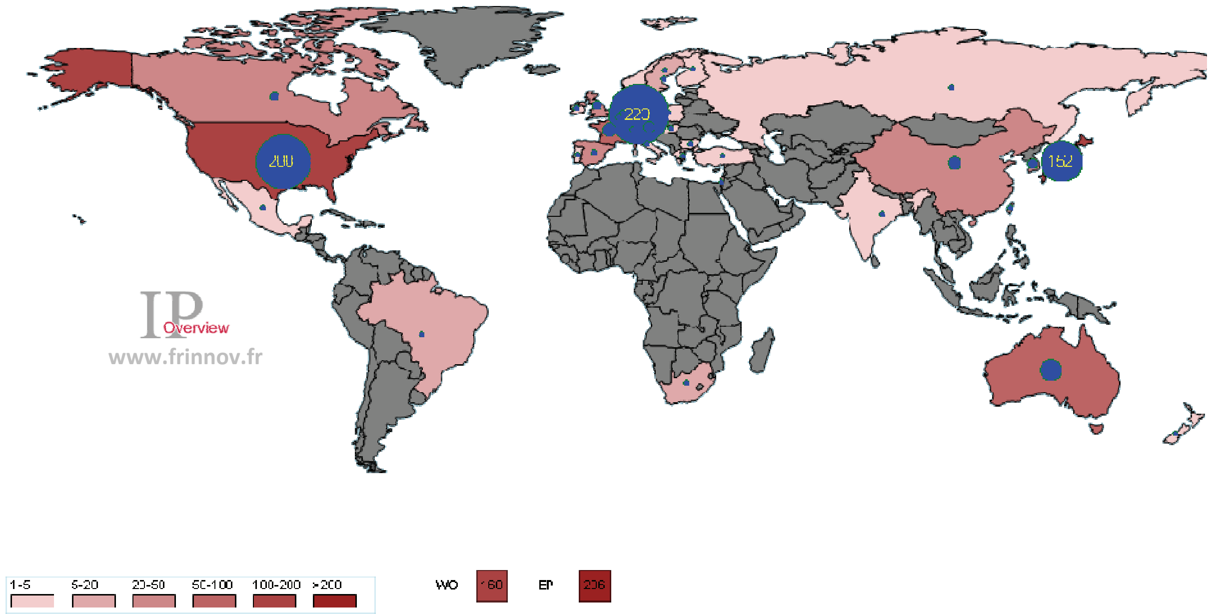


Figure 49 - Patent extensions map (European priority)

The countries mainly protected when extensions are made are the principal markets and production areas, namely Europe, Japan and the United States. It should also be noted that European players increasingly protect their patents in China, South Korea and Taiwan.

An observation of the grant rate by country over time makes it possible to highlight certain trends, such as a toughening of the granting conditions or instead a propensity to abandon the maintenance of patent applications before they are granted. An analysis of the grant rate over time cannot however be de-correlated from the evolution in the grant time. This grant time evolves and makes it possible to determine up to what date the grant rate may be taken into account.

Out of the 834 filings of European procedure patent applications that were made (priority or extensions), around 260 have been granted. This figure is however difficult to exploit because it does not take into account national patents within Europe, but uniquely those stemming from the European procedure. The following graph illustrates the average grant time observed for the European patents granted.

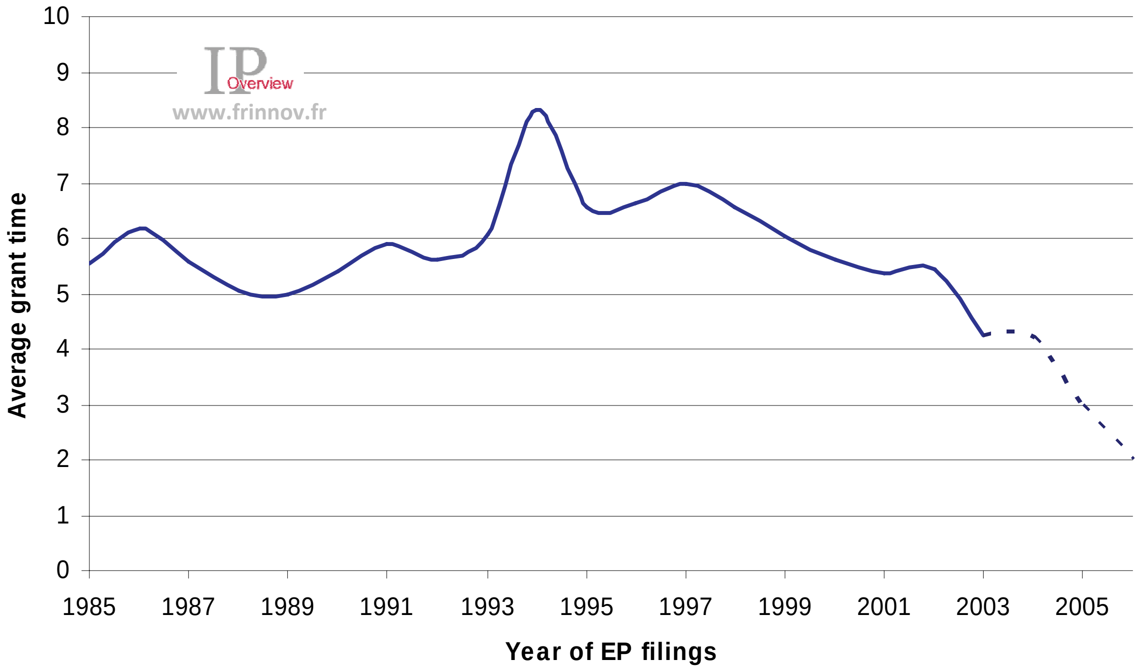


Figure 50 - Evolution of the grant time of European patents

This average grant time curve is only meaningful up to 2003. In fact, as of this date, the average time observed corresponds to the difference between the filing date and the present date and therefore cannot be taken into account, since the only patents granted cannot effectively have taken more time to be granted.

Between 1985 and 1993, the average grant time remained all in all quite stable (around 5-6 years after the European application filing date). A peak in the grant time was observed for applications filed in 1994, however this trend did not continue. Subsequently, the grant time of a European patent in this field shortened overall, reaching an average of between 4 and 5 years in 2003.

In the following figure, an evolution in the grant rate between 1985 and 2003 may be observed.

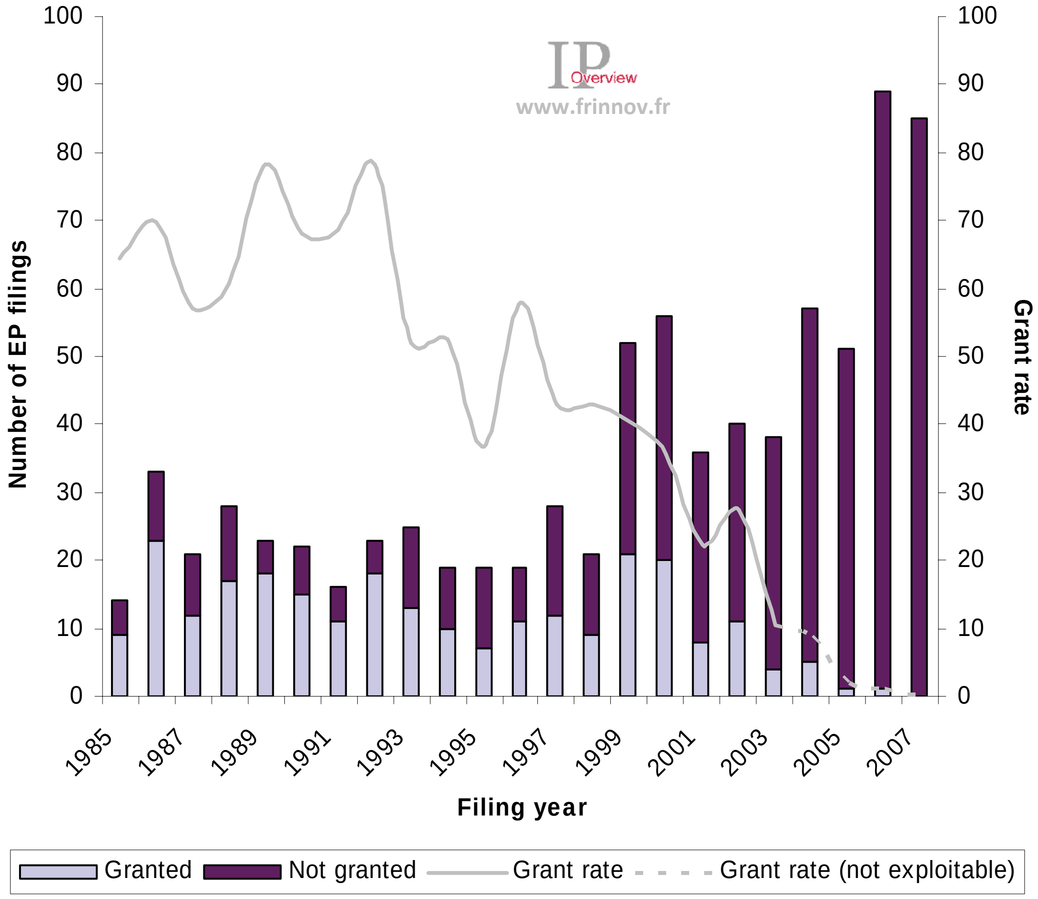


Figure 51 - Evolution of the granting of European patents

This graph shows that most European patent applications filed up to 1992 were granted (around 60-70% grant rate). As of 1993, the rate dropped to 30% of patents granted in 2002. This could be a sign of examination by the European Patent Office currently becoming tougher.

NB: It is important to keep in mind that this grant rate can evolve over the coming years as and when patents are granted that will have taken more than 4 or 5 years to be granted.

5.2. Applicants

Figure 52 illustrates the major applicants of priority patents filed in a European country or via the European procedure. The major applicants are for the most part German and it should be noted that out of the 20 biggest applicants, 9 are institutions.

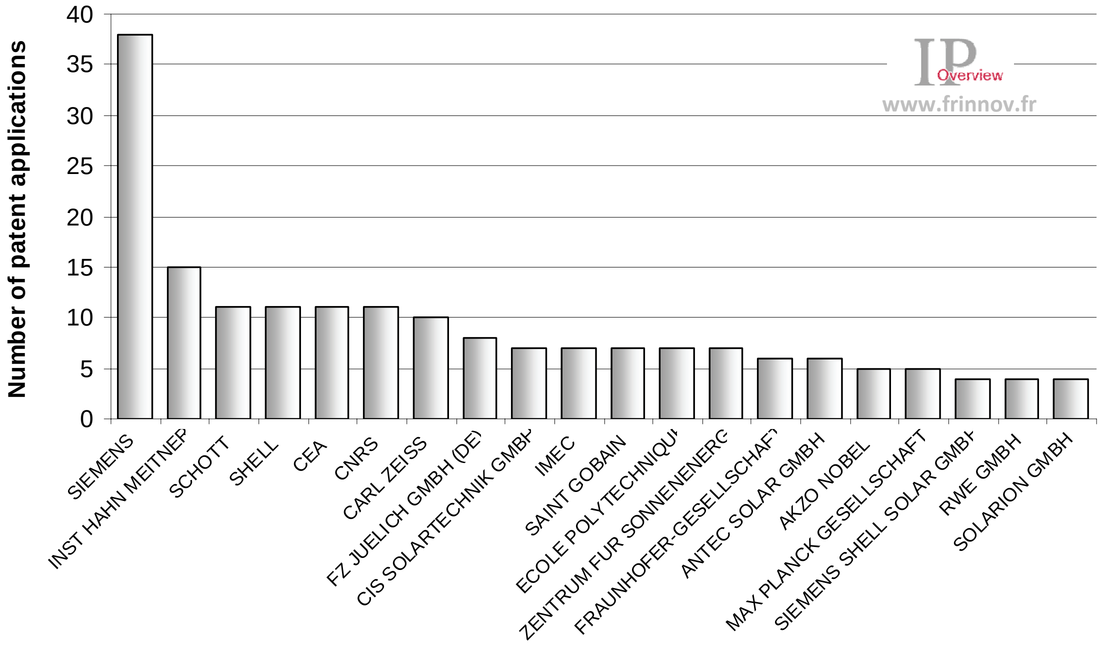


Figure 52 - Major applicants in the field (European priority)

Although SIEMENS remains the leading European applicant in volume terms in this sector, this company ceased to have a real filing policy in the photovoltaics field as of 1999. The activities of the group linked to the production of photovoltaic cells were transferred to SHELL (which has bought SIEMENS' shares in the SIEMENS SHELL SOLAR joint venture) and KONARKA (which purchased the organic part). SIEMENS is however still active in the field with regard to photovoltaic systems equipment (inverters, automation, installation of photovoltaic panels, etc.).

Institutions are very active in terms of patent filings. In fact, the second European applicant in volume terms is the German HAHN MEITNER INSTITUTE (HMI) with 15 patent filings listed. This institute is moreover the largest research institute in Europe in the field of PV thin films. HMI's rate of filing is relatively sustained (around 2 patents a year since 1999). We can cite a successful example of valorisation of the results of the institute such as SULFURCELL, a spin-off of HMI specialised in the production of photovoltaic CIS modules.

We can also cite the CEA (French Atomic Energy Commission), CNRS (French National Scientific Research Centre), the Forschungszentrum Jülich (FZJ, Germany), the Interuniversity MicroElectronics Centre (IMEC, Belgium), the Zentrum fur Sonnenenergie (ZSW, Germany) and Max Planck Gesellschaft (Germany). In general, these institutions protect quite a wide range of deposition techniques and equipment. Graphs summarising the largest research institutes involved in the photovoltaics field are available in Appendices 13 to 15.

Traditional glass makers (SCHOTT and SAINT GOBAIN) also appear in the top 20 European applicants. Such glass makers protect in particular solutions concerning glass substrates and their transformation as well as techniques of depositing thin films.

SAINT GOBAIN moreover created a joint venture with SHELL, known as AVANCIS, which produces and commercialises photovoltaic panels based on CIS technology, but does not have published patents listed in this study.

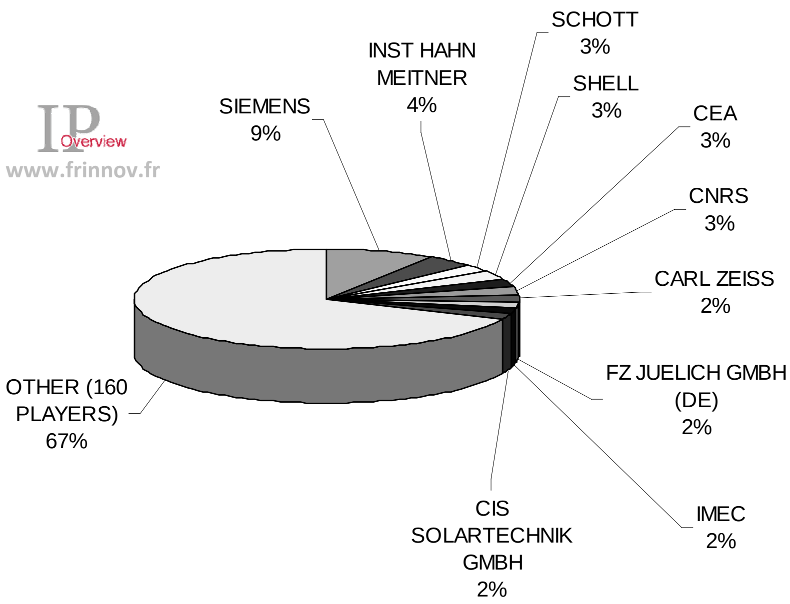


Figure 53 - Breakdown of patent portfolios by applicant (European priority)

The above graph illustrates the share held by the 10 leading applicants out of the total number of priority patents filed in Europe. This share represents a little more than a quarter of the total players. Numerous players have small portfolios, which is characteristic of emerging sectors. The following table and figure illustrate the filing dynamic of the major European applicants and the map of co-filings. Two institutional/industrial collaborations are then interpreted.

The collaboration between SOLIBRO and FORSKARPATENT I UPPSALA AB (transfer technology company on behalf of UPPSALA UNIVERSITY in Sweden) has given rise to three patent applications (SE20030001350, SE20040000582 and SE20040000631). The SOLIBRO Company and the ÅNGSTRÖM SOLAR CENTER laboratory have built up a patent portfolio in 2003 and 2004 concerning CIGS technologies.

The SOLARION Company, created in 2000, which has based its strategy on the roll-to-roll production of thin film CIGS cells deposited on a flexible substrate (polyimide), is an offshoot of the Institute of Surface Modification (IOM, Leibniz). The first of the two jointly filed patents is a key patent for the company (DE19902908 filed in 1999).

