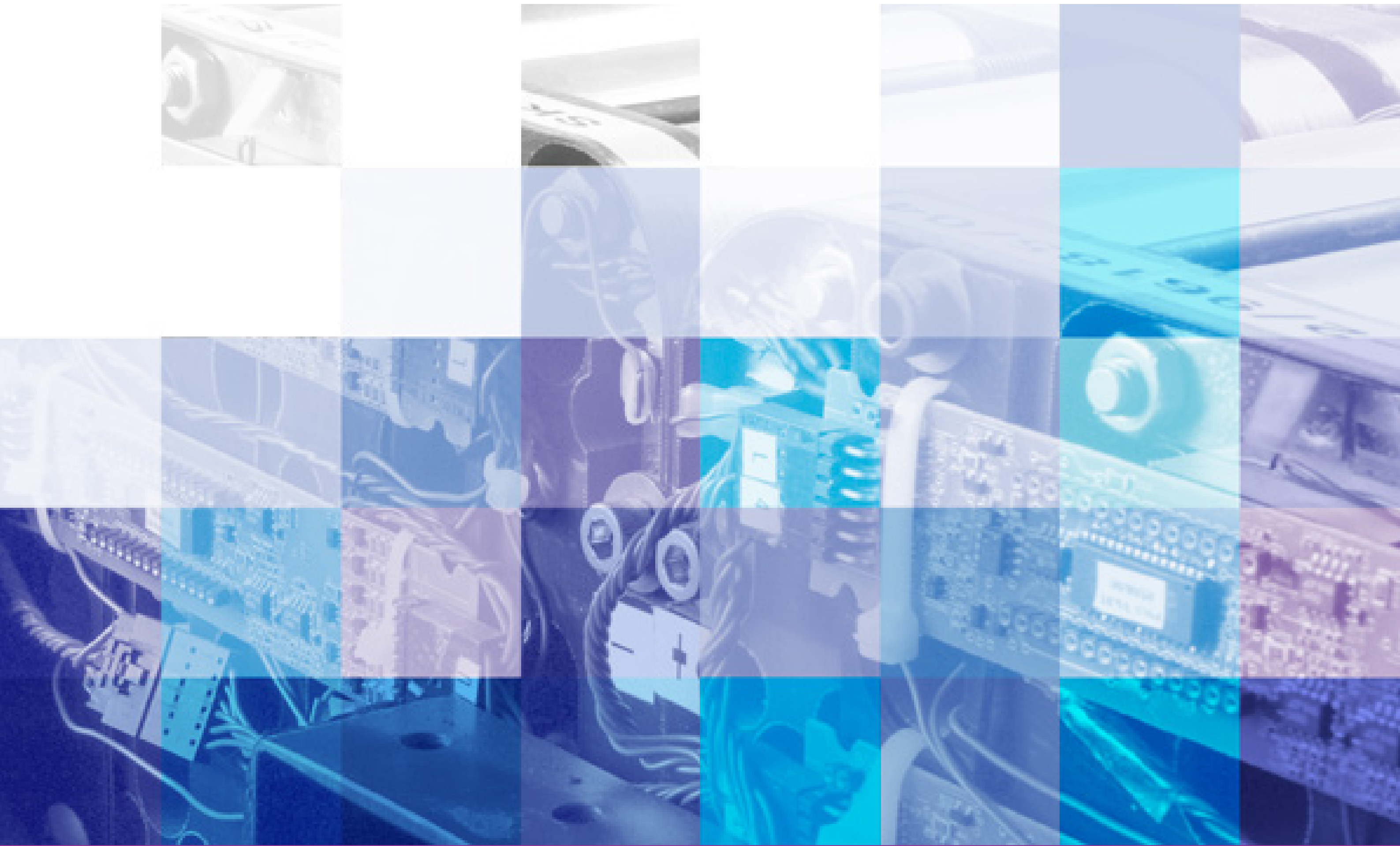
Dr Victor Zhitomirsky

ADVANCED ENERGY STORAGE TECHNOLOGIES

PATENT TRENDS AND COMPANY POSITIONING

Electric vehicle & other lithium-ion batteries, supercapacitors, ultracapacitors, battery management systems, chargers.



www.PatAnalyse.com

The author

Dr. Victor Zhitomirsky, PhD, is the founding director of PatAnalyse Ltd. In 2001, after initial successful academic career at Max-Plank Institute für Festkörperforschung and Oxford University in the UK, he moved to Cambridge in the UK, to start his career in the local technology and business consultancy cluster. He keeps specific focus in development and application of new tools for analysis of Patent Landscapes.
victor.zh@patanalyse.com

PatAnalyse Ltd
77A Shelford Rd
Cambridge, CB2 9NB
United Kingdom

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1. Executive Summary and Conclusions

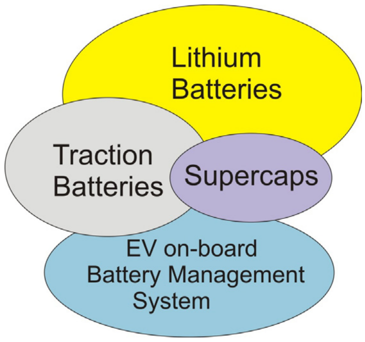
This study is centred on the first high level computer analysis of about 40,000 patents in advanced energy storage technologies, particularly those relevant to electric vehicles. The key learning from the patent maps generated is presented in text before them. Never before has there been a facts-based analysis of the intellectual property of this booming industry. For the first time, it reveals which countries, companies and technologies are dominant and trends over all recent years for which statistically meaningful data are available. We calculate which companies have widely cited, and therefore powerful patents and which do not. We drill down to such aspects as lithium-ion batteries specifically for electric vehicles, asymmetric supercapacitors, battery management systems and much more. The results are often startling and the opposite of popular understanding of the subject that is not based on facts.

Appendix 1 describes further services available from the analysts of PatAnalyse. We now summarise the analysis and give indicative conclusions, revealing many new and often surprising commercial and scientific insights primarily based on patent analysis on a scale never seen before in this subject.

1.1. Who needs this report

This report will interest those involved in advanced energy storage technologies whether or not they are directed towards electric vehicles. However, a significant part of the report relates to electric vehicle technologies in particular, the primary focus of the current study being the following overlapping sectors.

Fig. 1.1 **Focus of current study**



This report particularly provides a patent and business analysis of the rapidly developing related technologies of lithium- ion "Li-ion" rechargeable batteries, supercapacitors ie ultracapacitors, traction batteries used in electric vehicles, Battery Management Systems (BMS) and recharging.