	1985	1986	1987	1988	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
SAINT GOBAIN														2	1	2			2			
CARL ZEISS														4	5	1						
SOLARION GMBH														1			1	2				
SCHOTT														4	5	1		1				
CIS SOLARTECHNIK GMBH														1	4		2					
IMEC													1				5			1		
SIEMENS SHELL SOLAR													1	2		1						
AKZO NOBEL													1	2	1	1						
FRAUNHOFER												1	1	2				1		1		
RWE GMBH											1					1			1	1		
ZENTR. JUELICH GMBH									2	1		1	2						2			
ZENTR. FUR SONNENENERGIE									2						1	1	1				2	
SHELL								3	1		1			5						1		
ECOLE POLYTECHNIQUE							1							1	2					1	2	
ANTEC SOLAR GMBH						1								3	2							
MAX PLANCK GES.						2		1	1			1										
CNRS					1	1			1	1						1	3			1	2	
CEA		1					1							1			2	1		3	1	1
INST HAHN MEITNER	1												1		2		2	4	1	2	2	
SIEMENS	2	5	3	4	2	2	5	4	2	1	2		1	4				1				

Table 7 - Evolution in the patent filings of majors players (European priority)

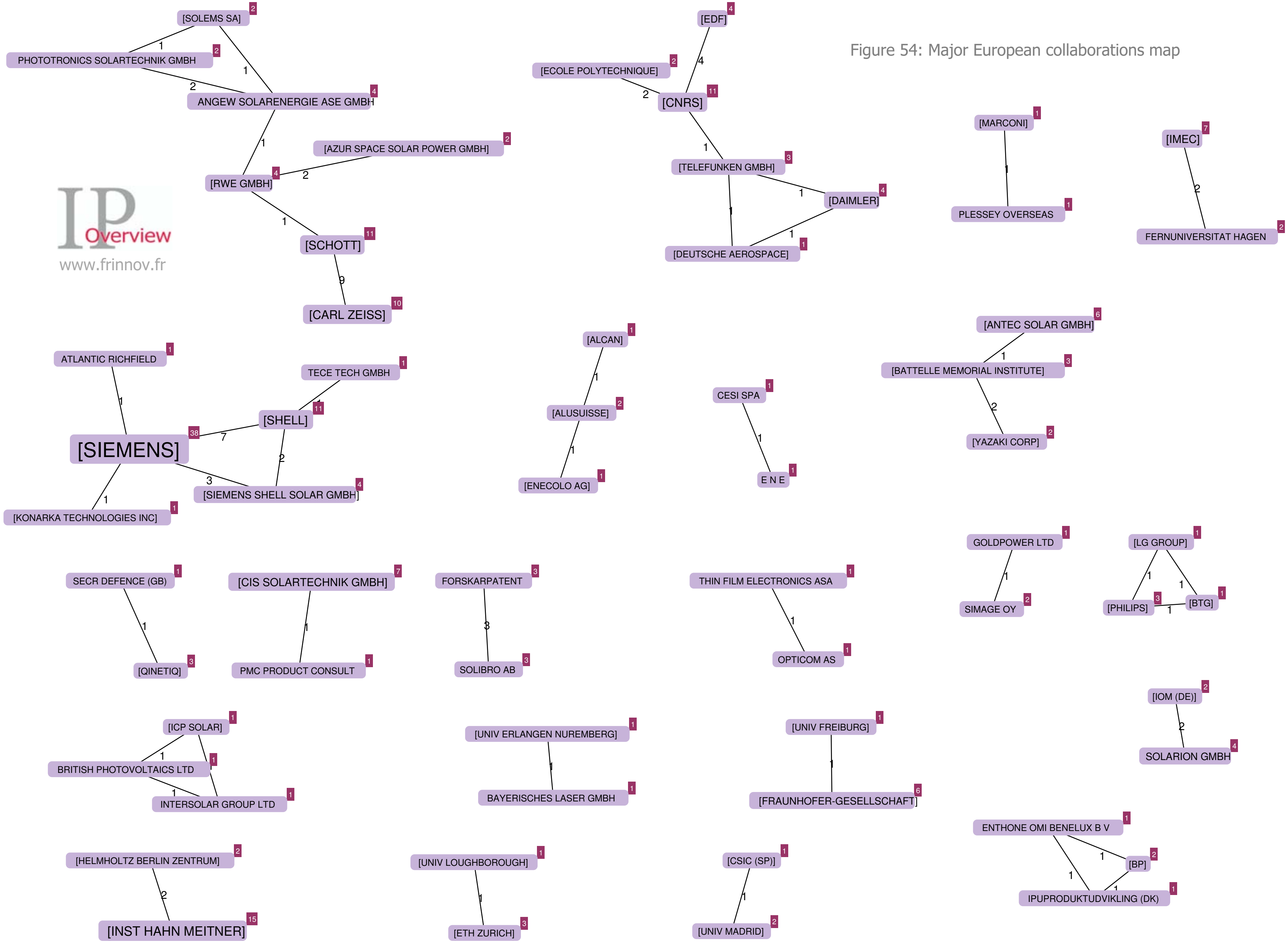


Figure 54: Major European collaborations map

5.3. Inventors

The inventors have been classified into three distinct categories:

- Firstly, **the most prolific inventors** in terms of filings. The leading five are Klaus Kalberlah (PVflex, cited as inventor in 12 patents), Franz Karg (SHELL, 9 patents), Ulrich Peuchert (SCHOTT GLAS/Carl ZEISS, 8 patents), Peter Brix (SCHOTT GLASS/Carl ZEISS, 7 patents) and Dieter Bonnet (ANTEC, 6 patents).
- Next, the inventors **considered as experts**. The expertise factor is calculated by multiplying the number of patents in which the inventor is cited by the number of different co-inventors. Of particular note are Martha Christina Lux-Steiner (HMI), Klaus Kalberlah (PVflex), Dieter Bonnet (ANTEC, 6 patents), Daniel Lincot (CNRS) and Rudolf Schropp (ECN).
- Finally, **emerging inventors**. The emergence factor represents the increase in patent filings calculated over the period 2004, 2005, 2006 and 2007. The four leading emerging inventors are as follows: Roca I Cabarrocas (CNRS/Ecole Polytechnique de Paris), Richard Menner (Zentrum für Sonnenenergie), Jérôme Damon-Lacoste (CNRS/Ecole Polytechnique de Paris) and Anton Naebauer (Gehrlicher Solar AG).

Figures 55, 56 and table 8 below outline the specific research topics and their teams (since 2003) and provide a quick summary, in volume terms, of their filings. We have provided details of some of these inventors hereafter:

Klaus KALBERLAH is head of R&D of PVFLEX SOLAR (company created in 2005). He firstly filed on behalf of CIS SOLARTECHNIK then on behalf of PVFLEX SOLAR.

Franz KARG is head of R&D and Technology of the SHELL Group. He is cited as inventor in 9 patents, all filed on behalf of SIEMENS, SHELL or their joint venture SIEMENS SHELL SOLAR GMBH.

The team of **Ulrich PEUCHERT** and **Peter BRIX** (SCHOTT GLAS - CARL ZEISS) filed 7 patents between 1999 and 2000 concerning glass substrates for photovoltaic thin film cells (alkali-free aluminoborosilicate).

Dieter BONNET (chairman of SOLARPACT E.V and founder of the ANTEC Company) appears to be a pioneer in photovoltaic Cd-Te technology. He has in particular filed in 1990 and 1991 for the BATTELLE MEMORIAL INSTITUTE then uniquely on behalf of the ANTEC Company (as of 1999). It should be noted that the 1991 patent (DE19914132882) has now become the property of the ANTEC Company.

Martha Christina LUX-STEINER of the HAHN MEITNER INSTITUTE in Berlin has filed 6 patents with the same institute since 1998.

Daniel LINCOT (CNRS) also appears as an "expert". He has filed 6 patents and works on the synthesis of thin films of cadmium sulphide and copper indium diselenide (CIS) in aqueous medium. He is involved in the joint CNRS/EDF laboratory and has filed 4 patents jointly owned by CNRS and EDF.

Rudolf SCHROPP (ECN) filed for the UNIVERSITY OF UTRECHT from 1996 to 1997, then for AKZO NOBEL (1998 and 2000) and finally ECN.

NB: A graph representing the potential movements (filing with different applicants) of the inventors in the field is available in Appendix 3.

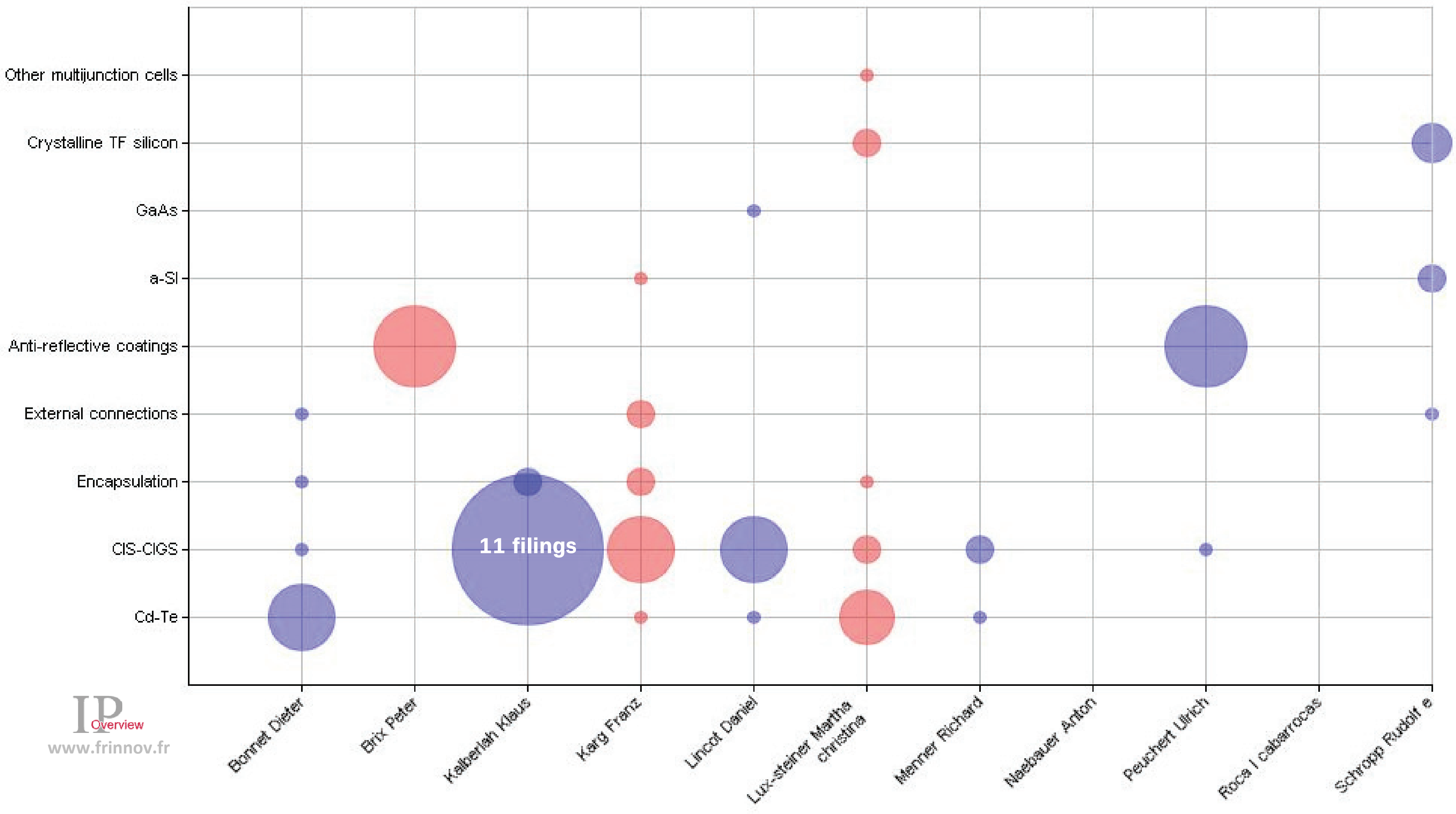


Figure 55 - Topics of the major European inventors

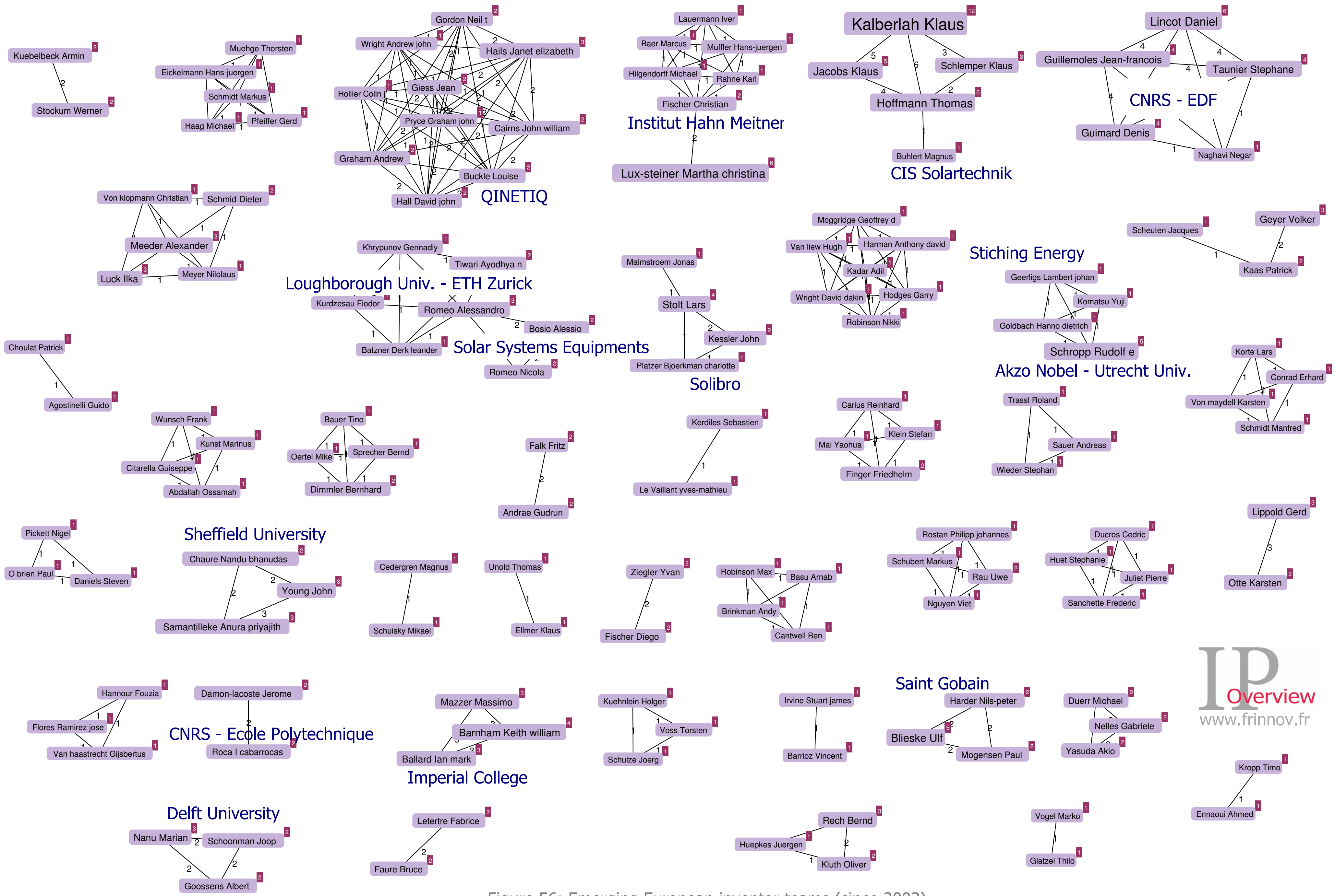


Figure 56: Emerging European inventor teams (since 2003)

	Most prolific European inventors				European experts			Emerging European inventors		
	Kalberlah Klaus	Karg Franz	Peuchert Ulrich / Brix Peter	Bonnet Dieter	Lincot Daniel	Lux-Steiner Martha Christina	Schropp Rudolfe	Menner Richard	Naebauer Anton	Roca I Cabarrocas
1987		1								
1988										
1989										
1990		1		1	1					
1991				1						
1992		1								
1993		2								
1994										
1995					1					
1996							1			
1997							1			
1998		1				1	1			
1999	1	3	3	2						
2000	4		5	2		1	1			
2001										
2002	1				3	1				
2003						2				
2004	4					1				
2005					1		1			
2006	2							2	2	2

Table 8 - Evolution in patent application filings by inventor (European priority)

6. Thin Film Cell patents - United States focus

6.1. Overall data

The number of priority patent filings in the field of thin films in the United States (a little less than 900 patent applications since 1985) remained stable (20 patents a year) up to 2000. Beginning in 2001, a patent race began and the number of priority filings attained more than 120 applications in 2006. This increase corresponds to the first announcements made by the American Government, via the DOE (Department of Energy), to develop the photovoltaics market. The DOE has in particular subsidised up to 25% the programme entitled “Utility PhotoVoltaic Group”, which since 2000 has enabled the set up of more than 1000 installations, or the programme entitled “PV for Schools”.

Today numerous projects concerning thin films are being put in place such as the “Topaz” project (550 MW photovoltaic installation by the FIRST SOLAR Company on behalf of the Californian utilities company PG&E), or FIRST SOLAR’s 30 MW installation project in New Mexico on behalf of the Tri-State Generation and Transmission Association electricity company.

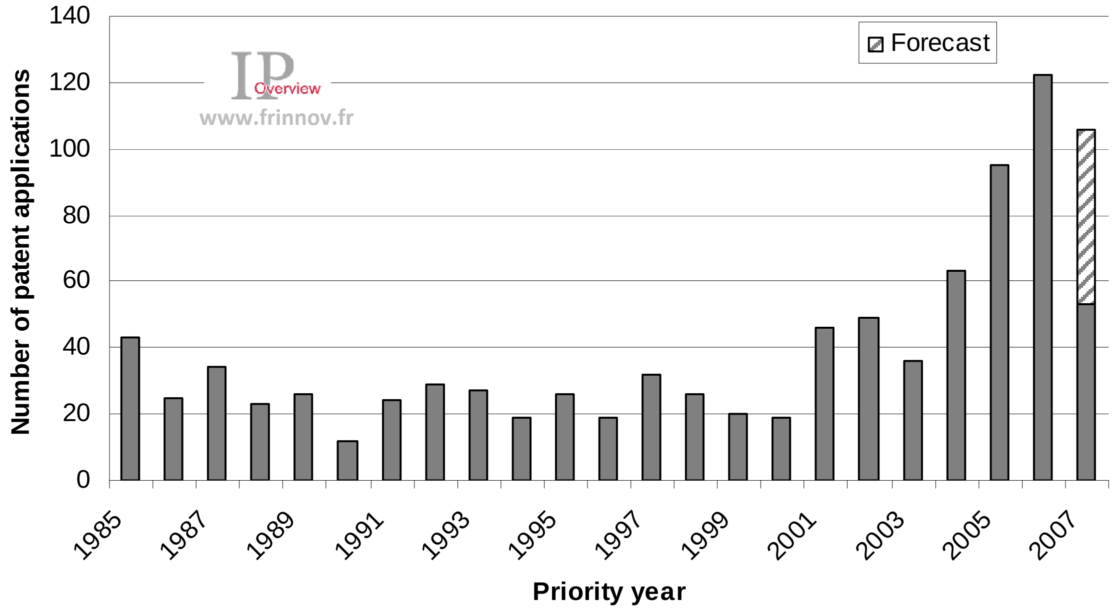


Figure 57 - Evolution in the number of filings (US priority)

The topology of applicants (figure 58) may be broken down in the same manner into 2 phases: a first phase, extending up to 1999, and a second after 2000. The first is characterised by a high proportion of academic patents (around 60%) and the second by:

- The massive increase in industrial filings
- The stabilisation in the volume of academic filings

American industrial concerns, which deserted the sector in terms of patent filings a long time ago, can thus rely on the considerable academic expertise that exists in the US, in particular that of the MIDWEST RESEARCH INSTITUTE.

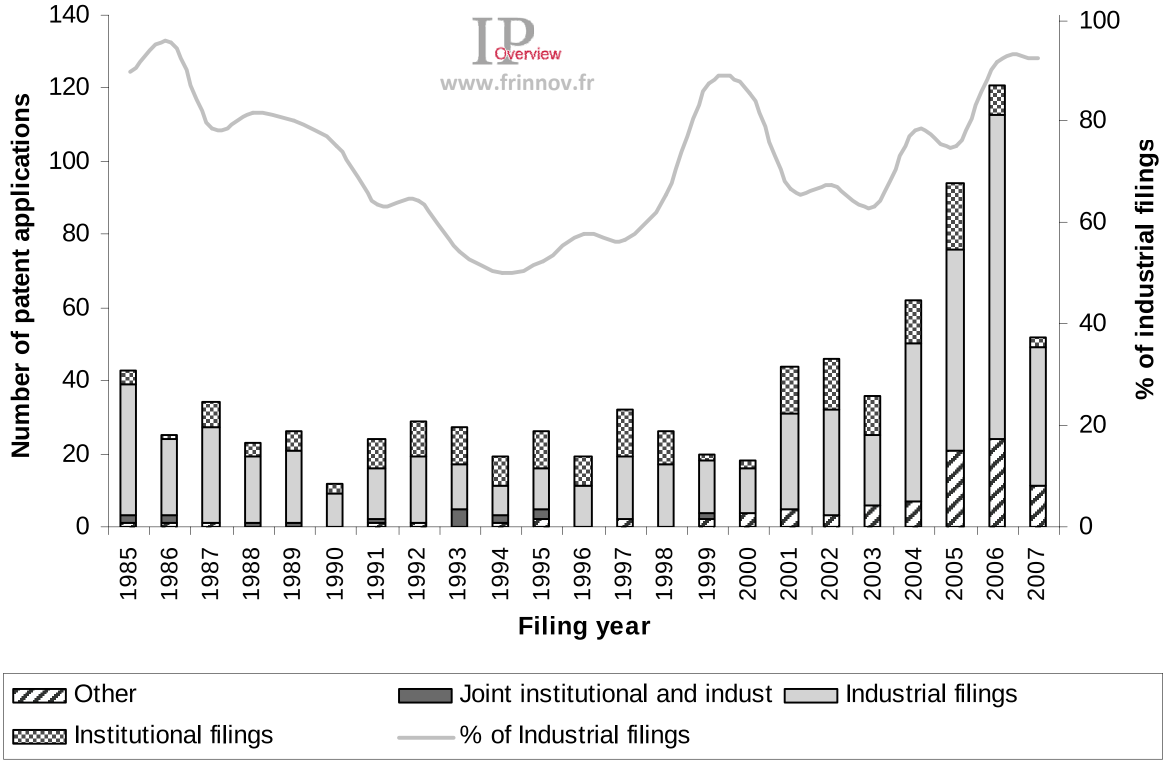
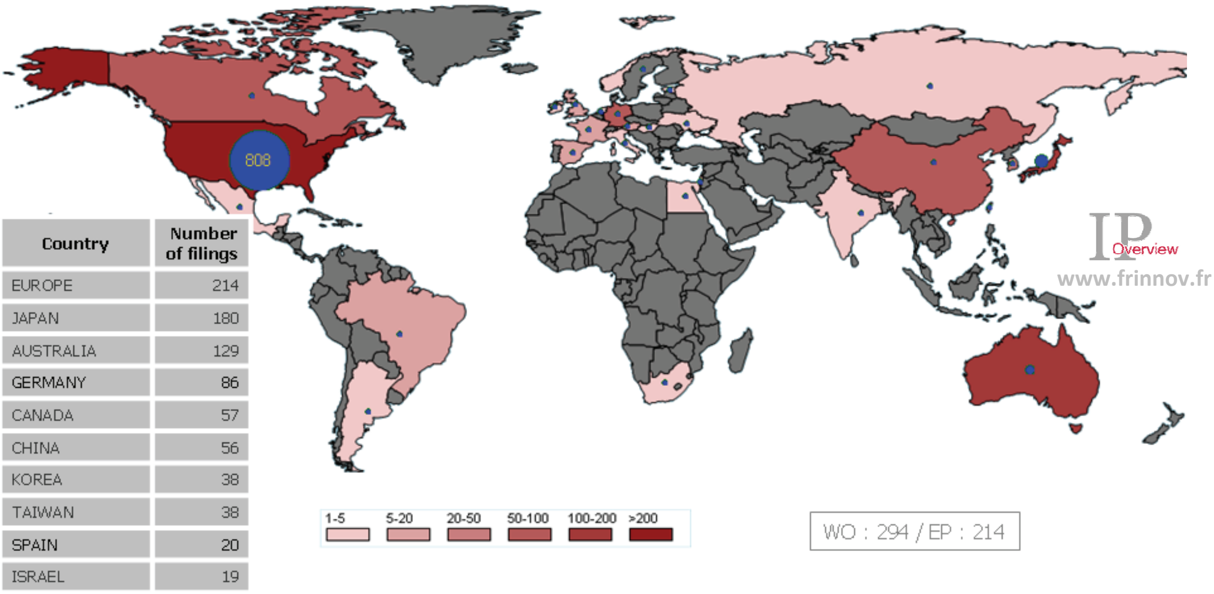


Figure 58 - Evolution in US filings and breakdown of industrial patents

When a patent is extended (figure 59), the regions the most often protected by American players are the key markets and production areas of today (Japan and Europe) as well as those of tomorrow (China, South Korea and Taiwan), particularly since 2001/2002. However, a more detailed analysis of the extensions of these priority patents filed up to 2006 shows that the large majority of these patents only protect the United States and have thus not been extended.



Country	Number of filings
EUROPE	214
JAPAN	180
AUSTRALIA	129
GERMANY	86
CANADA	57
CHINA	56
KOREA	38
TAIWAN	38
SPAIN	20
ISRAEL	19

Figure 59 - **Patent extensions map (US priority)**

An observation of the grant rate per country over time makes it possible to highlight certain trends, such as a toughening of the granting conditions or instead a propensity to abandon the maintenance of patent applications before they are granted.

An analysis over time of the grant rate cannot however be de-correlated from the evolution in the grant time. This grant time evolves and makes it possible to determine up to what date the grant rate may be taken into account.

Out of the 1643 filings of US patent applications that were made (priority or extensions), around 1100 have been granted to date. Furthermore, it is important to note that although there is a predominance of Japanese priority patents, a higher proportion of patents has been granted in the US, leading to a higher number of patents granted than in Japan (see figure 23).

The graph below illustrates the average grant time observed for the US patents granted.

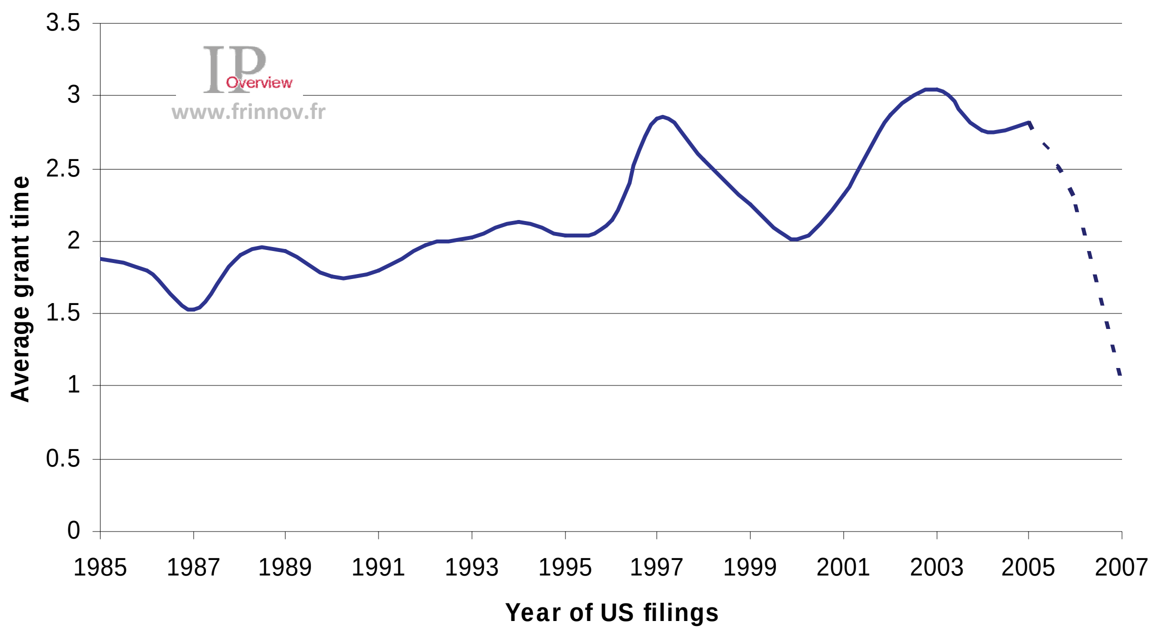


Figure 60 - Evolution of the grant time of US patents

This average grant time curve is only meaningful up to 2005. In fact, as of this date, the average time observed corresponds to the difference between the filing date and the present date and therefore cannot be taken into account, since the only patents granted cannot effectively have taken more time to be granted. This grant time remains lower than that measured for Japan and Europe.

Between 1985 and 2005, the average grant time thus increased overall, going from around 2 years to almost 3 years after the date of filing the US application.

It is also worth noting that the grant rate observed in figure 61 only has significance for US patent applications for which the filings are subsequent to 2000 since, before this date in fact US patent applications were only published on the day the patent was granted. Non granted applications were never, for their part, published. Thus, we can only analyse the evolution in the granting percentage for the period between 2001 and 2005.

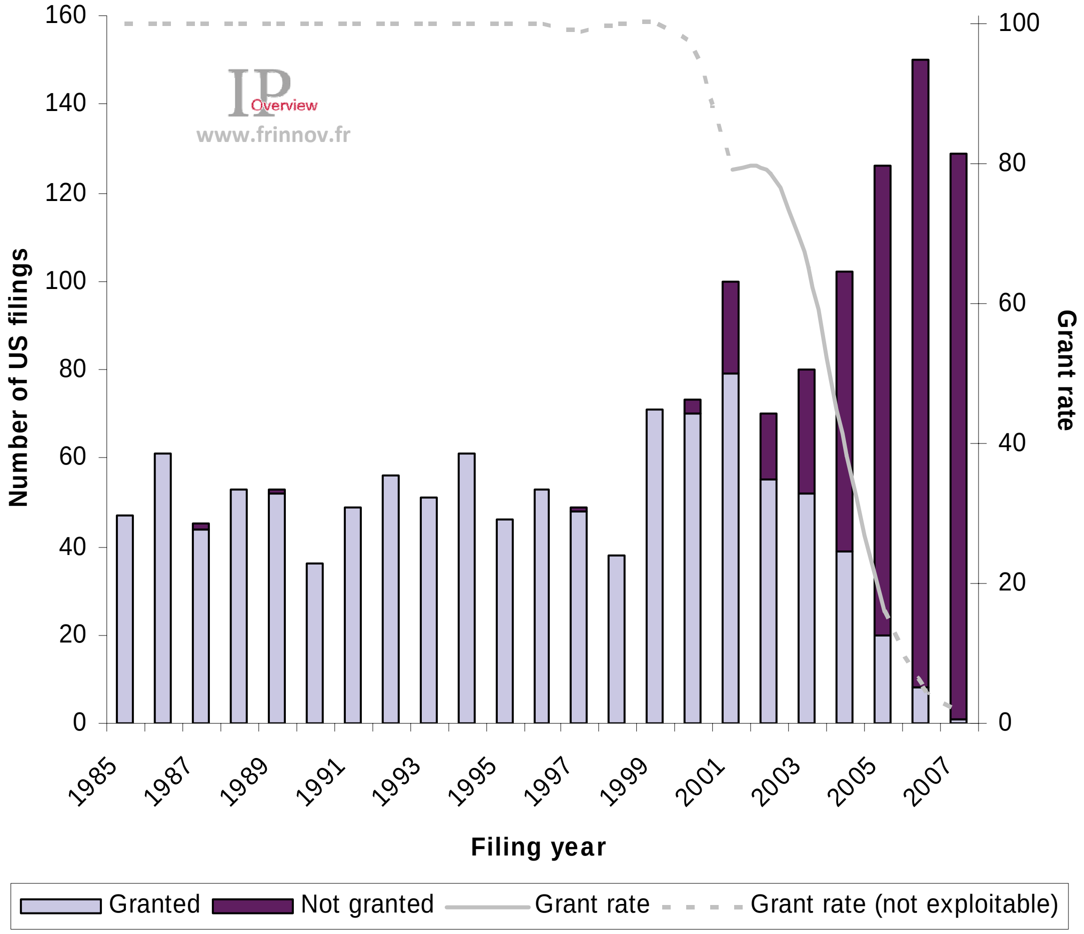


Figure 61 - Evolution in the granting of US patents

This graph shows that among the US patent applications filed in 2001, a high proportion were granted (nearly 80% grant rate). From 2003 onwards, the rate dropped dramatically to less than 20% in 2005. This fact could be the sign of tougher stance taken at present with regard to patent examinations in the US.

NB: It is important to keep in mind that this rate may change over the years to come as and when patents that have taken more than 3 years to be granted are in fact granted.

6.2. Applicants

The considerable increase in the number of patents filed in the United States over the last few years with regard to photovoltaic thin film cells has gone hand in hand with the number of start ups created over the same time period and the heavy involvement of the MIDWEST RESEARCH INSTITUTE and of the DOE in the field.

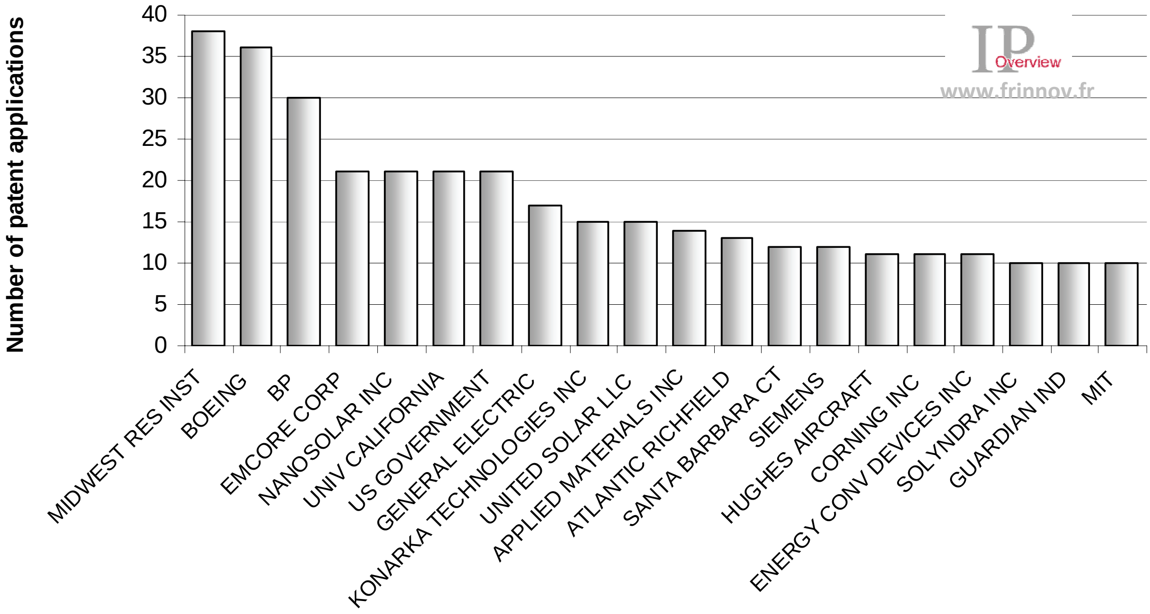


Figure 62 - Major applicants in the field (US priority)

In terms of volume of patent applications, the two leading American applicants are the MIDWEST RESEARCH INSTITUTE and BOEING (via its subsidiary SPECTROLAB, specialised in photovoltaic systems for space applications), with a little more than 35 patents each. Start ups occupy a privileged place among the 20 largest patent portfolios, which demonstrates the infancy of the American market, but also underlines its vigour and its strong involvement in innovation. Examples are NANOSOLAR (created in 2002, 5th place), KONARKA (created in 2001, 9th) and SOLYNDRA (created in 2005, 18th).

NB: It should be noted that the principal activity of KONARKA is based on photovoltaic organic cells and not on thin films, however certain patents fall within the scope of this field.