1.2. Methodology

The patent search strategy has been carefully developed via several rounds of iteration. A combination of about 150 Assignees + 1,100 inventors + 2,600 patent codes (including IPC, ECLA, US patent codes) and about 1,250 keywords were used to carry out the patent search. As a rule of thumb, it takes at least five years from invention to the first product on the market. In order to focus on the `hidden' R&D efforts which have not yet materialised as new products on the market, the initial study has been restricted to patents with a priority date from 2005. However because of a significant increase in the rate of patenting in this area, this initial patent portfolio contains over half of all patents with a priority from 1990 in this area. About 2,800 original Assignee names from the original bibliographic records were combined into 200 Top Assignees. The proprietary de-duplication algorithm aggregated about 12,000 simple patent families from about 40,000 national patents. Only 3% of the patent families have been left unassigned and it was further found that about 12% of the patent portfolio is assigned to small players with fewer than one invention per year. The remaining 85% of the patent portfolio is assigned to about 250 companies with about 66% of the patent portfolio assigned to the top 50 companies in terms of patenting. Almost a hundred Patent Maps have been provided in the report to facilitate the detailed understanding of various aspects of the patent landscape.

We use a comprehensive set of technical categories for analysing relevant patents as listed below.

Generic lithium battery technologies

- Cathode chemistry
- Cathode manufacturing
- Nanotechnology for cathodes
- Nanotechnology for anodes

- Anode chemistry
- Anode manufacturing
- Electrolyte - lithium salt
- Electrolyte - solvents, polymers
- Battery separator
- Mechanical construction

Details of anode chemistry

- Lithium non-metal compounds
- Germanium
- Polymers
- Carbon
- Nano-form carbon
- Graphite
- Silicon
- Silicon compounds
- Silicon oxide
- Other metal compounds
- Tin compounds
- Tin oxide
- Vanadium oxide
- Titanium oxide
- Titanium compounds

Details of cathode chemistry

- Lithium iron phosphates
- Other lithium metal phosphates
- Lithium cobalt oxide
- Lithium cobalt nickel oxide
- Lithium cobalt nickel manganese oxides
- Other lithium cobalt complex oxides
- Lithium manganese oxides
- Lithium nickel oxides
- Lithium nickel manganese oxides
- Lithium-vanadium complex oxide
- Lithium-titanium complex oxide
- Other metal lithium oxides
- Lithium-sulphur
- Other lithium compounds
- Carbon
- Conductive polymers

Traction and large scale batteries in general

- Li-based traction battery
- Non-Li traction batteries
- Battery mounting in EV
- Arrangement for cooling/heating
- Supercapacitors for EV

Generic supercapacitors technologies

- Asymmetric supercapacitors
- Lithium ion capacitor
- Electrode manufacturing
- Nanotechnology for electrodes
- Supercap electrolyte chemistry
- Separator for supercaps
- Supercap construction

On-board electric vehicle battery management system and external charging equipment

- Battery temperature control
- General monitoring of voltage and current
- Battery recharging
- Battery depth of discharge control
- Battery or supercap balancing/redistribution
- Battery related regenerative breaking
- Battery safety system
- Battery life prediction and modelling
- Other commercial aspects of using battery in EV
- External equipment related to battery recharging

1.3. Report layout

After the Introduction, the report is organised in seven further chapters:

- General overview of combined portfolio
- Generic Lithium Batteries technologies
  - Further details of Anode chemistry
  - Further details of Cathode chemistry

Lithium Traction Batteries

- Traction batteries in general, their mounting and mechanical arrangement for cooling and heating
- On-board Electric Vehicle Battery Management System and external charging equipment
- Generic Supercapacitor (ultracapacitor) technologies

And finally, the very different trends shown by the ownership of the most offensive granted patents with priorities prior to 2000.

Building on the marketing intelligence, the report pulls together a facts based analysis of patent filings over the years, li-ion technologies in use, customer relationships and investments made by traction battery makers. It helps to answer such questions as:

- Which chemistries, construction techniques etc. are prioritised by whom?
- Which firms are spending heavily on new factories and gaining major sales successes but throttling back R&D so fewer patents are filed every year? eg LG Chem and Samsung SDI
- What are the aspects prioritised by different regions, countries, companies and academia?
- Which individuals are the most prolific inventors?
- Which aspects receive more attention nowadays (eg cathodes, anodes, nanotechnology, mechanical assembly) and which are increasingly ignored (eg electrolytes, anode manufacturing, separators, supercapacitors, regenerative braking)?

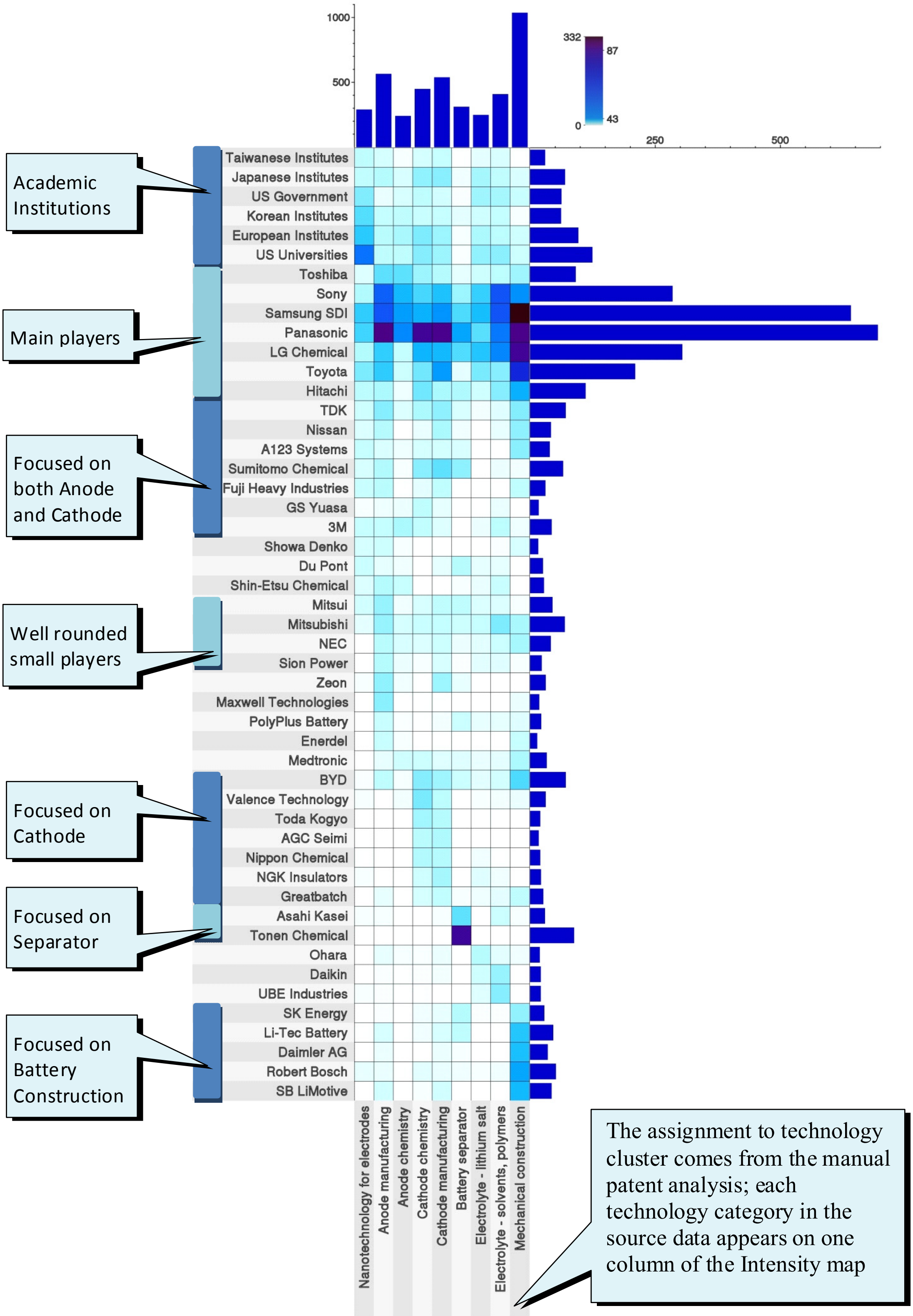
Absolute and normalised patent maps

Where appropriate, we provide both absolute and normalised patent maps. Normalised Patent Maps are required to show activities of small players which otherwise are almost invisible. The normalized Patent Map is a true benchmark. If all players have similar behavior – the Patent Map will have a consistent colour representing values quite close to one. If some players are underrepresented in certain years (or categories) and overrepresented in other years (or categories), the Normalised Patent Map will show substantial deviation from mean value equal to one. Some cells will be well below the one (underrepresented activities) or well above one (overrepresented activities). However the absolute Patent Map should be consulted together with the normalized one, as the normalized presentation does not present the absolute number – just the deviation from the common trend.

1.4. Indicative results

We have examined the patents for the above subjects we call Advanced Energy Technologies and established that lithium-ion traction batteries continue to dominate. Patent numbers are growing fast, but not as strongly as those specifically in lithium traction batteries. At every stage we reveal information, in instantly graspable form, digesting the previously impenetrable mass of patents on these subjects. For example, for the all important lithium batteries we reveal below the parts and technologies that are the patenting focus of the leaders in number of patents. This is for the latest timeframe for which statistically meaningful data are available.

Fig. 1.2 **Top 50 Assignees vs Technical categories**



Source PatAnalyse

Toyota

The world's largest electric vehicle manufacturer by far is Toyota (forklifts, buses, cars etc). Its patenting and production rollout of lithium-ion batteries are both impressive. Care is needed with company names here. Traction battery manufacturer Panasonic EV Energy was formed in 1996 as a joint venture between Toyota and Panasonic, with Panasonic holding 60% of the capital. Panasonic sold 40.5% of the company to Toyota as a condition of purchasing Sanyo, which has a major activity in NiMH traction batteries and some in lithium-ion. Panasonic decided to reduce its stake in Panasonic EV Energy Co to speed up approval from anti-trust authorities in China and the U.S. The company name was changed to Primearth EV Energy when Toyota took control. In early 2011, it was reported that Primearth EV Energy will start mass-producing lithium batteries for plug-in hybrids of Toyota. We report patents filed by Toyota, Panasonic and Primearth in the top 50. However, Toyota seems to be primarily filing relevant patents under Toyota these days, though Primearth retains an enviable position in many of our rankings.

LG Chemical

LG Chemical is winning major design-ins and orders for lithium-ion batteries in leading electric vehicles from under the nose of Panasonic, world number one in lithium-ion batteries in general. It is also investing impressively in production facilities and it is a major recipient of the Obama battery investment in the USA. However, its relevant patent position is weakening, putting it at risk in the longer term. It has substantially reduced its patent filings during last several years. LG Chemical patenting has been aggressive with its portfolio heavily dominated by prolific inventors but these patents are rarely cited, warning of below average quality. It seems that LG Chemical is at threat of losing its leading position in the lithium battery market due to reduced focus on developing its future position in this rapidly changing technology landscape.

Companies filing as well as their joint ventures

Both Daimler and its joint venture with Evonic Industries called LiTec Battery feature in the top patentors in this subject but, even taken together, they are not yet among the leaders, the Germans being somewhat late into the subject, having prioritised the hydrogen economy including fuel cells. Similarly SAFT and Johnson Controls –SAFT appear. Nissan has filed strongly in its own name as has NEC and Nissan now gets supplies from its Automotive Energy Supply AESC joint venture between the two companies which is also very successful in selling traction batteries into the open market. However, during the time period analysed, AESC was not a major patentor. The only patent to AESC is taken exclusively in Japan and it is therefore considered as an insignificant invention in our analysis. Similarly Continental is a major patentor but its joint venture Continental ENAX making lithium-ion traction batteries does not yet appear in our top listings. GS Yuasa and Mitsubishi appear individually in our top listings, though they now have a joint venture making lithium-ion traction batteries called Lithium Energy Japan which is not yet in our top listings. SB LiMotive is owned by Samsung and Robert Bosch and all three patent strongly in this space. GS Yuasa and Honda have a joint venture, BASF is allied with Sion Power and LG Chemical has separate joint ventures with both Changan New Energy Automobile and Hyundai Mobis all concerning Li-ion traction batteries but with the participants also patenting separately. Alliances frequently change and proliferate. However, because most of the joint ventures are relatively new, if we added them to their owners in ranking patenting there would be little change.

Here are some highlights of our discoveries:

1.5. Overview of patents

1.5.1. Advanced Energy Storage

Number of patents

The overall patent portfolio for what we call Advanced Energy Storage is dominated by Panasonic and Toyota of Japan and Samsung SDI and LG Chemical of Korea. Japanese companies dominate but even Korean companies are ahead of the US – rare in patent mapping studies. Second tier companies are more international - Sony, Hitachi, Mitsubishi, Denso, Nissan, Toshiba, and Honda for Japan plus General Motors and Ford in the USA, Robert Bosch in Germany and Chinese BYD. US governmental grant support powers a strong position of US government and universities.

Trend and quality

Patent applications increase not least because of European and US players and BYD China playing catch up. Japanese companies are mostly stable in filing with Toyota slightly increasing. Sumitomo Chemical, Seiko Epson, Zeon, and SK Energy are recent entrants. LG Electronics, Hyundai, Samsung, SB LiMotive (Samsung Bosch), Yazaki, Mitsui, and Primearth EV Energy are reducing the rate of patenting, probably reflecting a cut in R&D in most cases. Patenting growth is also shown by US Universities, General Motors, General Electric, Tesla Motors, Enerdel, Sion Power, Corning, Johnson Controls – Saft, Robert Bosch, Peugeot Citroen, Daimler AG, Li-Tec Battery (Daimler/Evonik), Renault, Valeo and Behr. Ford, Maxwell Technologies, Valence Technology, 3M, Medtronic, Greatbatch, and O2Micro patent less. The top four patentors no longer dominate citations, an indication of patent quality. Indeed, LG Chemical has dropped out from the list of the first tier players in this respect.