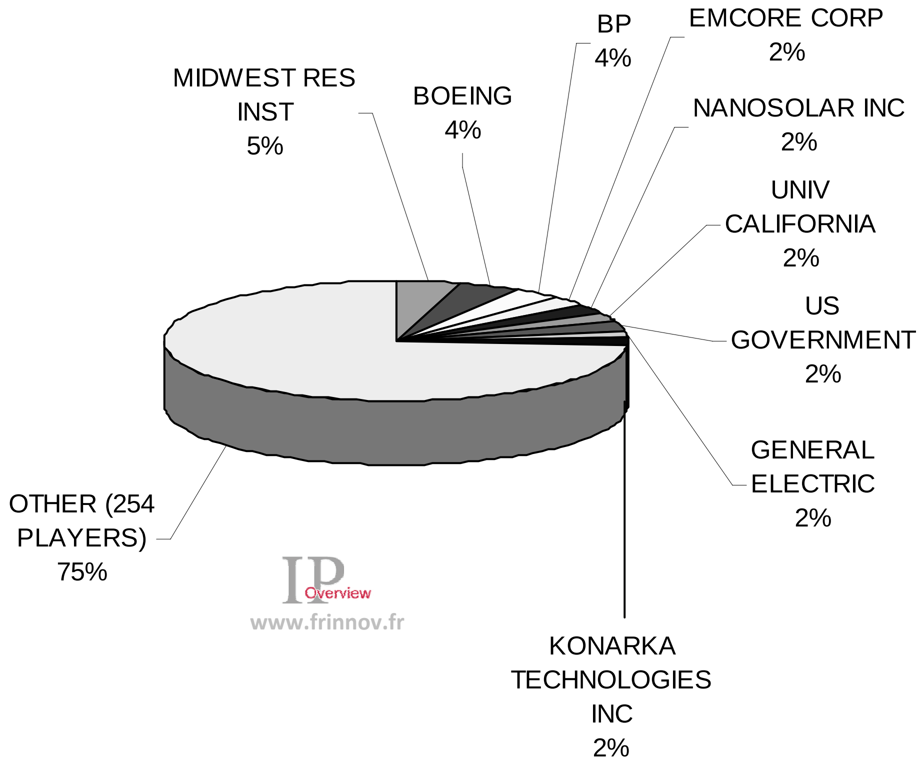


Figure 63 - Breakdown of patent portfolios by applicant (US priority)

The intellectual property is quite fragmented (264 players share all of the priority US patent applications) and the 10 leading applicants account for a little more than one quarter of the total. This latter point is typical of emerging sectors.

The following table and figure illustrate the filing dynamic of the major American applicants and the co-filings map.

Table 9 makes it possible to differentiate the pioneer players that were already filing in 1985 and which are still filing today, such as BOEING, the US GOVERNMENT (which includes the US AIR FORCE, the US ARMY, the US DEPT. OF ENERGY, the US FEDERAL ADMINISTRATION and the US NAVY), the BP Group, ECD and its subsidiary UNITED SOLAR, the MIDWEST INSTITUTE and the UNIVERSITY OF CALIFORNIA. Conversely, this table also highlights the newcomers that are active in terms of intellectual property such as GENERAL ELECTRIC, EMCORE, CORNING, GUARDIAN INDUSTRIES, APPLIED MATERIALS and the start ups cited previously.

American players do not co-file many patents (only 65 patents out of the 877 US priority applications, 7.5% compared to 13.5% in Europe). The main co-filings have moreover been made with the European company SIEMENS. This collaboration has been described in the first part of this study.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
GUARDIAN IND																						6	4
APPLIED MATERIALS INC																					1	9	4
KONARKA TECHNOLOGY																			1	1	11	2	
CORNING INC																			1		5	3	2
NANOSOLAR INC																		1	1	12	4	3	
EMCORE CORP														5		1	2	1		1	3	4	4
MIT													3		1		1	2	1		2		
GENERAL ELECTRIC											1								1		4	7	4
UNIV CALIFORNIA									1	2				2	1		2	2		4	3	2	2
MIDWEST RES INST								5	2	1	3	5	5	4	1		6	3	2	1			
UNITED SOLAR LLC						2	2	3			1	2	1					1			1	1	1
3M				6			2													1	1		
SANTA BARBARA CT		1	1		3		1	2	2	1	1												
ENERGY CONV DEVICES	3		2	1	1		1				1	1									1		
ATLANTIC RICHFIELD	8		3	2																			
BP	2	3	1		1	1	3	1	1	5		1	1	1		1	3	3		1	1		
HUGHES AIRCRAFT	2	1			2		1		1		1	3											
US GOVERNMENT	2		1	2	1	2	3	4	1		1	1			1			1	1				
BOEING	3	1		2	5	3	1	1			1				2	1	2	5	3	2	4		

Table 9 - Evolution in patent filings of major players (US priority)

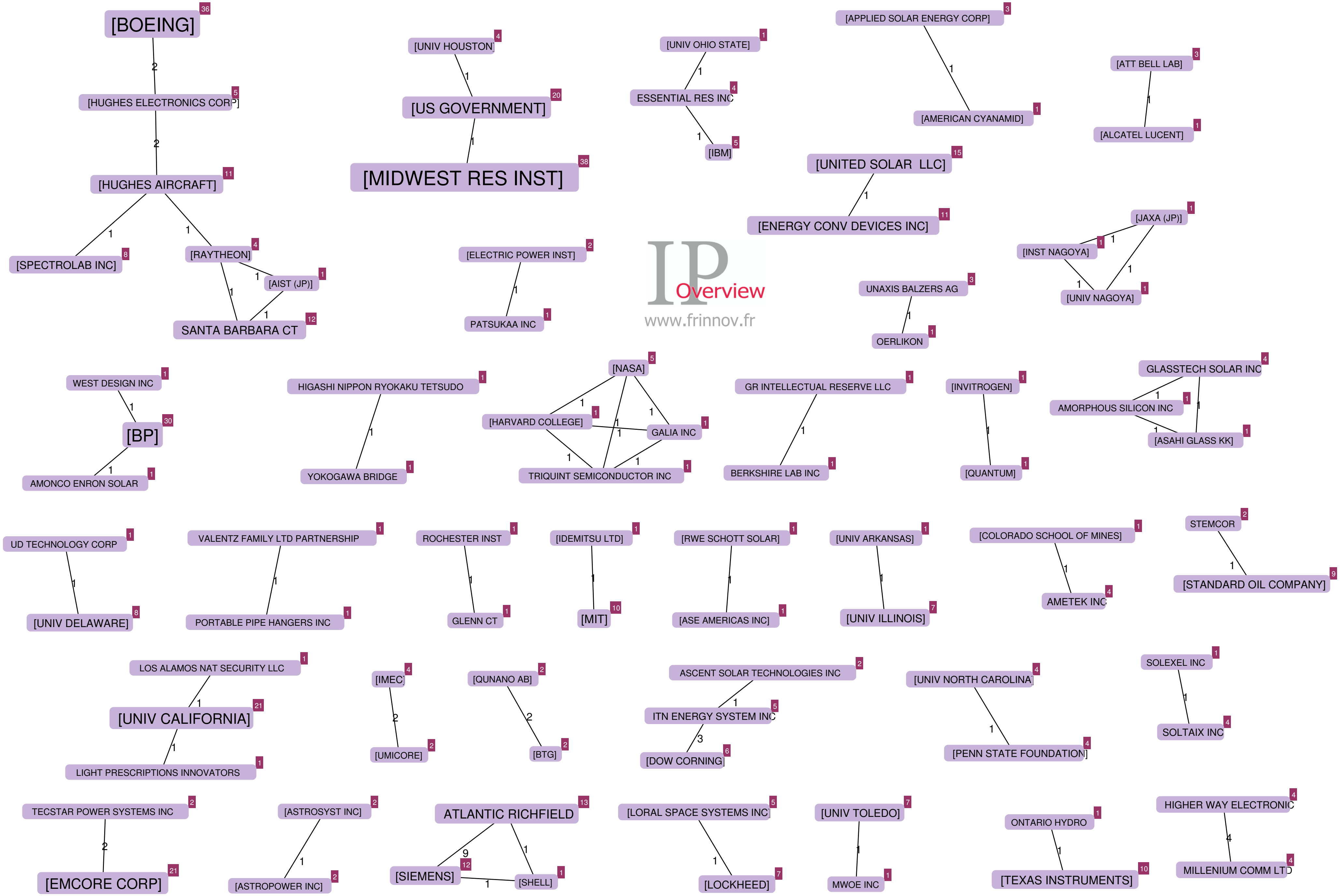


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Figure 64: Major US collaborations map

6.3. Inventors

The inventors have been classified into three distinct categories:

- Firstly, **the most prolific** inventors in terms of filings. The leading five are in order: Bulent Basol (ASM Nutool Inc., 19 patents filed in which he is cited as inventor), Richard King (BOEING, 13 patents), Brian Sager (NANOSOLAR, 13 patents), Paul Sharps (EMCORE CORP, 13 patents), Lewis Fraas (JX Crystals, 12 patents).
- Then, the inventors **considered as experts**. The expertise factor is calculated by multiplying the number of patents in which the inventor is cited by the number of different co-inventors). Names that stand out in particular are Russell Gaudiana (KONARKA TECHNOLOGIES INC, 12 patents), Subhendu Guha (ENERGIE CONVERSION DEVICES / UNITED SOLAR OVONIC, 12 patents), Martin Roscheisen (NANOSOLAR, 12 patents), James Ermer (BOEING, 10 patents) and Craig Leidholm (SOLEXANT, 9 patents).
- Finally, **emerging inventors**. The emergence factor represents the increase in patent filings over the period 2004, 2005, 2006 and 2007. The five leading emerging inventors are the following: Richard Allen Hayes (DU PONT, 9 patents), Peter Borden (APPLIED MATERIALS INC, 7 patents), Bastiaan Korevaar (GENERAL ELECTRIC, 7 patents), Alexey Krasnov (GUARDIAN IND, 7 patents) and Loucas Tsakalakos (GENERAL ELECTRIC, 7 patents).

Figures 65, 66 and table 10 below outline the specific research topics and their teams (since 2003) and provides a quick summary, in volume terms, of their filings. We have provided details of some of these inventors hereafter:

Bulent Basol is currently head of operations (CTO) and Vice President of the start up SOLOPOWER and was also one of its founders. He is a leading light in the photovoltaics field and in particular on Cd-Te electrodeposition techniques. Moreover, he has continued to participate in the development of solar cells based on Cd-Te technology while working for MONOSOLAR Inc. This technology, which had been patented, was then sold to BP in 1984. In 1985, he was one of the founders of the INTERNATIONAL SOLAR ELECTRIC TECHNOLOGY Company. He then joined NUTOOL Inc in 2000, where he developed a patent portfolio based on Electro Chemical Mechanical Deposition (EMCD™) technology. The ASM Company later took over NUTOOL in 2004 then, in 2008, sold the corresponding portfolio.

Richard King and **James Ermer** work on behalf of SPECTROLAB, which is a subsidiary of BOEING. They have in particular participated in the development of the terrestrial concentrator photovoltaic cell, which has attained an laboratory efficiency of 41.7% (2006). These results seem promising for the future, because they are produced using a new class of metamorphic semi-conductor materials that enable an optimal conversion of the solar spectrum. The development of high efficiency concentrator cell technology has been funded by the "High Performance Photovoltaics" programme of the NREL and SPECTROLAB. Richard King is the scientific head of the Photovoltaic Cell R&D Unit of SPECTROLAB. As for James H Ermer, he filed his first patents (1985, 1987 and 1989) in the field with the ARCO Company. The patents of its subsidiary, ARCO Solar, having been sold to SIEMENS in 1989, were then in the names of ARCO and SIEMENS. In 1999, he began to file his patents in the name of BOEING.

Martin Roscheisen and **Brian Sager** are the two founders of the NANOSOLAR Company. Martin Roscheisen, currently Chief Executive Officer of NANOSOLAR, had already created several companies, in particular FINDLAW and TRADINGDYNAMICS. In the early 2000s, he began to work in the field of green energy. Brian Sager, currently Vice President of Corporate Development of NANOSOLAR, is in particular an expert in the intellectual property field (licence negotiations, management of patent portfolios).

Paul SHARPS is Director of Cell Technology on behalf of the Emcore Photovoltaics Company. His team has in particular developed the Inverted Metamorphic Multijunction (IMM) solar cell. This solar cell attains very useful laboratory efficiencies, namely 40.8% under concentrated light (2008).

Gaudiana Russel, Vice President of R&D of the KONARKA TECHNOLOGIES Company, is a chemist by training and works in particular on the architecture of solar cells. He worked for 27 years on behalf of POLAROID CORPORATION as head of the chemistry R&D department. He is cited as inventor in 12 patents.

Subhendu Guha is Senior Vice President for photovoltaic technology of the ENERGY CONVERSION DEVICES (ECD) Company and chairman of its subsidiary UNITED SOLAR OVONIC. He is an expert in the field and began to work for ECD in 1982 and was first cited as inventor in 1987 (in the data base consulted for this study).

Fraas Lewis worked for a long time in the photovoltaics field intended for space applications with BOEING, CHEVRON RESEARCH and HUGHES RESEARCH LABS. He now works on behalf of the JX CRYSTALS Company.

NB: A graph representing the potential movements (filing with different applicants) of the inventors in the field is available in Appendix 3.

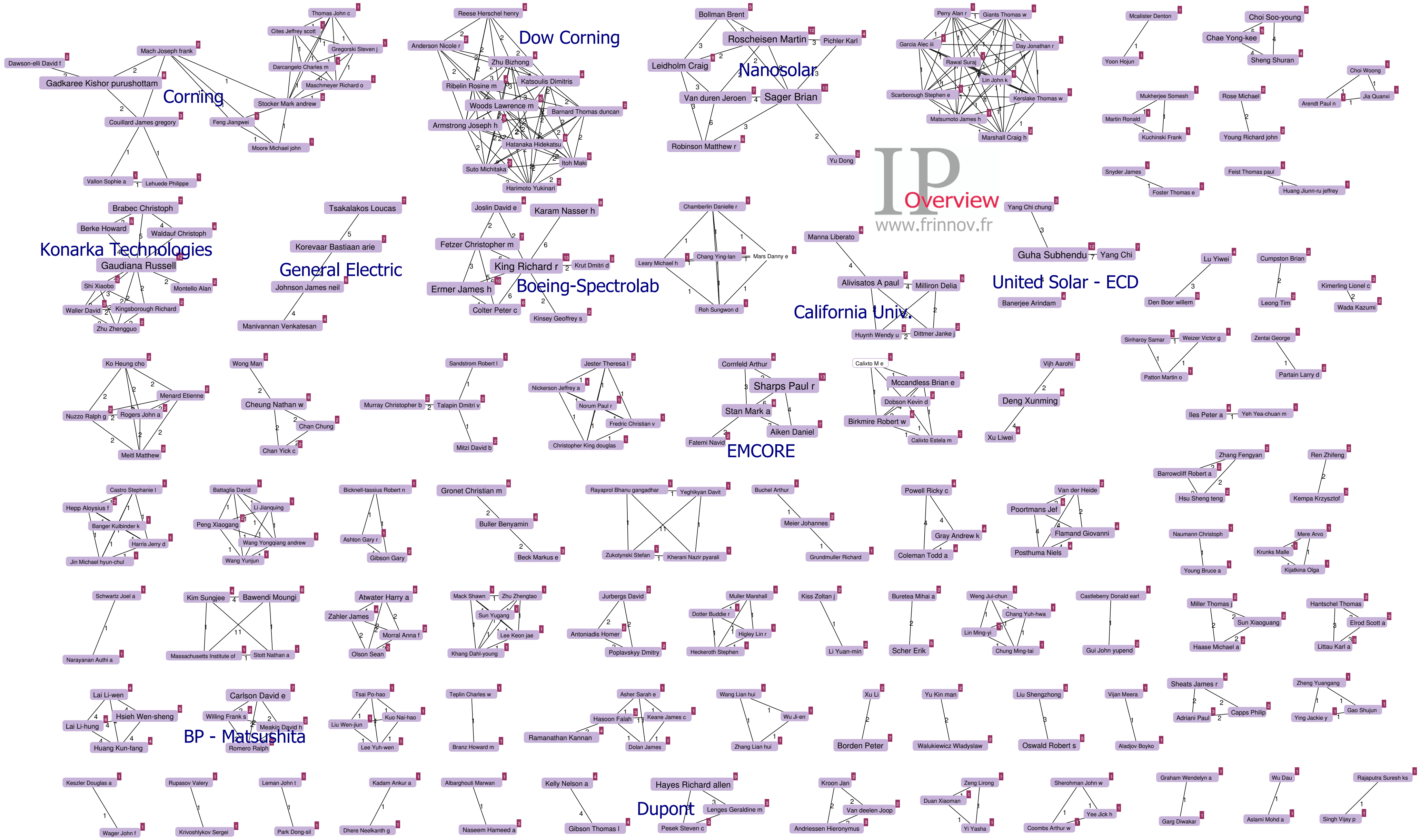

Figure 65: Emerging US inventor teams (since 2003)

	Most prolific US inventors					Experts					Emerging US inventors				
	Basol Bulent	King Richard	Sager Brian	Sharps Paul	Fraas Lewis	Gaudiana Russell	Guha Subhendu	Roscheisen Martin	Ermer James	Leidholm Craig	Hayes Richard Allen	Borden Peter	Korevaar Bastiaan Arie	Krasnov Alexey	Tsakalakos Loucas
1985	3				1				1						
1986					2										
1987							1		1						
1988							1		1						
1989	2				3										
1990					3										
1991					1		1								
1992							3								
1993					1										
1994															
1995							1								
1996							2								
1997	1									1					
1998	2				1					2					
1999		2							2						
2000		1		2											
2001	1	2		2					2						
2002		2	1				1	1	2						
2003		1	1			1		1	1						
2004	1	2	9			1		7		4					
2005	3	3	1	3		9		2		1		1			1
2006	4			3		1	1	1		1	5	6	3	4	4
2007	2		1	3			1				4		4	3	2

Table 10 - Evolution in patent application filings by inventor (US priority)

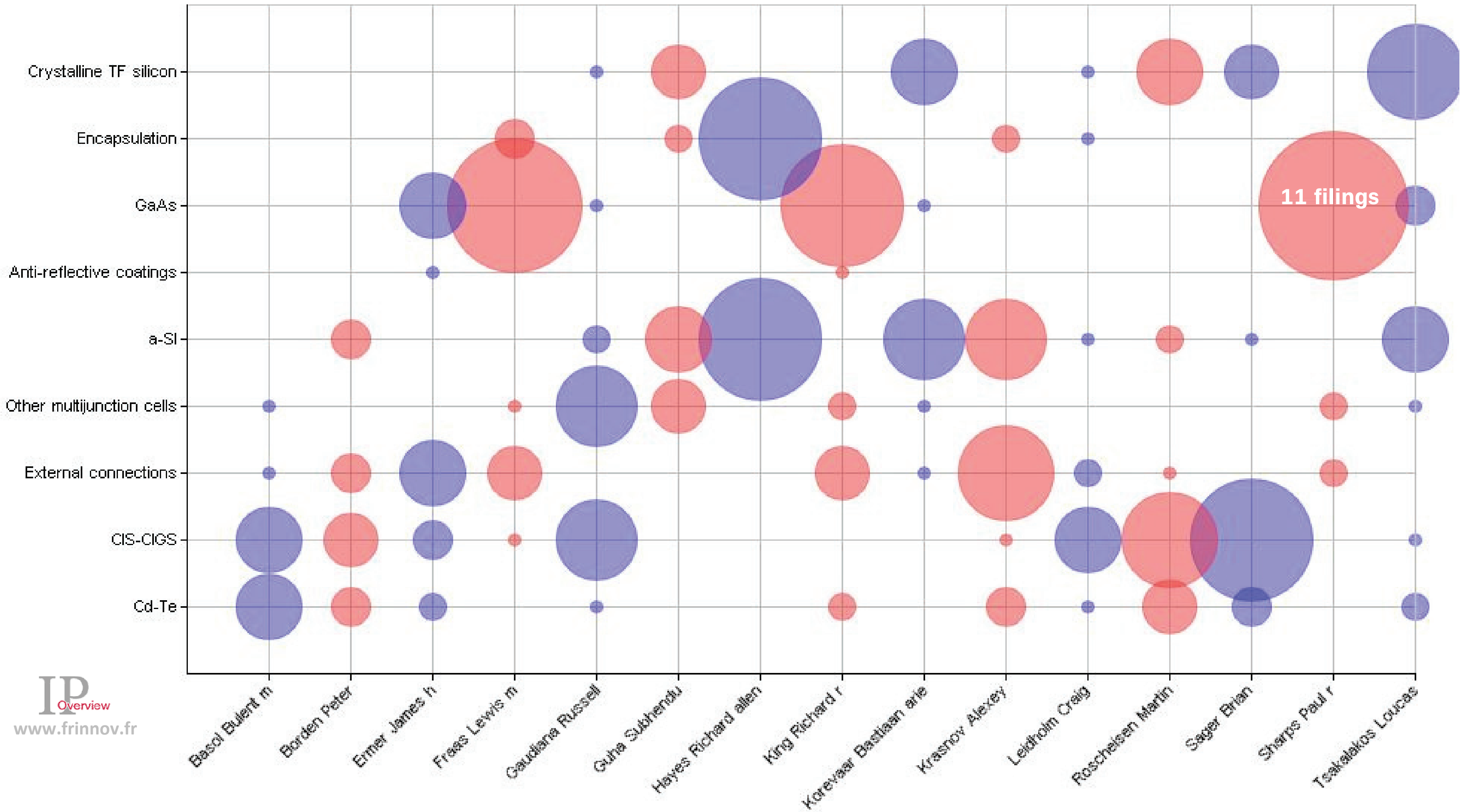

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Figure 66 - Topics of the major US inventors

Conclusions

The different market studies available for this sector predict an outlook of exponential growth of photovoltaics technology based on thin films. For example, the market assessment of NanoMarkets reports that this market should go from nearly 2.4 billion dollars in 2008 to more than 12 billion in 2013, i.e. growth of 50% a year. They base their analyses in particular on overall criteria such as the political willingness displayed by countries such as the US and China to develop solar energy to diversify supply.

Among photovoltaic cells based on thin film technologies, four major types may be distinguished:

- Cells based on the deposition of silicon, whether amorphous (a-Si), microcrystalline (µ-Si) or nanocrystalline (n-Si)
- Cells based on Cd-Te technology
- Cells based on CIS or CIGS technology
- And finally, other multijunctions, and principally cells based on Ga-As

The first three types, which are also the most widespread, have numerous shared advantages, which promises them a bright future in the context described previously. In fact, this type of technology enables deposition on large surfaces such as large glass plates, or even flexible substrates several hundreds of metres long. Their method of production is very advantageous compared to that of cells based on crystalline silicon, because continuous on-line production is possible, using very little raw material. The characteristics of this type of cell are very interesting, for example with regard to their efficiency, which is in constant progress (up to 10% for a-Si, 16% for Cd-Te and 19% for CIS) or instead with regard to their very good resistance to exterior conditions. Finally, photovoltaic thin film cells are capable of meeting the needs of the most important market, i.e. the building sector, which requires a solution to turn roofs (industrial or private) into producers of electricity.

However, after nearly 30 years of research and development into these cells, they still only represent around 10% of the market and the revolution that is constantly being announced is constantly being put back...

The industrial environment of these technologies has not been very favourable, unlike crystalline silicon technology where silicon producers got on-board at an earlier stage. Glass manufacturers (such as SAINT GOBAIN, SCHOTT or CORNING), which would appear to be obvious suppliers of the substrates required for thin film cells, only became involved in this technology at a relatively late stage. The first filings registered in this study date back to 1999 for SAINT GOBAIN and SCHOTT and only to 2005 for CORNING. The presence of Ulrich PEUCHERT and Peter BRIX, who file for SCHOTT

GLAS-KARL ZEISS and who are among the most prolific European inventors, underlines the fact that glass makers are now fully-fledged participants in this technology and support it. Equipment manufacturers have generally held back before getting actively involved as well. APPLIED MATERIALS illustrates this point well. This company, which is specialised in deposition machines and high technology instrumentation, waited until 2006 to file its first patents. However, and in the image of glass manufacturers, its investment has been both considerable and rapid: 13 patents recorded by this study between 2006 and 2007, an inventor considered as an emerging inventor in the US and numerous press releases announcing their arrival in the field.

Without a favourable industrial environment, thin film cells cannot compete in terms of costs with their crystalline silicon rivals, the cost/power ratio being however the real key success factor. However, the new involvement of players linked to substrates and equipment in the specific field of thin films is going to change the situation in the medium term.

Although historically it is Japanese players that have dominated the intellectual property in the sector, the dynamism of patent filings is now being sustained by American players. In fact, although there were nearly 200 Japanese priority filings at the end of the 1980s (compared to a little more than twenty or so in the US), nowadays there are around fifty or so in Japan compared to more than 120 in the US. To maintain a high level of innovation, the American and European players can count on the presence of numerous academic players (MIDWEST RESEARCH INSTITUTE, the UNIVERSITY OF CALIFORNIA or the HAHN MEITNER INSTITUTE). There are also a significant number of start ups and very close collaborations between academic institutions and industry, made concrete through exploitation licences. This innovation model is radically different to the Japanese model where industrial property is concentrated in the hands of 10 major players (MATSUSHITA, FUJI ELECTRIC, SANYO, SHARP, MITSUBISHI, KANEKA, FUJITSU, SUMITOMO, HITACHI and NEC).

An analysis of patents by technological thin film segment makes it possible to illustrate several differences between them with regard not only to their technological maturity but also the industrial environment. In fact, even though the market is still only in its infancy, the race to build up strategic patent portfolios in these different technologies has already begun but the major different types of thin film technology are at different technological maturity levels.

The most tried and tested technology and which covers half of the photovoltaic thin films market (with 5.2% of the world photovoltaics market) is amorphous silicon technology. Even though this technology does not offer high efficiencies, it has the advantage of offering long lifetimes and, above all, a very accessible cost. It appears as the most mature technology among thin film technologies and well positioned in the markets that it has conquered (markets linked to the supply of watches, calculators, emergency lighting, etc.) and only a technological revolution could push it into second position. Its major players, dominated by Japanese industrial concerns, are SHARP, FUJI ELECTRIC, MITSUBISHI and SANYO. In terms of industrial property, the drop in filings based on this technology is clearly observable, synonymous with players involved in the field backing out from research and development in the subject. Few major technological evolutions can thus be expected in this sector, unless perhaps two different areas of know-how are combined: crystalline silicon and amorphous silicon. This is in particular what SANYO is counting on. This company is the specialist in amorphous silicon cells and, since the 1990s, has developed photovoltaic cells based on its high performance HIT (Heterojunction with Intrinsic Thin layer) technology.

Cd-Te technology represents the second technology in terms of thin film market share, with 4.7% of the world market. This technology benefits from the commercial success of the FIRST SOLAR Company, which has established itself as undisputed leader in this market segment. The principal patent portfolios belong to FIRST SOLAR, ANTEC SOLAR and especially MATSUSHITA and FUJITSU, which have locked out the technology through very early and massive filings. The large portfolios of the American research centres MIDWEST RESEARCH INSTITUTE and the UNIVERSITY OF CALIFORNIA are also worthy of note. At present industrial projects are multiplying, such as the creation of a plant by ABOUND SOLAR (representing an investment of 150 million dollars, the production start up of which was planned for early 2009). However, although this technology seems for the moment to be economically flourishing, the presence of cadmium risks acting as a brake to its expansion due to its toxicity. The number of filings in this technological segment has more or less stagnated over the last ten or so years.

The technological segment that shows the highest growth rate in terms of filings of priority patent applications is CIS technology. In 2006, the number of filings in this segment represented 25% of the total number of filings on thin films compared to 21% for a-Si, 17% for Cd-Te, 18.6% for thin films based on micro- or nano-crystalline silicon and 10.6% for Ga-As . The principal portfolios belong to SIEMENS, CIS SOLAR TECHNIK, BOEING, EDF/CNRS, KONARKA TECHNOLOGIES, NANOSOLAR, SOLYNDRA, HONDA and MATSUSHITA. It is the only segment that is not widely dominated by Japanese industrial players. European (IMEC, HAHN MEITNER INSTITUTE or the ZENTRUM FUR SONNENENERGIE) and American research institutes (the MIDWEST RESEARCH INSTITUTE or the UNIVERSITY OF CALIFORNIA) are also very active. This technology is still in the gestation stage and seems very promising for the future in terms of efficiency and price. A new European record for this type of cell has recently been claimed by the ZENTRUM FÜR SONNENENERGIE UND WASSERSTOFF-FORSCHUNG (ZSW): 19.6% efficiency for cells produced under pilot conditions using a multi-process line in an automated production plant. This result has been accredited by the Fraunhofer Institute for solar energy systems.

The other techniques based on thin films (the most developed being Ga-As heterojunctions) are more in search of efficiency performance than efficiency/cost ratio. The trend is towards niche markets such as aerospace or sports engine equipment (World Solar Challenge). Ga-As multijunction devices are the most efficient cells. For example, SPECTROLAB obtained a laboratory efficiency rate of 40.7% in 2006 and a team from the University of Delaware obtained a laboratory efficiency rate of 42.8% in 2007. The main problem with these types of technique based on gallium or germanium is their high cost, in particular linked to the price of the raw materials used.

Thin film technologies thus seem to be on the point of being capable of exploding in market terms. However, although the markets that they target are slightly different to crystalline silicon technologies and should enable them to co-exist with this technology, thin film cells could nevertheless face stiff competition from organic and hybrid technologies (DSSC, Dye-Sensitized Solar Cell), whose potential is also promising but which are still in the technological maturation phase.

Appendices

APPENDIX 1: List of 124 companies present in the photovoltaics market and their associated patent portfolios

Company	N° of patents
Aleo Solar	0
ANTEC Solar Energy	7
Apollon Solar	12
Astropower	17
Avancis	0
Baoding Yingli New Energy	6
Bengbu Polar Beam Co	0
Big Sun Technology Inc	1
BP solar	79
Brilliant 243	0
Calyxo	0
Canadian Solar	1
China Sunergy	0
Conergy	10
CSG Solar	8
Daiwa House	20
Daystar Technologies	5
DelSolar	0
Deutsche Cell	0
Deutsche Solar	5
Elkem	11
EMEI Semiconductor Material Factory	0
EMIX	1
Energy Conversion Device	37
ErSol Solar Energy	1
E-TON Solartech	0
Evergreen	23
EverQ	0

Company	N° of patents
First solar	13
Formosun Technology Corp	0
Fuji Electric	517
FujiPream/Clean Venture 21	11
GE Energy	78
Gintech Energy Corp	0
Global Solar Energy Inc	3
Green Energy Technology (GET)	1
Helios Technologies	0
Hemlock Semiconductor Corp	5
Hitachi	319
Hoku Scientific	0
Honda	136
Isofoton	5
JA Solar	0
JFE Steel	0
JiangSu Shunda Group Corp	0
Jinglong Industry and Commerce Group Co	0
Jinzhou Xinri Silicon Material Co	0
Johanna Solar Technology	0
Kaneka	409
Kobelco (Kobe Steel)	14
Kyocera	641
Kyosemi Corp	12
LDK Solar Co	0
M.Setek	4
Matsushita	782
MEMC Electronic Materials Inc	119
Misawa Homes	100
Mitsubishi	871
Mosel Vitelic Inc	0
Motech	0
MSK Corp	33
NanoSolar	38
Nanowin Technology	0

Company	N° of patents
Neo Solar Power Corp	4
Nexpower Technology Corp	0
NingBo Solar electric Power Co	2
NorSun	0
Odersun	1
Oerlikon Solar	7
Osaka Titanium Technologies	21
PanaHome Corp	6
Photovoltech	0
Photowatt	4
PV Crystalox Solar	2
Q-Cells	9
ReneSola	0
Renewable Energy Corp	0
RWE	13
RWE Schott Solar	16
Sanyo	1032
Scheuten	4
Schott	31
Sekisui LTD	318
Semiconductor Manufacturing International Corp (SMIC)	3
Shanghai Solar Energy Science&Technology	0
Shanghai Topsun	0
Sharp	1187
Shell	110
Shenzhen Sun-Moon-Circle	0
Shenzhen Topray Solar Co	3
Sheuten Solar	0
Shihua	0
Showa Corp	11
Showa Denko KK	21
Sichuan Xinguang Silicon Technology Co	0
Siemens	160
Siemens Shell Solar	11
Sinonar Corporation	0

Company	N° of patents
Solaicx	2
Solar EnerTech Corp	1
SolarWorld	9
Solarfun	4
Solartec	14
Solibro	3
Solland Solar Energy	0
Solterra Fotovoltaico	0
Sulfurcell Solartechnik	6
Sunpower	32
Suntech Power	8
Sunways	4
Sunwell Solar Corporation	0
Systaic	4
TaiZhou Sopray Solar Co	0
Tenesol	0
Tianjin Jinneng Solar Cell	0
Tokuyama Corp	16
Topco Scientific	0
Trina Solar Ltd	0
United Printed circuit Board (UPBC)	0
United Solar	66
VHF Technologies	5
Wacker Chemie	23
Wangxiang Guifeng Electronics Co	0
Wurth Solar	0
Yunnan Semiconductor Factory	1

APPENDIX 2: Evolution over time of the filings of the 124 companies present in the photovoltaics market