Where they patent

The most popular destinations for patenting the inventions follow the markets – foreign patent applications are taken predominately to the US, China and Europe. Japan and Korea are dominated by local companies but overspill from Korea to Japan and vice versa. Many companies ignore the International Patent Office (PCT). including Sony, Denso, TDK, Primearth EV Energy, Yazaki, Seiko Epson, Samsung SDI, Hyundai, General Motors, Greatbatch, and O2Micro. European patenting is ignored by Sony, Primearth EV Energy, Zeon, Seiko Epson, Hyundai, and O2Micro. Chinese patenting is ignored by Yazaki, Tesla Motors, ISE Corp., Medtronic, Greatbatch, and Peugeot Citroen. Japanese and Korean patents are ignored by many US and European companies. However, many Korean filings are from foreigners A123 Systems, Enerdel, Sion Power, and Valence Technologies.

Aggressive patent strategies

The major four players Panasonic, Toyota, Samsung SDI, and LG Chemical have a relatively similar number of patents in the project portfolio. From the analysis of the most prolific inventors from these four companies it is obvious that all four first-tier players have most aggressive and rather questionable patent strategies. For instance, LG Chemical has 65% of its patent portfolio authored by most prolific inventors. For other companies this figure is slightly lower:

- LG Chemical 65%
- Panasonic 53%
- Samsung SDI 45%
- Toyota 34%

The lower percentage number for Toyota is probably related to the substantial increase in Toyota's patent activities during the timeline of the study. Most other companies have a much smaller part of their portfolio underpinned by the most prolific inventors.

1.5.2. Lithium-ion batteries

"Batteries are inherently complex and virtually living systems – their electrochemistry, phase transformations and transport processes vary not only during cycling but also often throughout their lifetime. Although they are often regarded as simple for consumers to use, their successful operation relies on a series of complex, interrelated mechanisms involving thermodynamic instability in many parts of the charge-discharge cycle and the formation of metastable phases. The requirements of long term stability are extremely stringent and necessitate control of the chemical and physical processes over a wide variety of temporal and structural length scales."
UK Department of Energy Report, "Basic Research Needs for Electrical Energy Storage".

Panasonic and Samsung SDI dominate in number of patents for lithium ion batteries in general. Sony, LG Chemical and Toyota are second-tier.

A list of technical categories was created in order to clarify technology trends in the patents. The chemistry of anode and cathode are the subject of separate detailed analysis. Nanotechnology emerges as important for anode and cathode materials. Improved mesoporous/nanoporous physical structure of electrodes facilitates faster recharging. About 70% of patents related to nanotechnology describe material systems for more reliable anodes.

Electrolytes can be classified as liquid, gel, polymer or ceramic. Liquid and gel electrolytes need a separator between electrodes; polymer electrolytes do not but they typically add a gel for low temperature performance. Safe operation has been improved by developing separators, where needed, with a built-in thermal shutdown mechanism. Most separator patents concern form-factors that reduce strain during thermal cycling, improve electrical breakdown strength, etc. Chemical composition for a built-in thermal shutdown mechanism is patented. Combined polymers are frequently used for functionality in the normal regime of operation with the additives mainly responsible for the safe battery functionality in the extreme regime.

30% of patenting activities in the separator technologies are related to a single company – Tonen Chemical. Separator technology tends to integrate electrode material onto the separator or provide barrier/ separator coating on the surface of the electrode, providing a more robust and reproducible manufacturing method and smaller size. Patented liquid electrolytes are typically based on organic solvent with dissolved lithium salts. The range of salts varies from $LiPF_6$; $LiAsF_6$; $LiSbF_6$; $LiClO_4$ and $LiBF_4$ to more specialised. Patented Li-ion battery additives improve electric conductivity, density, viscosity, lithium salt solubility, temperature tolerance, gas emission and safety during overcharging.

Ionic liquid electrolytes have become a focus. They are based on liquid salts with complex organic anions and lithium cations. A large amount of lithium can be dissolved giving high conductivity. Washing out the lithium ions from the electrodes is problematical but patents claim to deal with this. Commercialisation is restricted mainly because of cost and limited temperature stability.

Trends in polymer electrolytes are revealed as form-factor, notably polymer electrolyte as separator, "lithium polymer" batteries now being very popular. Here, nanotechnology - nanofibers, nano-domains, mesoporous structures, etc. - help. Secondly enhancing the lower temperature range (below minus 20C) and higher temperature range (above 80C) are a focus. Thirdly, additives optimising the electrochemical process involve solid electrolyte interphase film on the surface of the anode and gas neutralisation or a free radical capture in polymer electrolytes. They can be further improved but the obvious is taken. In seeking to meet the market need of higher energy density, notably for longer pure electric range, some attention is therefore now turning to inorganic solid electrolytes in what are commonly called third generation lithium-ion traction batteries.

45% of patenting activities in relevant nanotechnology are directly related to academic efforts. Another 30% are related to the first and second tier players. This provides an indication that such technologies are gradually changing their status from being just an academic emerging technology to become a pacing technology widely accepted by the whole industry.

Equal attention is provided to four main subgroups in the portfolio:

- Anode
- Nanotechnology in electrode manufacturing (mainly related to anode), anode manufacturing and anode chemistry
- Cathode
- Cathode manufacturing and cathode chemistry
- Electrolyte and separator

- Electrolyte – lithium salts, electrolyte – additives, solvents and polymers, battery separators

Mechanical construction and packaging is an important focus of most companies involved in traction lithium batteries. Overall patenting rate increased 40% in only four years. Many organisations are accelerating their patent filing rate. The list of such companies is dominated by Toyota, which is showing an impressive rate of growth. Others include BYD, TDK, Fuji Heavy Industries, Zeon, UBE Industries, Nippon Chemical, NGK Insulators, Daimler AG, Li-Tec Battery (Daimler/ Evonic), Robert Bosch, and SB LiMotive (Samsung/ Bosch). Surprisingly, a substantial number of companies are reducing their patenting activities in Li-ion batteries. The most dramatic reduction is shown by LG Chemical, but first tier players Panasonic and Samsung SDI have cut back plus smaller companies PolyPlus Battery, Medtronic, Valence Technology, AGC Semi, A123 Systems, Greatbatch, and giant Mitsui.

US patent activities are well behind the Japanese, who are ahead by a shocking 150%, and Korea.

European and Chinese patent activities are well behind the Japanese, Koreans, and US but are growing much faster than average. Europe has shown fourfold increase in the patent activities made it to comparable to US and Korean patent activities in 2008. Europe may overtake the US and Korea in future.

There is no growth in electrolytes and anode manufacturing while nanotechnology has attracted 100% growth in 4 years. Nanotechnology is a strong focus for patent activities originated in US followed by Europe: government policies are the cause. Japan dominates patents for manufacturing anodes and cathodes. Samsung SDI and LG Chemical target mechanical construction.

As with Advanced Energy Storage technologies as a whole, the location of Li-ion patent filings follows major markets. China has a similar number of national patent applications if compared to Japan and Korea but almost all Chinese patent applications have been invented outside of China ; US patent filings are ahead of everyone else, however most of these patents are invented in Japan and Korea (see Fig 6 for comparison). Nanotechnology related patents are filed predominantly in the US and this subject area is most pronouncedly under-represented in China. Anode manufacturing and anode chemistry is a substantial specialisation of Asian national patent filings with most patents invented in Japan.

1.5.3. Further details of Anode chemistry

In many ways, though the cathode largely controls cost and performance, the anode is the weakest part of the battery cell due to the possible breakdown of the thin passivating Solid Electrolyte Interface/Interphase (SEI) layer on the anode.

The deposition of the SEI layer is an essential part of the formation process when the cells take their first charge. The electrolyte reacts vigorously with the anode material during the initial formation charge and a thin passivating SEI layer builds up moderating the charge rate and restricting current. The SEI layer increases the cell internal impedance and reduces the possible charge rates as well as the high and low temperature performance. The thickness of the SEI layer is not homogeneous and increases with age, increasing the cell internal impedance, reducing its capacity and hence its cycle life.

Excessive heat can cause the protective SEI barrier layer to breakdown allowing the anode reaction to restart releasing more heat leading to thermal runaway. The initial overheating may be caused by excessive currents, overcharging or high external ambient temperature. Lithium titanate anodes do not depend on an SEI layer and hence can be used at higher charge/discharge rates. However lower anode reactivity means that cell voltage is substantially reduced which results in 25% to 30% lower energy density hence bulkier battery cells.

The anode is typically based on various material variations of carbon and its compounds. Substantial emphasis is given to developing the mesoporous/nanoporous carbon based structures at the surface of the anode in order to increase the recharging rate and to reduce the deformation of the lattice of the host active material related to the intercalation of lithium.

The current trend in patent activities is related to using various active materials embedded in the carbon host structure. Some patents are discussing the usage of conductive polymers as a way of increasing the conductivity of the anode, but most efforts are related to using compounds of silicon, tin, and titanium oxide as an active material. Many patent applications are describing the method of embedding the nanoparticles of the active material inside the carbon mesoporous shell. Some patents goes a step further by describing novel systems which are not using carbon matrix and are fully based on the non-carbon nanocomposite active materials like aluminosilicate, silicon oxide, titanium oxide, etc.

Top companies developing anode technology are Panasonic, Samsung SDI, and Sony. Samsung SDI has specific focus in vanadium oxide but has a gap in silicon based material systems. Sony has a clear gap in using nanotechnology and in developing titanium oxide material system. Toshiba is showing quite strong focus in titanium oxide material system. LG Chemical is working with conductive polymers

High level of patent activities of academic institutions is focused on nano-form carbon; it is further supplemented with other areas of interest such as conductive polymers and titanium oxide.

The list of players showing growth in patent activities includes Toyota, Sion Power, Sumitomo Chemical, LS Mitron, Enerdel, Philips, and academic players like Korean Institutes, US universities, and European Institutes. A substantial decline in patent activities is demonstrated by LG Chemical, PolyPlus Battery, 3M, Mitsui, DuPont, Panasonic, Samsung SDI, and Toshiba.

It is very unusual to have a Patent Map showing the overall growth of patent activities against the substantial decline of patent activities of major players. The reduced activities of major players are substituted with a growing activity of small players and academic institutions. Most probably this reflects the second wave of innovation occurring now in the industry. Current technology for lithium batteries for mobile applications is reaching a maturity stage, the new growth is related to traction batteries, where many technical challenges might be related specifically to the anode chemistry. The result of such new wave of innovation might challenge the status quo in the industry and might lead to a number of forced acquisitions of small innovative companies by larger players in the near future.

There is a clear trend towards nanotechnology. Titanium oxide looks as an area of future growth in spite of reduced patent filings from Toshiba – the single largest proponent of this material system. It also seems that carbon is not going to give up the top spot in the list of active anode materials. Patent activities for using carbon based material system are just increasing right now.

The US is well ahead of Korea. This is related to a major focus on mechanical construction for the main Korean player - Samsung SDI. Both China and Europe are increasing their contribution to R&D in the anode chemistry and manufacturing. However the Chinese contribution is still disproportionately small.

Silicon, silicon oxide, silicon compounds, tin compounds and graphite are mainly a Japanese activity.

Titanium oxide, nanocarbon, carbon and lithium non-metal compounds are strong activities in the US.

China is a very popular destination for national patents invented in Japan, Korea and to some degree in US. Japanese companies are actively patenting material systems related to silicon, silicon oxide, silicon compounds, tin compounds, and graphite in Korea and China. As a result, this group of material systems is overrepresented in the Asia. Nanotechnology patents are underrepresented in Asian countries

Titanium oxide material systems are more actively patented in US and Europe compared to other material systems. Vanadium oxide technology – patent activity originated from Korea – is taken to other countries but its share of European filings is slightly larger than it might be expected normally.

1.5.4. Further details of Cathode chemistry

Panasonic is leader in patenting cathode material technologies. Second are LG Chemical, Samsung SDI, Sony, Toyota, Toshiba, Hitachi, Sumitomo Chemical and academic institutions in Europe and

US. Lithium nickel cobalt Manganese NCM is a focus of most second tier players excluding Toyota and European Institutes. The proponents of lithium iron phosphate material systems include Panasonic, Toyota, BYD, and European Institutes. TDK, Toyota, and Valence Technology are developing non-Iron lithium phosphate. Lithium manganese oxide and lithium nickel oxide technologies are well represented with top players like Panasonic, LG Chemical, Samsung SDI, Hitachi, and Toshiba. The usage of conductive polymers is under development by LG Chemical, Panasonic, Samsung SDI, Sony, Toyota, NEC and Zeon. Carbon – mainly as a mesoporous/nanoporous host material for nanoparticles of the active material (like lithium iron phosphate) is under development by US Universities and Toyota. LG Chemical, Panasonic, Samsung SDI, and Sony have their own established development activity in this area.

Increasing patenting activities is Toyota then BYD, TDK, BASF, Zeon, and Sion Power (developer of lithium sulphur third generation batteries used in pure electric unmanned aerial vehicles UAVs)

Companies decreasing their cathode patent activities include Valence Technology, LG Chemical, A123 Systems, AGC Semi, Nissan, Mitsubishi, Mitsui, and Greatbatch.

Lithium phosphate material systems are the hottest subject of patent activities. At the moment the patenting rate for lithium phosphate is similar to the lithium cobalt based material systems but it has overtaken cobalt based chemistries since 2008. As have been mentioned earlier, the phosphate based cathode material is not prone to thermal runaway and offers a longer cycle life. Cobalt based chemistries, especially Lithium (NCM) Nickel Cobalt Manganese are attracting steady interest in spite of being quite mature and established material systems.

Nanotechnologies based on nano- carbon as a host material are attracting increased attention right now

It is usual to see Korean activities declining; this reflects behaviour of two major Korean players Samsung SDI and LG Chemical. However, it is quite unusual to witness a decline of patent activities originated from US. Europe as usual shows the steep increase in patent activities, China was waking up with its own patent activities in this subject area only from 2008.