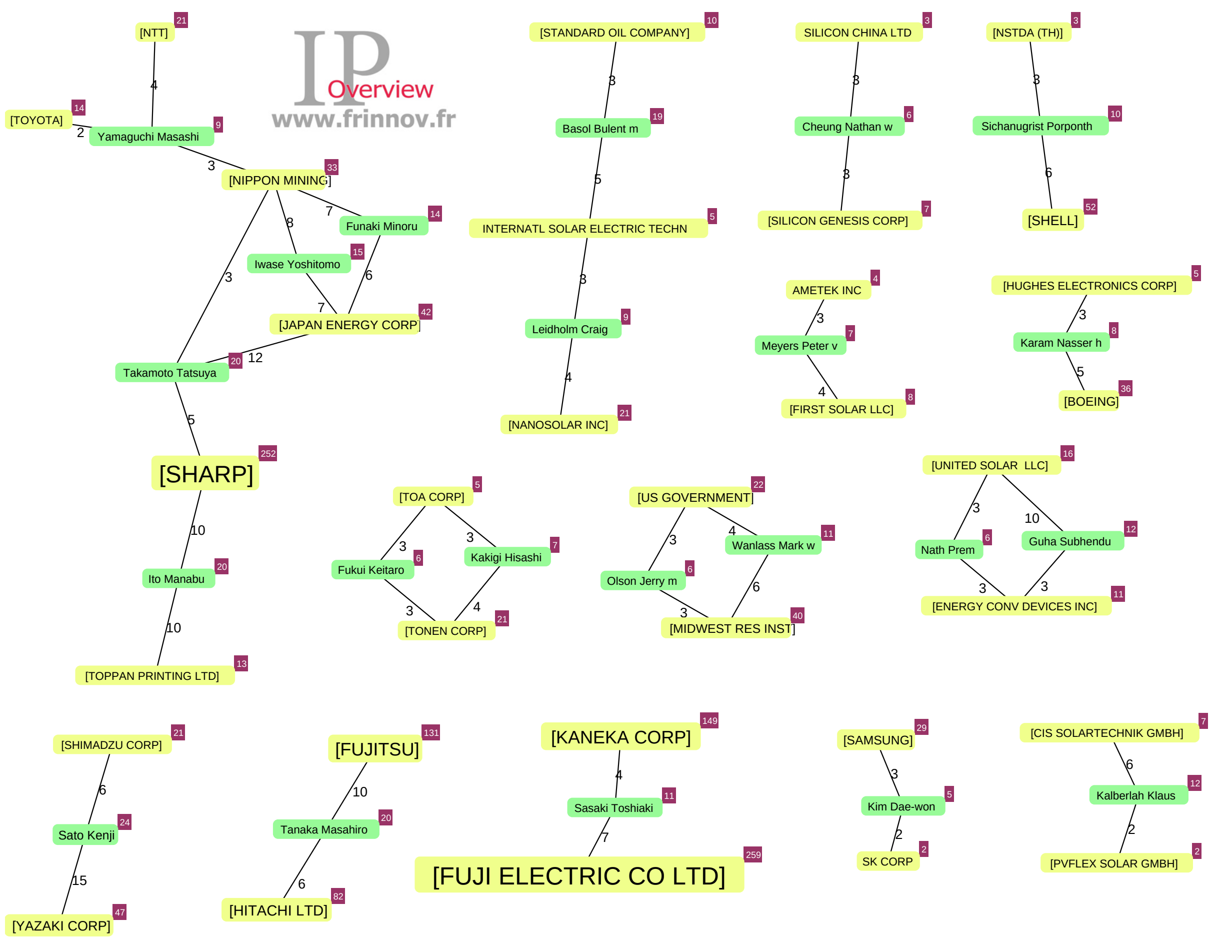
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
CANADIAN SOLAR INC																							1	1
BAODING YINGLI NEW ENERGY																							6	6
NINGBO SOLAR ELECTRIC POWER																							2	2
SOLAR ENERTECH LTD																							1	1
BIG SUN INC																							1	1
NEO SOLAR POWER																						4		4
SHENZHEN TOPRAY SOLAR LTD																						2	1	3
SOLARFUN																					1	1	2	4
SULFURCELL SOLARTECHNIK GMBH																					4	2		6
SMIC (CN)																					1	2		3
SYSTAIC AG																					4			4
QCELLS																					1	5	3	9
CONERGY AG																					7	2	1	10
M SETEK																				1		3	0	4

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
YUNNAN SEMICONDUCTOR FACTORY																				1				1
SOLAICX INC																			1	1				2
SOLARTEC AG																			1	1	4	3	5	14
SOLIBRO AB																			1	2				3
SUNWAYS AG																			2	2				4
KYOSEMI																			3	2		7		12
VHF TECHNOLOGIES SA																		1	2	1	1			5
NANOSOLAR INC																		8	2	15	7	5	1	38
SUNTECH POWER LTD																		1			5	1	1	8
ERSOL THIN FILM GMBH																		1						1
OERLIKON																	1	2	1		1		2	7
APOLLON SOLAR																	1		7		1	1	2	12
PANAHOME																	2	1		2	1			6
GET INT																	1							1
EMIX																1								1
GLOBAL SOLAR INC																2		1						3
SOLARWORLD AG																3	1				2	3		9
ODERSUN																1								1
CLEAN VENTURE 21 KK																2		2	1	1	2	2	1	11
SCHOTT														1	6	5	3	3	2	1	2	8		31
CSG SOLAR AG														3	2				3					8

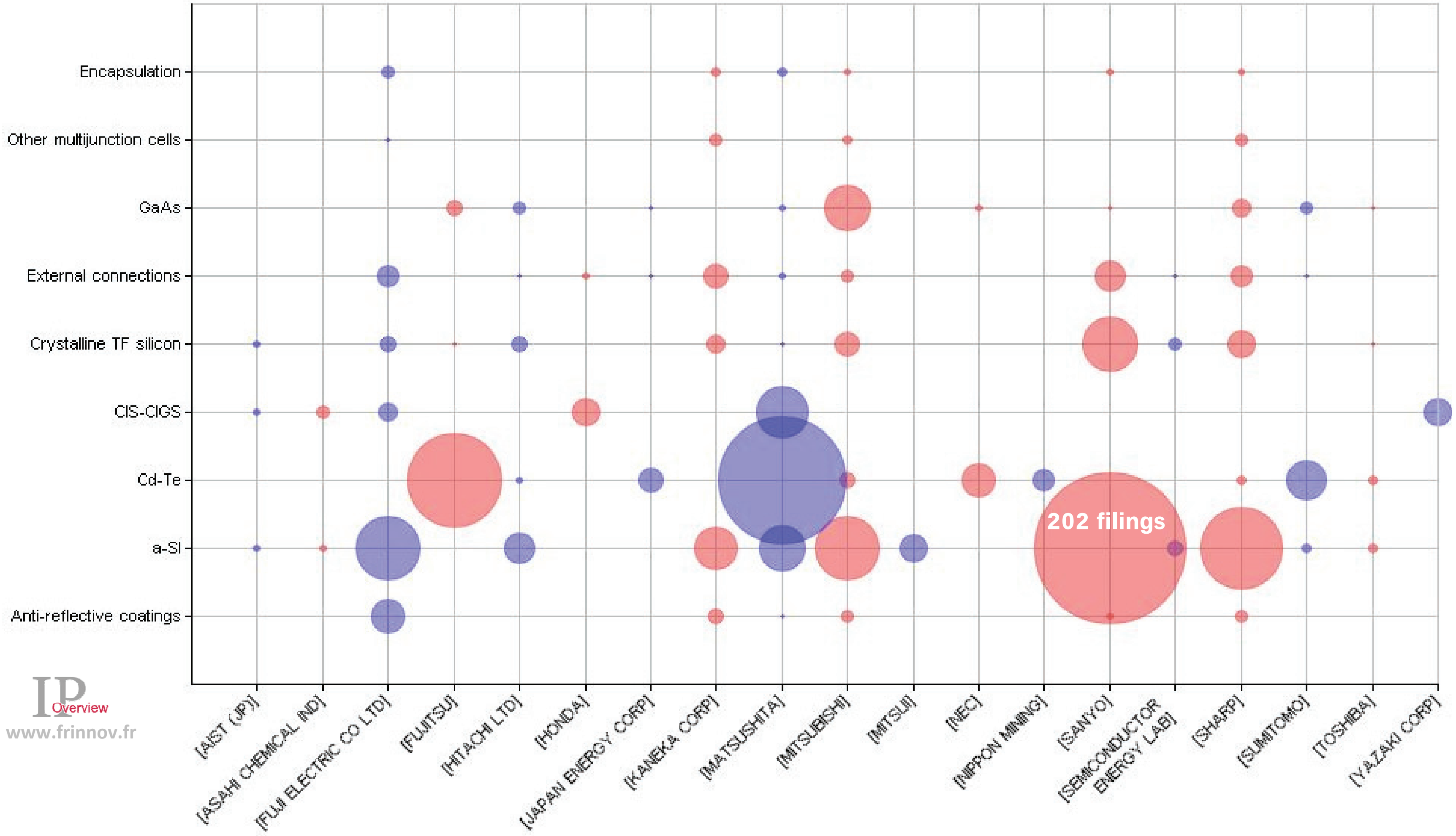
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
DEUTSCHE SOLAR AG													1			1		1		1	1			5
DAYSTAR TECHNOLOGIES INC													1							3	1			5
EVERGREEN SOLAR INC												3	5		3		2	3	1			5	1	23
SCHEUTEN SOLAR GMBH												1	1	1				1						4
RWE GMBH												1		2	3		2			3	2			13
MSK CORP											1	3	2	4		2	2	2		6	3	6	2	33
SIEMENS SHELL SOLAR GMBH										1	1	1		2	2	1	3							11
TOKUYAMA CORP									1	1			1	1		4	1	3	2	1	1			16
DAIWA HOUSE IND									1		1		4	4	4	2	2		1		1			20
MISAWA HOMES CO								5	5	3	5	8	12	17	27	11	2		1	2		1	1	100
FIRST SOLAR LLC								2						1	1		2		1	1	2	3		13
MEMC INC								2			6	4	24	20	12	18	17	5	2	6	2	1		119
ANTEC SOLAR GMBH							1								3	3								7
HEMLOCK SEMICONDUCTOR CORP							1	1										3						5
SUNPOWER CORP							1								4	2		1	9	3	3	5	4	32
SEKISUI LTD						10	2	1	6	5	9	27	47	29	32	29	26	21	18	14	19	21	2	318
UNITED SOLAR LLC						6	13	8	2	3	6	4	2			2	2	3		3	2	1	2	59
ASTROPOWER INC				1				5				2	1	1	1	1	1	4						17
RWE SCHOTT SOLAR			1							1				1	1		4	3	2	1	2			16
CRYSTALOX SOLAR			1												1									2
ELKEM AS			1	1						1					1				2	2	1	1	1	11

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
HONDA		2					1	4		1			5	22	19	27	9	17		6	11	11	1	136
KOBE STEEL		1								1	1			4	2	1		1	2				1	14
SHELL		1	1		2	4	3	7	3	5	10	7	5	4	8	4	6	2	1	6	9	15	7	110
PHOTOWATT INT		1		1							1								1					4
ISOFOTON S A	1														2				1			1		5
KANEKA CORP	7	8	11	5	5	2	2	24	6	10	14	9	16	17	135	61	29	6	13	11	11	6	1	409
ENERGY CONV DEVICES INC	19	1	4	3	1		1		1	1	1	1					2		1		1	2		39
BP	2	5	2	2	5	2	6	1	3	5	1	1	1	2		3	6	3	7	5	8	8	1	79
OSAKA TITANIUM	1	2	8	1	1	3	3	2																21
HITACHI LTD	25	15	19	15	4	16	6	6	10	18	12	14	12	15	13	17	8	14	30	17	9	19	5	319
SHOWA DENKO KK	2		1							1					2		3	3	1	6		1	1	21
FUJI ELECTRIC CO LTD	21	19	32	19	20	10	16	18	16	35	25	17	17	14	31	37	35	39	32	26	28	7	3	517
WACKER CHEMIE GMBH	1	1			2	1	2		2					2			5	4	2	1				23
SIEMENS	14	11	10	16	3	10	7	14	10	8	12	6	3	2	7	1	7	9	4	2	1	1	2	160
SHARP	53	33	31	23	20	24	27	24	27	24	34	51	41	49	59	77	85	104	97	124	93	61	26	1187
SANYO	42	36	42	17	71	58	52	38	51	49	62	38	39	49	40	65	40	20	38	34	59	62	30	1032
MITSUBISHI	28	34	60	38	50	37	40	16	15	12	15	27	30	42	62	67	65	60	28	52	40	42	11	871
MATSUSHITA	41	49	68	42	11	37	29	44	29	28	24	31	48	41	50	36	30	49	41	24	16	14		782
KYOCERA	10	6	7	1	3	2	4	4	3	10	13	6	5	14	17	31	30	74	141	85	107	51	17	641
GENERAL ELECTRIC	1			2	1		1				2							13	12	10	19	11	6	78
Total	267	225	299	187	199	222	218	226	191	223	256	262	323	364	550	517	435	488	516	485	496	406	155	

APPENDIX 3: Potential inventor movements



APPENDIX 4: Topics of the major Japanese players



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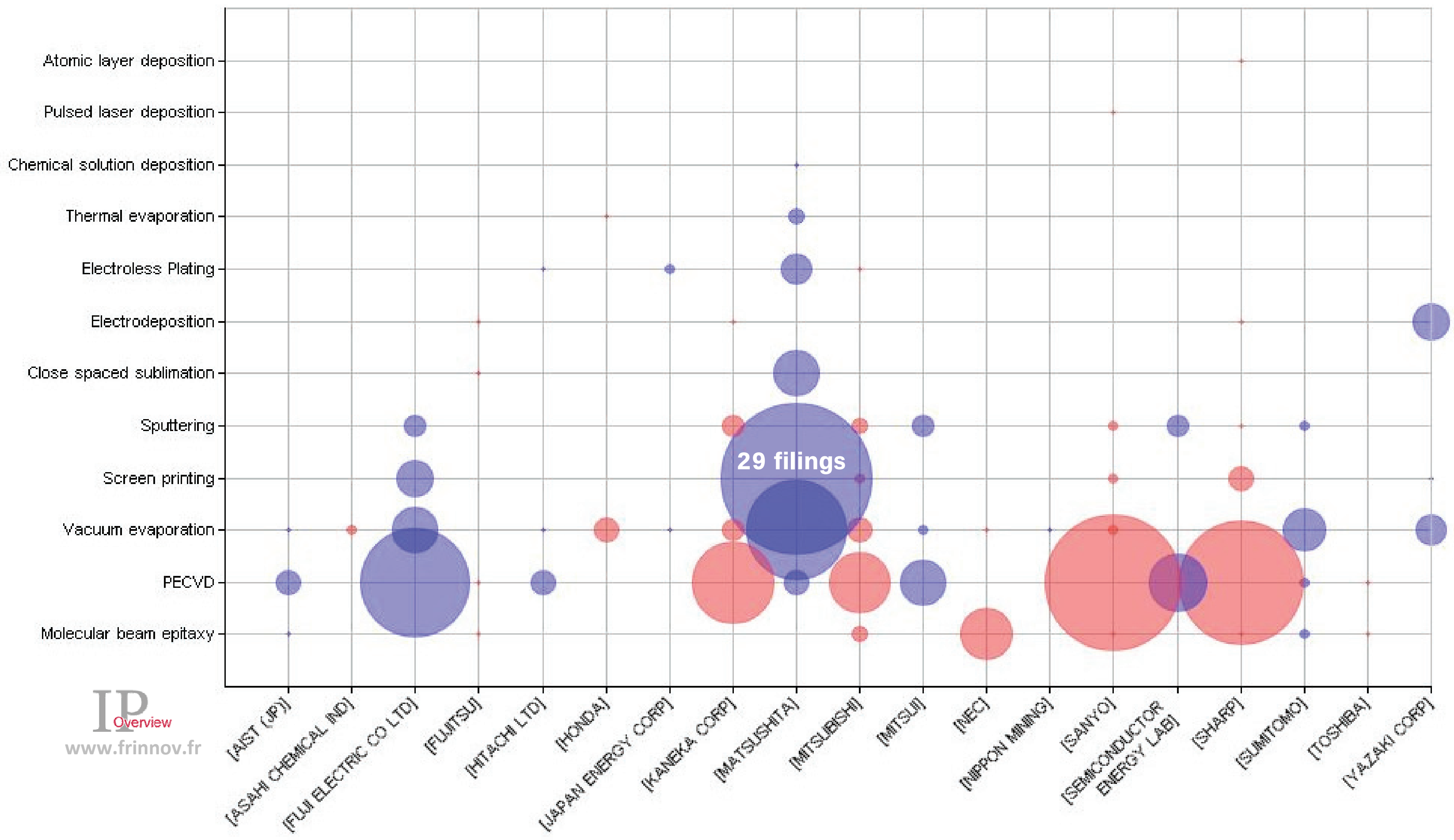
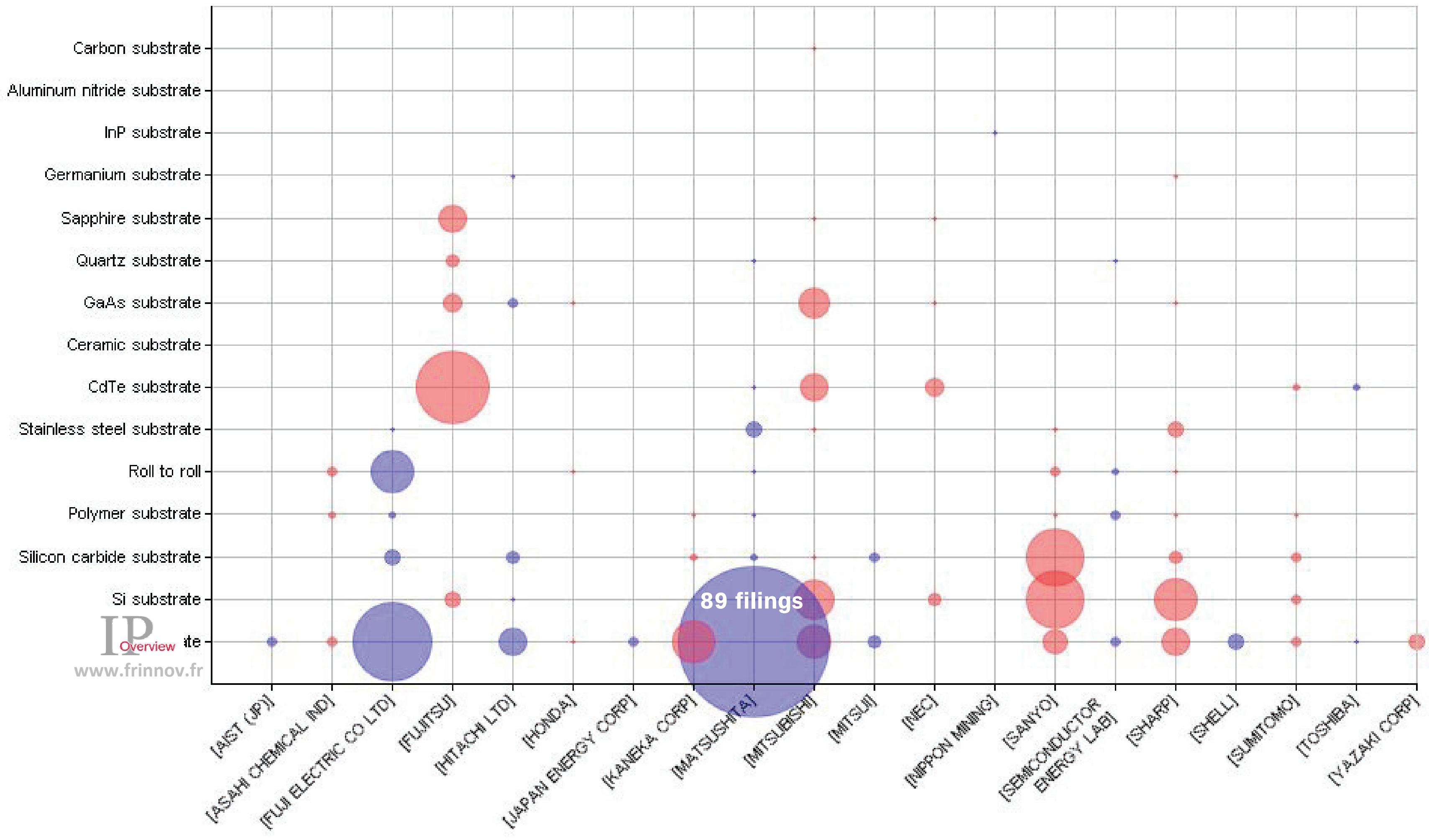
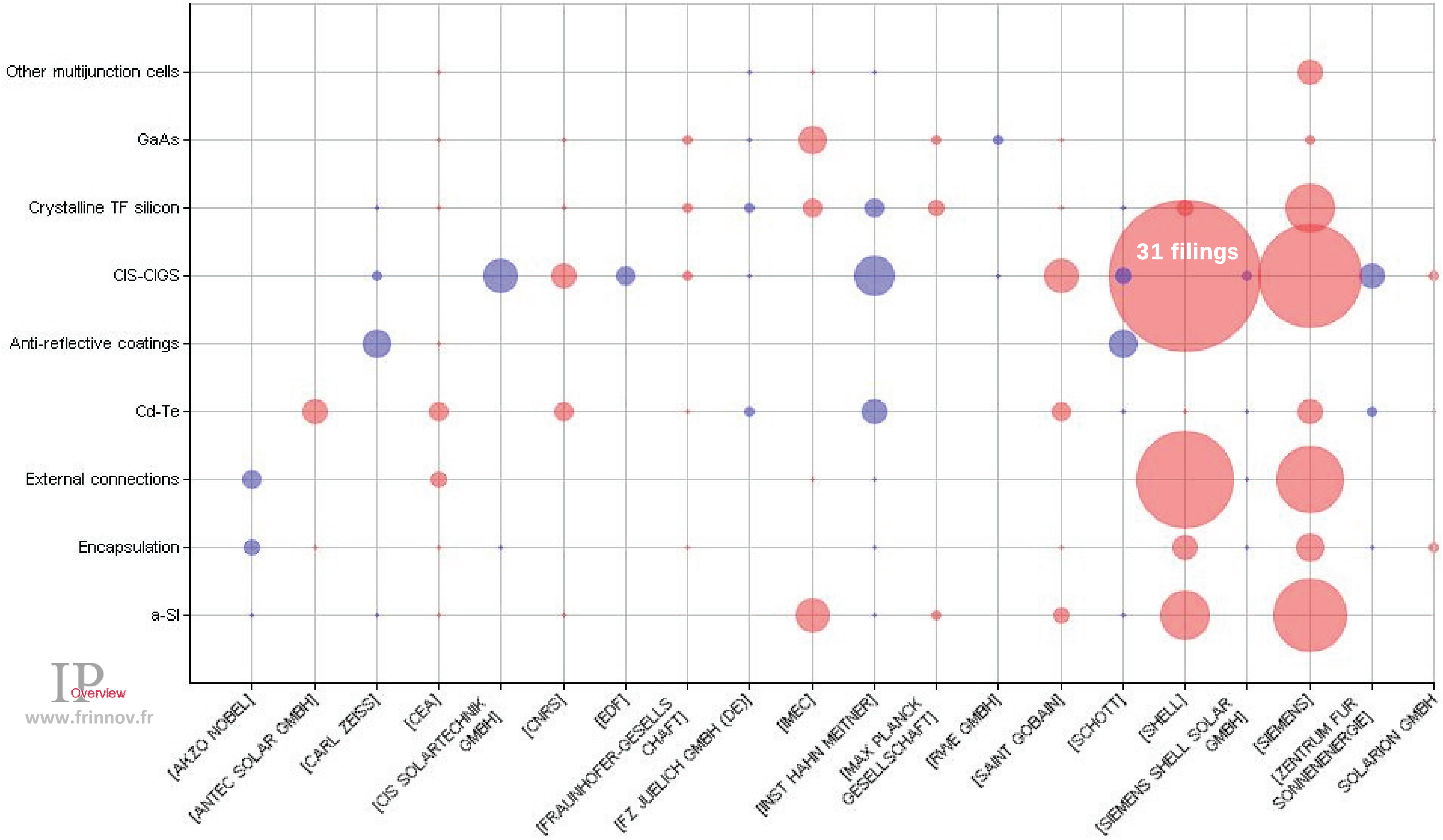
APPENDIX 5: Deposition process protection for the major Japanese players



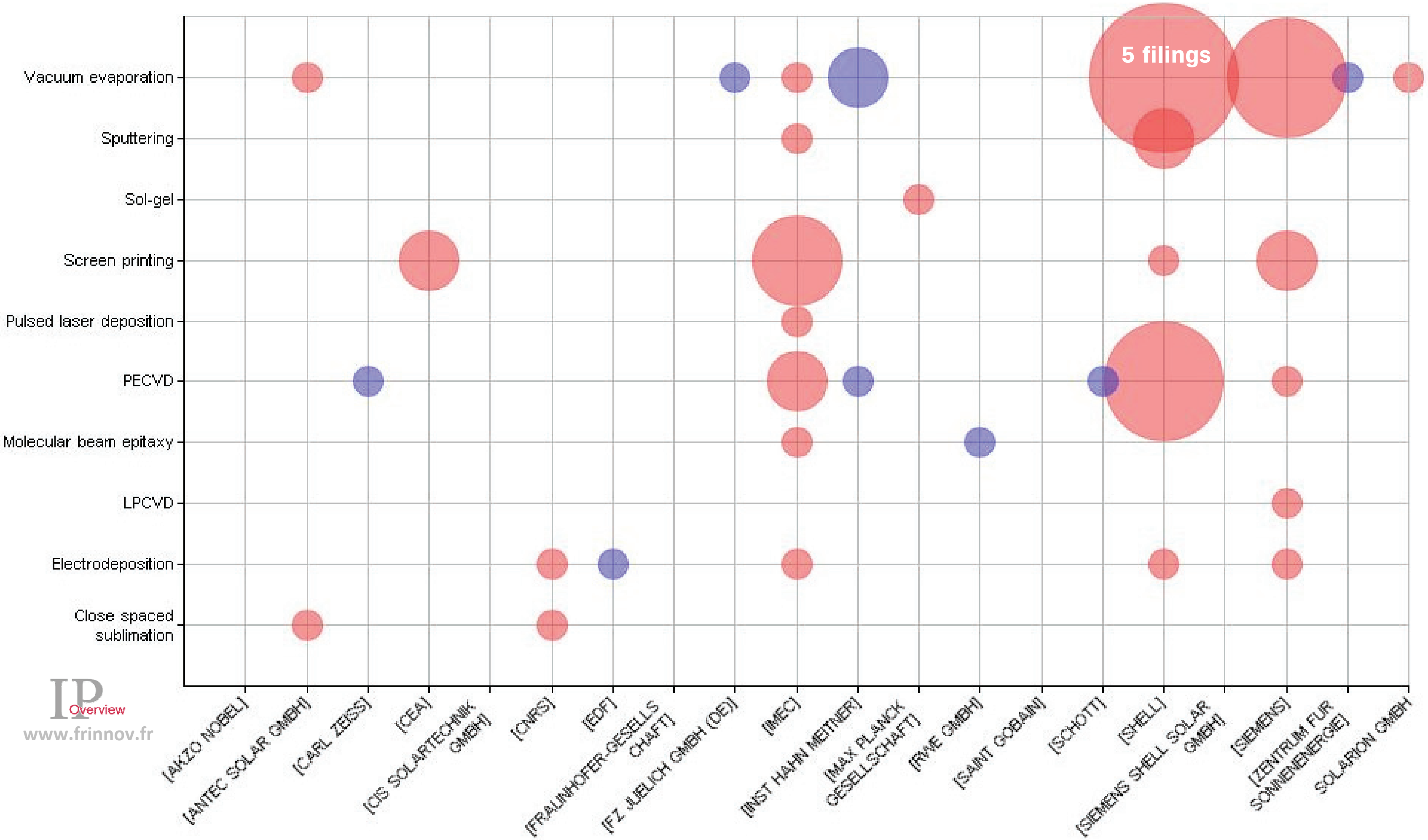
APPENDIX 6: Type of substrate for the major Japanese players



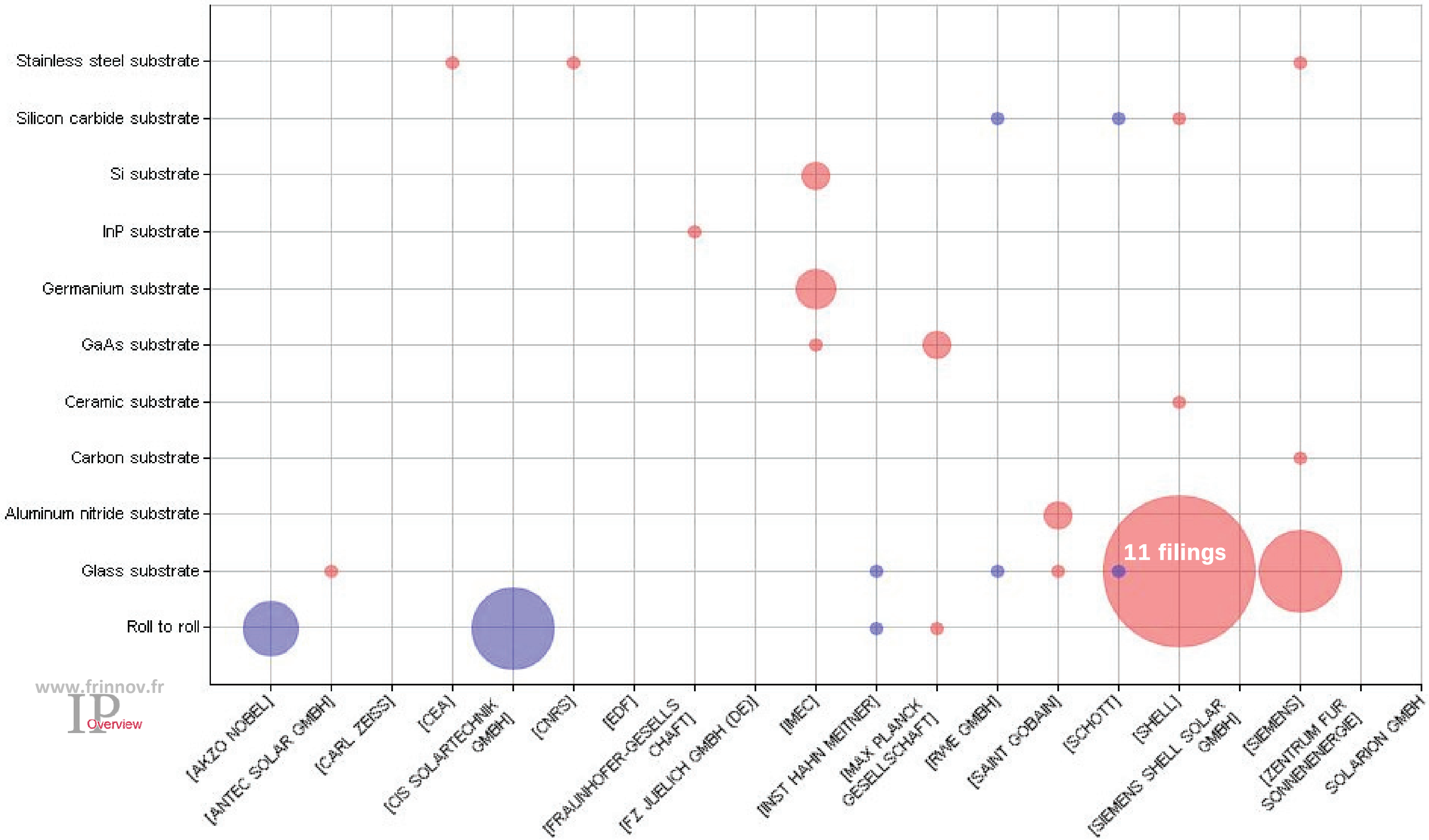
APPENDIX 7: Topics of the major European players



APPENDIX 8: Deposition process protection for the major European players



APPENDIX 9: Type of substrate for the major European players



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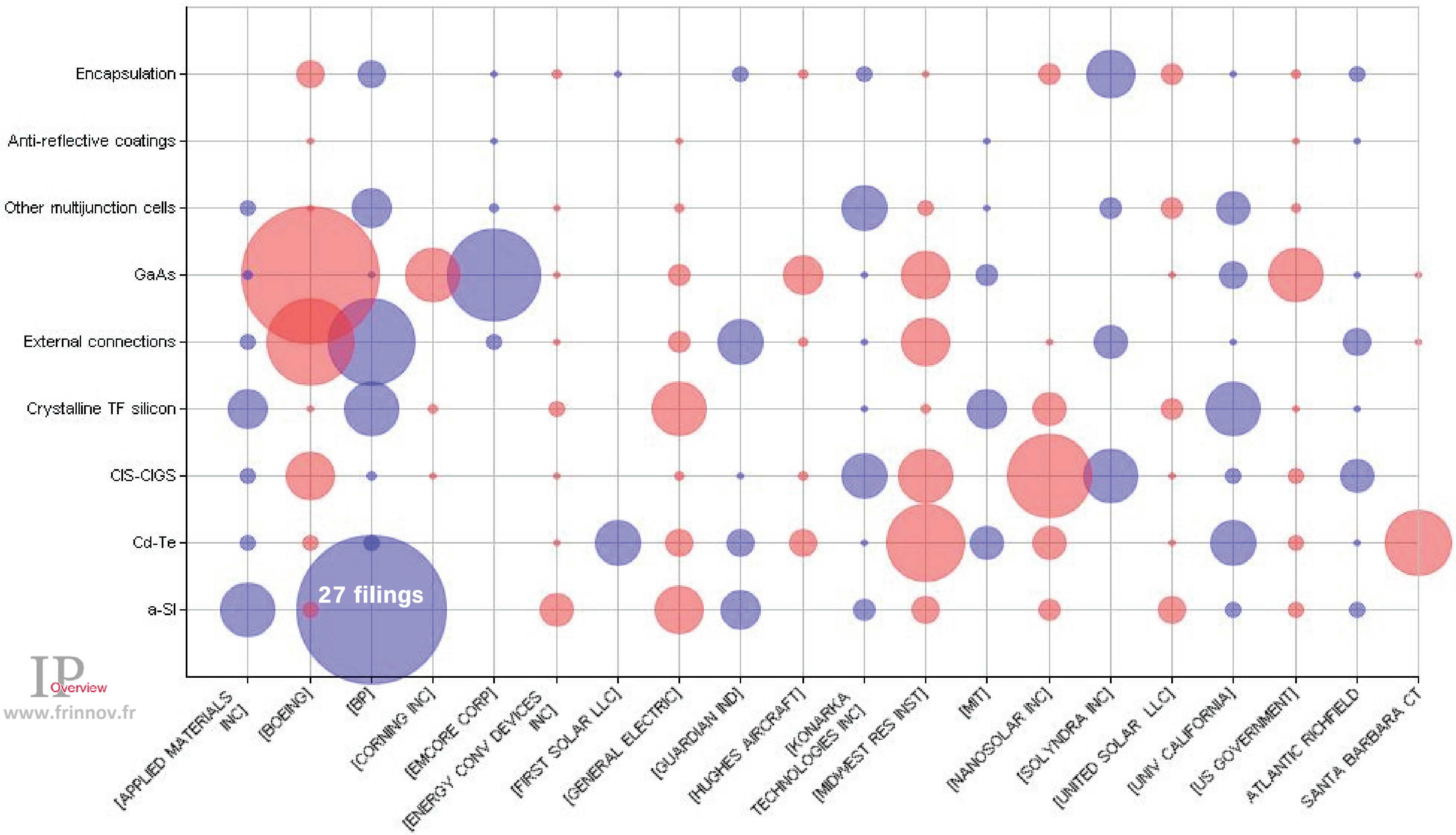
APPENDIX 10: Topics of the major US players