Lithium Iron Phosphate is not a pure Asian technology; in fact it is under represented in Japan and is a focus of US and European patent activities. Lithium (NCM) Nickel Cobalt Manganese is a good example of Asian technology, with the US lagging behind Korea and Japan. US is a strong proponent of Lithium Sulphur and Vanadium Oxide material systems. Vanadium oxide is a '3 – 4 V' battery material and is thus capable of high power and energy densities. However substantial volume changes during lithium intercalation are leading to serious cathode pulverization. Vanadium Oxide nanostructured battery electrodes could circumvent these problems. Outside of US these material system is under development by NEC and Samsung SDI.

Cobalt based materials and lithium spinel (lithium manganese oxide and lithium nickel oxide) are remaining as Asian activities. A niche material technology – lithium titanium oxide – used typically as a coating for other spinel materials is originated from Japan (by Panasonic and Toshiba) and it is taken mainly to US and China. Nano-form Carbon and conductive polymers are biased towards US patent filings

1.5.5. Lithium Traction Batteries for EVs in particular

This section analyses those patents clearly mentioning traction battery applications. These are dominated by the mechanical construction and packaging. The battery management system can form part of a Li-ion traction battery pack but it is discussed in the separate section.

Panasonic and Toyota are two leaders in the Lithium Traction Batteries market. Their activities mainly address anode and cathode manufacturing, mechanical construction and packaging of the battery pack. Panasonic outweighs Toyota in patenting anode and cathode material chemistry and separators. Toyota beats Panasonic in patenting nanotechnology and electrolytes. Second-tier players include LG Chemical, Toshiba, and Hitachi. Third echelon come Nissan, A123 Systems, Mitsubishi, Samsung SDI, Robert Bosch, SB LiMotive (Samsung/Bosch), Daimler and Li-Tec Battery (Daimler/Evonik).

The 100% growth in patenting activities during just 3 years is very impressive particularly since

LG Chemical, Panasonic, Toshiba, A123 Systems, Nissan, and Mitsubishi are staying flat or reducing their patenting activities. The growth is headed by Toyota: indeed, its EV related Li-ion patenting activities have overtaken Panasonic since 2008. Quite a lot of companies on the top companies list are actually newcomers – they did not have any patent activities in 2005, and some started filing patents only since 2007.

Toyota has shown an aggressive growth by being the new but bold entrant to the area since late 2006.

Nanotechnology is one of the strong growth areas for Toyota. Panasonic has demonstrated a steady activity. The activities in separator technologies has been recently dropped. LG Chemical is showing a declining level of patent activities especially in the aspects related to mechanical packaging which most probably reflects a reduced development budget for the new generation of lithium traction batteries. It seems that LG Chemical is shifting its financial resources from R&D to manufacturing which should pay off in a short term but might become quite a risky strategy in the long run. Patent filings by Toshiba show flat behaviour over last years. The recent increase in the patent filings in the mechanical construction and packaging might signal some increase focus on manufacturing away from pure R&D.

Mechanical construction and packaging of the traction battery is not only the main focus but also the area of growth above the average. Other areas of growth are related to nanotechnology and cathode manufacturing. Other categories shows the absolute growth which is below the average.

Lithium Traction Battery is a Japanese technology. Japan is too big in comparison with everyone else. Partially this is reflected by the fact that both two first-tier players – Toyota and Panasonic – are Japanese companies. Europe is a late entrant to the Lithium Traction Battery market; however in 2008 Europe had already overtaken Korea and had almost caught up with the US.

Nanotechnology is the only category in which Japan is not dominating the market – in spite of the big support from Toyota. Korea and Europe are strong in mechanical construction and packaging and are weak in most other areas but Europe has a higher than average contribution to nanotechnology

More than 60% of National patents represented on this Patent Map have originated in Japan; Japanese companies are taking more patents in China if compared to Korea or Europe. Nanotechnology and Mechanical construction are overrepresented in Europe which is reflecting the original European patent filings in this subject areas. Categories related to Manufacturing and Chemistry of anodes and cathodes were especially dominated by Japanese companies; as a result these activities are still overrepresented in Japanese National filings.

1.5.6. Traction batteries in general

The previous section – Lithium Traction Batteries – form part of traction batteries in general that we now discuss.

Panasonic and Toyota remains at the top of the game but LG Chemical is much closer to these two rivals compared to its position for lithium traction batteries alone. Toyota has stronger emphasis on the mechanical aspects such as mounting the battery pack in the EV or arranging a mechanical system for cooling or heating of the battery pack. Panasonic has stronger focus in developing supercapacitors for EVs. There are several new second-tier players including Honda and Nissan.

The overall growth is modest if compared to the phenomenal growth of the patent activities in lithium traction batteries. Toyota entered this market in 2006 and is growing on a par with the rest of the market since then. LG Chemical and Primearth EV Energy are down; this behavior probably reflects their reduction of R&D activities. Many newcomers (since 2006 or later) from the automotive industry are evident on these Patent Maps including Behr, Renault, Peugeot Citroen, Hyundai, Ford, General Motors, Tesla Motors, General Electric, Continental AG, Robert Bosch, Mitsubishi, BYD, and Daimler AG.

Toyota entered this market with initial equal emphasis on the lithium traction batteries and their use in the EV, notably battery mounting in the EV and mechanical arrangements for heating and cooling. In 2008, Toyota apparently decided to focus mainly on developing its own product in lithium traction batteries: it has substantially scaled down other activities. From 2006, Panasonic shows steady focus on non-lithium and lithium traction batteries.

Lithium traction batteries is the most strongly growing part. Their success will determine the speed at which the market will be able to move from the hybrid EV to the plug-in hybrid EV. All other areas are growing but at a slightly lower rate than lithium traction batteries.

1.5.7. Supercapacitors

Supercapacitors, often known as ultracapacitors in the world of electric vehicles and electrochemical double layer capacitors ELDCs elsewhere, are used in some electric vehicles in order to keep batteries within resistive heating limits and extend battery life. Supercapacitors are even known as supercondensers or pseudocapacitors. Compared to conventional electrolytic capacitors the energy density is typically hundreds of times greater. There is even development taking place to get them to carry do more of the work carried out by the battery. Indeed, some buses use only supercapacitors, recharging through the road every five kilometres or so. The ultrabattery (supercabattery, asymmetric electrochemical double layer capacitor) combines a supercapacitor electrode and a battery electrode in one unit, creating an electric vehicle battery that may last longer, cost less and be more powerful than current traction batteries. Supercapacitors have a variety of other commercial applications, mainly for the "power smoothing" and momentary-load devices, for example, extending the range of the flash in a mobile phone camera.

In a conventional capacitor, the opposite charges are separated by the relatively thick dielectric layer. Supercapacitors do not have a conventional dielectric. The supercapacitors use "plates" of opposite charges separated by the vanishingly thin (on the order of nanometers) depletion layer on the surface of the electrodes. Each "plate" layer by itself is quite conductive, but the physics at the interface where the layers are effectively in contact means that no significant current can flow between the layers. However, the double layer can withstand only a low voltage which limits their energy density.