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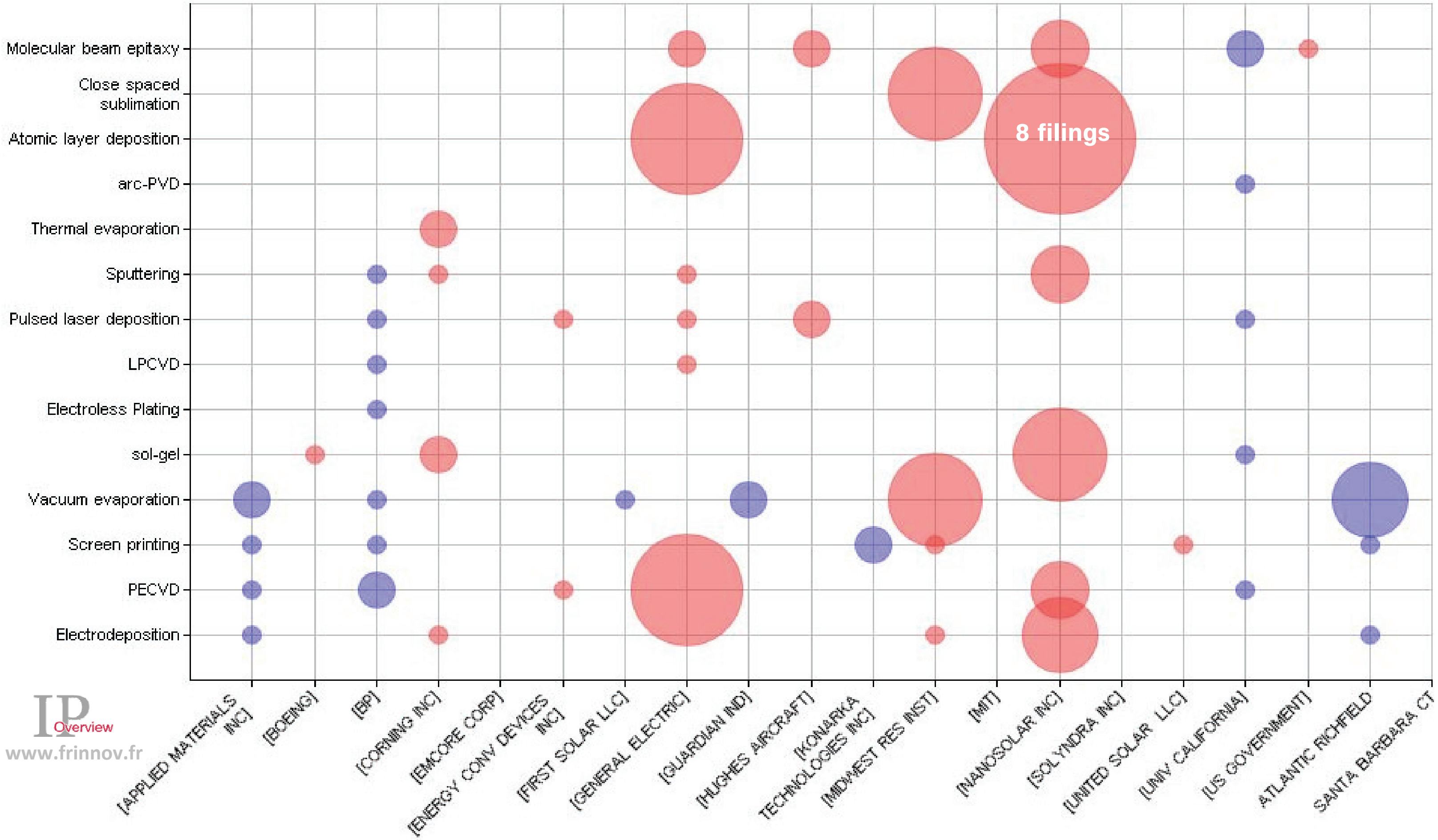
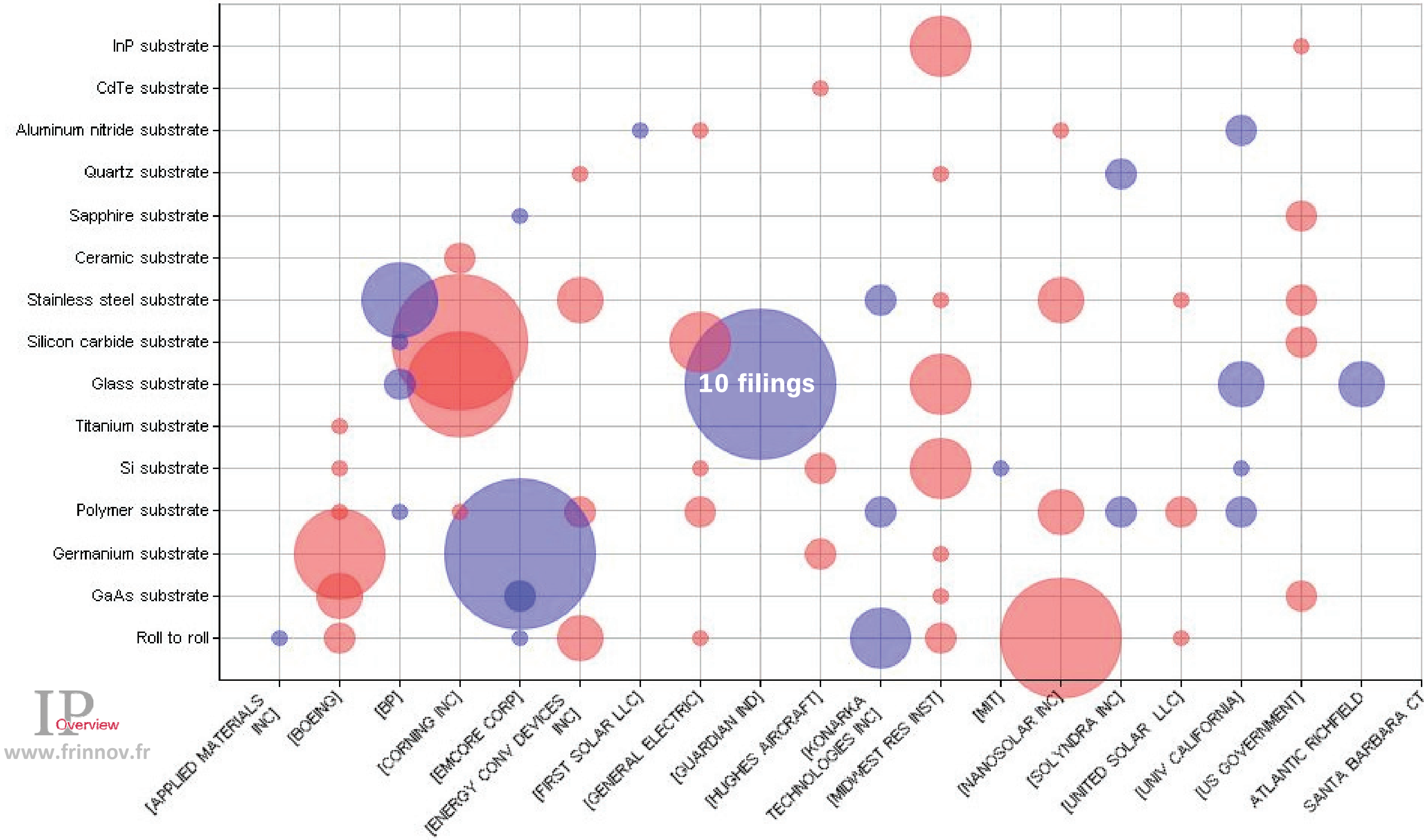
APPENDIX 11: Deposition process protection for the major US players



APPENDIX 12: Type of substrate for the major US players



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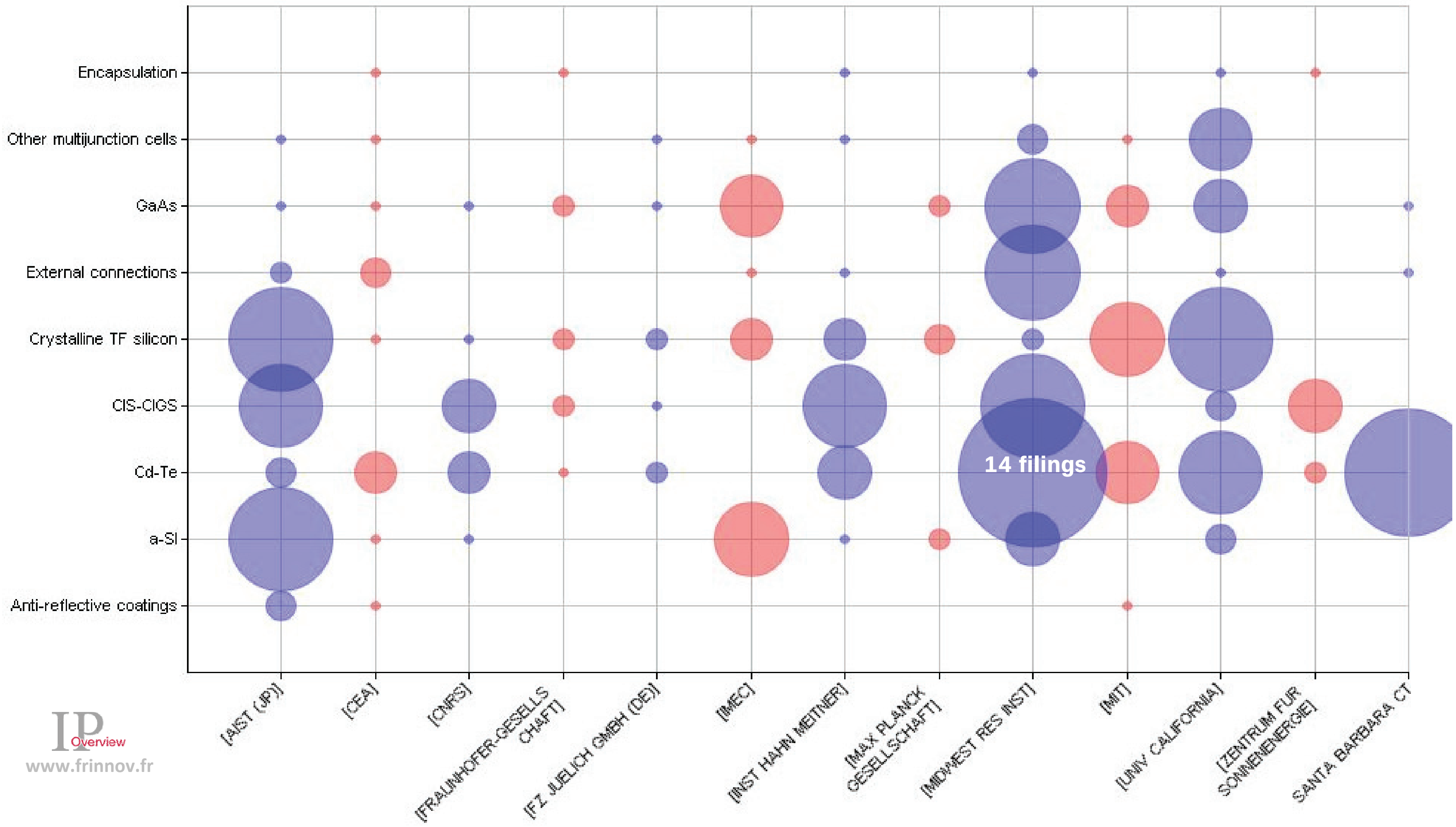
APPENDIX 13: Topics of the major academic players



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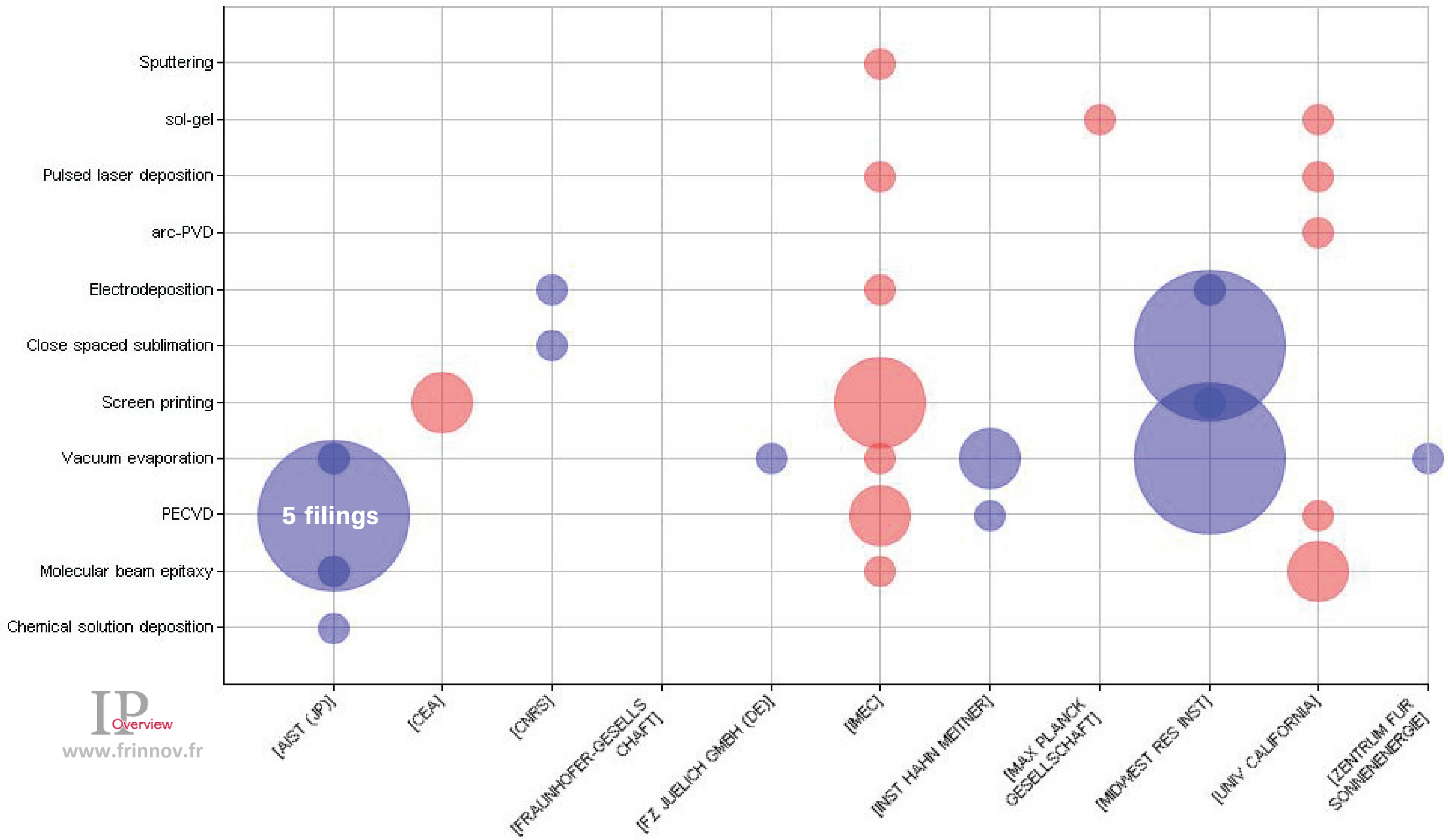
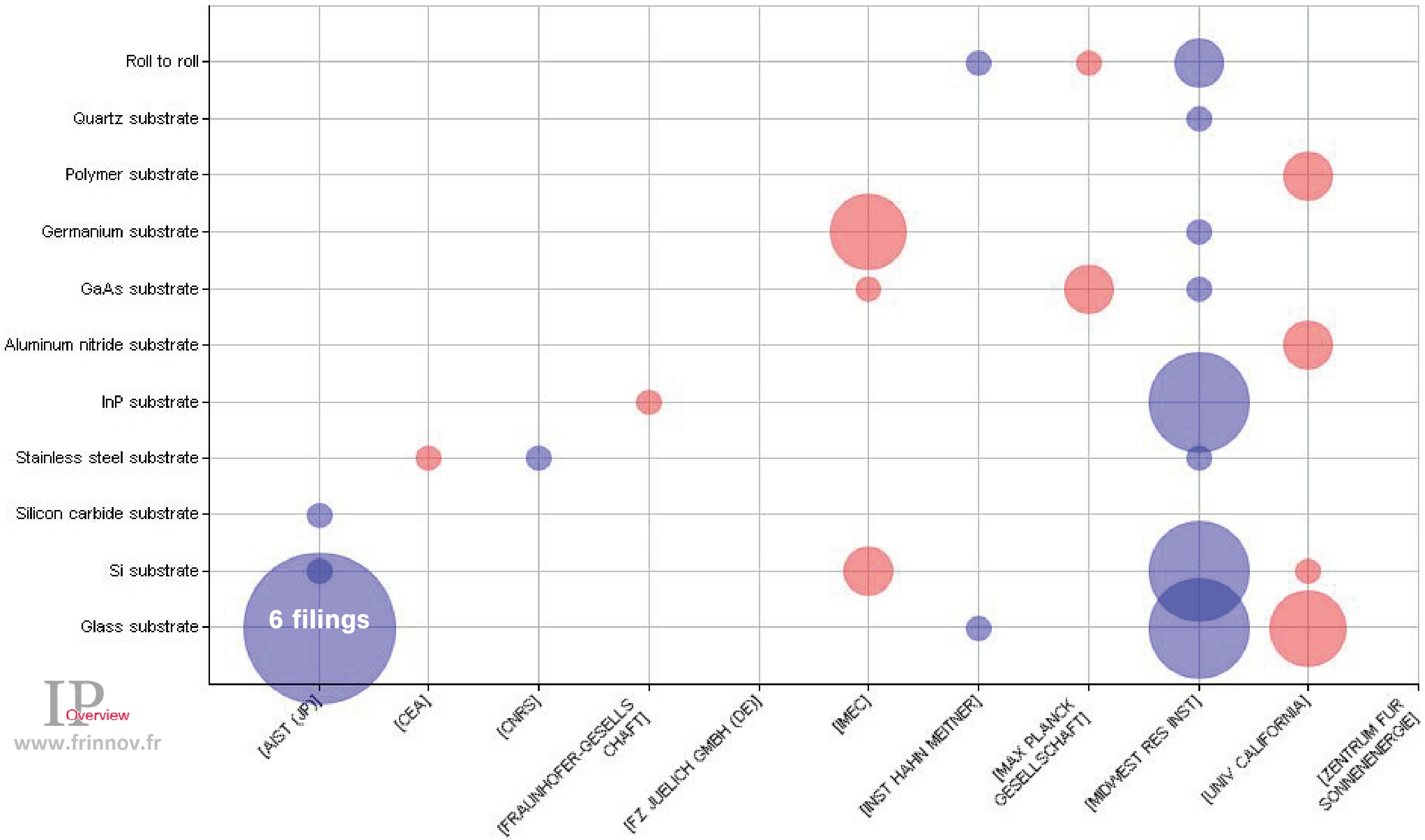
APPENDIX 14: Deposition process protection for the major academic players



APPENDIX 15: Type of substrate for the major academic players



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