The supercapacitor advantage is lack of ionic transport through the electrolyte: existing supercapacitors have energy densities one tenth of that of a conventional battery but power density is generally 10 to 100 times better. Most commercial supercapacitors use powdered activated carbon made from coconut shells. Higher performance devices are available, at a significant cost increase. One way of improving the energy density of supercapacitors is related to replacing one electrode with a battery-like electrode with the redox (reduction-oxidation) storage mechanism along with a high surface area.

Supercapacitors with redox electrode in which voltage is proportional to the charge are called pseudo-capacitors or asymmetric supercapacitors. Such pseudo-capacitors are typically based on ruthenium oxide. This material allows more than 10 million charge/discharge cycles but is expensive so polymers (e.g. polyacenes, conducting polymers) are sought with robust cycle life. More improvement can be achieved by using a battery type redox electrode in which voltage is nearly independent of the intercalated ions charge as with a "lithium ion capacitor".

Supercapacitor patenting is not growing but there may be a renaissance since many recent startups target them and Elon Musk, founder of Tesla Motors thinks they will become more important than batteries. Meanwhile, unusually, we find US Universities in the list of the first-tier players in this area of stagnating patenting. Other top supercapacitor patentors are Maxwell Technology, NEC, and Panasonic. The main focus for commercial players is in the technologies related to electrode manufacturing and mechanical construction and packaging. Panasonic, NEC, and US Universities also target electrolyte chemistry. Next come Samsung SDI, TDK, Sumitomo Chemical, Zeon, Mitsubishi, Corning, Fuji Heavy Industries, and Daikin.

Several players like US Universities, NEC, Corning, Sumitomo Chemical, Daikin, and AVX Corporation are increasing their patent activities. Panasonic activities are relatively steady. Several companies are clearly reducing their filing efforts. The list includes companies like Fuji Heavy Industries, Honda, Maxwell Technologies, etc.

Technical development in lithium ion capacitors, asymmetric supercapacitors, and nanotechnology is growing well above the average. The lithium ion capacitor was a strong focus for Fuji Heavy Industries modest activities at Panasonic, TDK, Sumitomo Chemical, and Zeon. More commercially focused activities related to the electrode manufacturing, mechanical construction and packaging of supercapacitors and electrolyte chemistry are gradually declining.

US patent activities are similar to the patent activities of Japan. European and Korean activities are growing, however from a relatively low level. This is the only Patent Map showing patent growth in Korea. Japan is on a second place (after US) in the nanotechnology related patent filings but it seems to be ignoring opportunities provided by the nanotechnology. Japan has very strong focus in lithium ion capacitors and to a less degree in electrolyte chemistry and electrode manufacturing. Apart from nanotechnology Europe has substantial activities in supercapacitors manufacturing and packaging.

Lithium ion capacitors remain a predominantly Asian activity; Japanese patents are taken equally to Korea, China, Europe and US. National patent filings for nanotechnology, asymmetric supercapacitors, mechanical construction and packaging are more biased towards US and Europe reflecting the origin of man patents in these areas.

1.5.8. Charging and battery management systems

Toyota is the most active player in the patenting technologies for charging stations with main emphasis on the aspects of the battery recharging via regenerative breaking, battery safety and battery temperature control. Next come Panasonic, Denso Corp., General Motors, Ford, and Robert Bosch. They target managing the process of battery recharging and controlling depth of battery pack discharge. V2Green, IBM, RWE, and General Electric are developing IP position in recharging stations and business methods related to using batteries in plug-in EVs.

Toyota is a well established player in the battery management and its activities while growing in 2006 and 2007 are actually reduced in 2008 in contrast with a surge in its battery patents as it shift from developing systems supporting the usage of the traction batteries to the development of the traction batteries per se. Rapid growth in BMS patents originates from General Motors, Peugeot Citroen, BMW, Robert Bosch, Daimler AG, Chery Automobile in China, Chrysler and Aisin Seiki with activity down at Ford, Denso Corp., Hyundai, Nissan, Samsung SDI, LG Chemical, Primearth EV Energy controlled by Panasonic, Continental AG, and SB LiMotive (Samsung/ Bosch).

Toyota has substantially reduced its BMS focus in temperature control and regenerative braking aspects of battery management. Toyota increased its focus on charging stations, battery recharging and battery safety systems. General Motors shows very strong jump in the patenting activities which might have some artificial component in it with possible political gains in mind. GM has special focus in the battery depth of discharge control.

Commercial aspects of using batteries in EVs and charging station patents are the fastest growing areas. Reduction of patenting regenerative braking technology is because it is mature with little potential for strong IP protection. The US is on a par with Japan. If it was not for Toyota, the US be a much stronger player than to Japan. European positions are relatively strong – much stronger if compared to the battery technologies. The US and Europe are growing much faster than average. Korean activities are on a down (cf LG Chemical and Samsung SDI policies) .

Patenting activities related to regenerative braking technologies are strong in the US. Business method patents related to commercial aspects of using batteries in EV are patented mainly by US companies. Patents related to the recharging stations are patented by companies from US, Europe, and Japan. European activities in this category are on a par with the Japanese one. Battery safety and temperature control of the battery pack are relatively more important for Japanese and Korean companies

Battery safety and temperature control of the battery pack remains an Asian activity due to the origin of substantial number of patents from Japan and Korea. Korea is substantially underrepresented on this Patent Map. It seems that Japanese companies are taking their patents to US, China, and Europe mainly ignoring the opportunity to file Korean patents. Due to the lack of patent activities originated from Korea itself, the overall number of Korean patents in this particular sub-portfolio is quite small.

1.6. Commercial situation today

To put this newly revealed patent landscape into the context of today's commercial activities, we have examined trading and investment by 71 leading Li-ion traction battery manufacturers that make their own cells. Here is a summary of these aspects, with some of our conclusions.

Who will win in lithium-ion traction batteries?
Long term, marketing theory shows that there are unlikely to be more than about three enduringly profitable, large manufacturers of vehicle traction batteries. To have a chance of being in the top three in Li-ion vehicle traction batteries, creating enterprises of at least ten billion dollars in yearly sales, companies have to invest at least two billion dollars over a twenty year period that has already started. Panasonic, Nissan, which has a joint venture with impressive patentor NEC, and LG Chemical, which also has joint ventures, clearly qualify, though we have warned that LG Chemical is losing the race for intellectual property.

"Elephant in the room" is the world's largest electric vehicle manufacturer Toyota, not yet making many Li-ion batteries but with a huge pent up demand because it is forced to switch from NiMH to Li-ion with its hybrids as they have to achieve improved pure electric range in line with user needs. It has also had the essential lanthanum used in its NiMH batteries rationed by China. Even its forklifts are starting to use Li-ion in place of lead acid batteries and its buses already use Li-ion. Indeed, Toyota has announced the launch of pure electric on-road vehicles that can only use Li-ion. Given that Toyota, potentially the world's largest user, also has the most impressive trend in relevant patents, it is very much a company to watch.

Let us put this another way. Based on recent commercial success and factory investment, it is popularly believed that the Koreans will capture the vehicle traction battery business from the Japanese. It is thought that this will be due to LG and Samsung repeating their success in taking the flat screen display business from the Japanese. However, we measure that the quantity and trends of relevant patents over the years as analysed in this report show that the Japanese are much stronger than this implies and Toyota is potentially the most important battery maker of all. Alliances and acquisitions are strengthening other Japanese players with formidable intellectual property and sales success in traction batteries for electric vehicles, Panasonic including Sanyo and the NEC-Nissan joint venture AESC being of note in sales success. So far, there is no company outside Japan and Korea that has a strong chance of leadership in Li-ion traction batteries or even clear commitment to the necessary amount of investment.

Partially closed market

It is unlikely that a Li-ion traction battery company can be number one without selling to the largest users such as Toyota and Nissan, yet in doing so, an outsider has to compete with its customer. In the "maybe" category of those that will definitely invest over $0.5 billion to try to win in Li-ion traction batteries are Samsung, Johnson-SAFT, BYD and Dow-Kokam. This second group are leading neither in the building of production facilities, in valuably unique patent-protected technology nor in overall Li-ion R&D as reflected in the number and trend of relevant patent filings. Indeed, Samsung and its joint venture have particularly modest sales successes, as yet. None have captive markets because they do not make electric vehicles.

Disturbingly, therefore, there is no company outside Japan and Korea that has a strong chance of leadership in Li-ion traction batteries or even clear commitment to the necessary amount of investment, as yet.

Much has been made of the $2.4 billion in direct investment that President Obama committed to the traction battery business in 2009 and sundry other investments since. However, this is spread so thinly that it is nothing more than a useful, but not sufficient, investment for the US to catch up in this subject. Indeed, the second largest beneficiary from Obama was global first division player LG Chemical of Korea, in the form of funding for its Compact Power subsidiary in the US and assistance to GM to incorporate such batteries in planned electric vehicles. That was sensible, because the priority was to get US electric vehicles on the road, not to create a leading US-owned traction battery industry.

The most that one can say is that Johnson Controls-SAFT got the largest tranche and it leverages a patent position from French partner SAFT. However, the pre-eminence of Johnson Controls in lead acid batteries will not help it significantly. As yet, its joint venture is in the second division when it comes to working with and getting designed in by the potentially largest users of vehicle traction batteries in the world. It must try harder.

Can the West leapfrog?

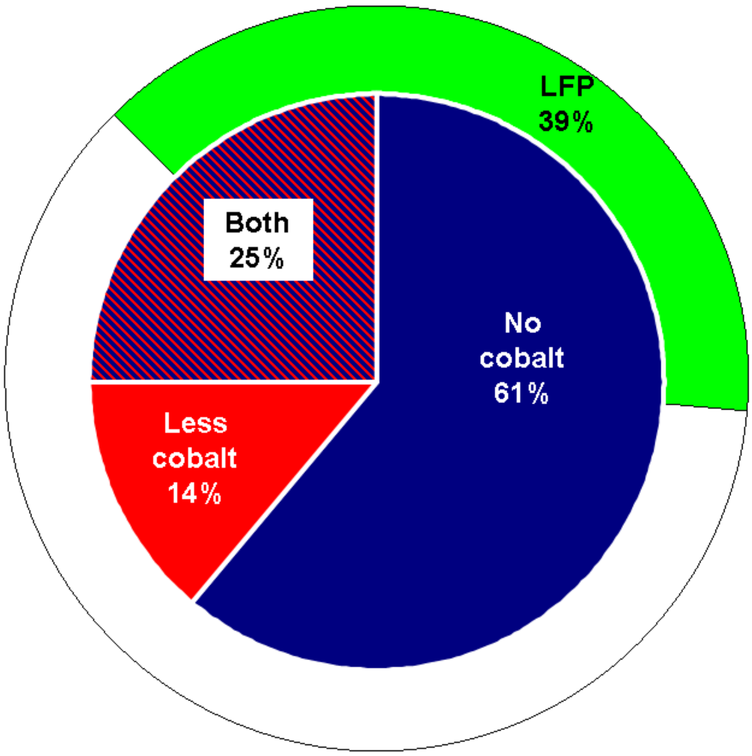
A ray of light for the Americans and Europeans is that their surge of investment in third generation traction batteries such as lithium sulphur and lithium air is rarely matched in East Asia beyond the formidable Toyota R&D program underpinned by patents.

Niche opportunities abound

However, there will be many successful niche players with modest sales to add to the West's Valence Technology, SAFT and Enerdel. Indeed, Dow-Kokam and Kokam itself in the East are already doing some niche marketing into trucks, buses, aircraft and conversions.

The figure below shows the favourite cathode chemistries and cell geometry in Li-ion vehicle traction batteries offered commercially today. The prevalence of lithium iron phosphate cathodes and lithium polymer electrolyte assembly reflects patenting activity. However, most of the biggest orders are being landed by less-cobalt and no-cobalt assemblies with wet electrolytes to gain higher energy density etc. Strong patenting also supports this yet, curiously, it does not support the strong adoption of supercapacitors and the good performance of the Maxwell Technologies share price compared to that of most manufacturers of vehicle traction batteries. Supercapacitors are heavily used in buses, other on road vehicles of similar size and military vehicles and are being considered for cars and many other electric vehicles. Some are already in e-bikes. Their self leakage and energy density continue to improve. Accordingly there seems to be an opening for a company to invest heavily in their R&D.

Fig. 1.3 **Approximate percentage of manufacturers offering traction batteries with less cobalt vs those offering ones with no cobalt vs those offering both. We also show the number of suppliers that offer lithium iron phosphate versions.**



Source IDTechEx

A table such as the one below can never be more than indicative, because the industry is in a constant state of flux. However, in support of our arguments, those aligned for the largest Li-ion traction battery orders in the near term seem to be Panasonic and LG Chemical, the more so if we include their joint ventures and acquisitions. AESC, the joint venture of strong patentors NEC and Nissan, is also very strongly placed for orders. Indeed, Nissan, as a user, is investing more in pure electric cars than any other company on earth. As the table shows, these companies use lithium nickel cobalt aluminium, lithium manganese spinel and other cathodes, mainly carbon anodes as yet and sometimes lithium polymer electrolyte. Prismatic assembly is favoured. Their success is based on serving the needs of both hybrid and pure electric vehicles in all cases and cars in particular but with some larger on-road vehicles being equipped with their lithium-ion batteries. Odd ball is regular Panasonic cylindrical batteries being used in huge numbers in each Tesla pure electric car.

Paradoxically, the increasing, considerable overall popularity in patenting and use of lithium iron phosphate cathodes is caused not by these first division players but by the less successful and newer ones. It is commonly believed that LFP is attractive with this host of smaller manufacturers partly because the patent situation is considered easier if you are a new entrant but also, of course, because they should lead to low cost, relatively safe batteries of adequate energy density, the future priority for all forms of electric vehicle.

2. Introduction

"Unlike marketing reports which analyse information accessible via an intelligent use of Google, a Patent Mapping study is a deep dive into the Invisible Web – to the reliable information derived from paid subscription patent databases."

2.1. Patent mapping and landscaping

The importance of IP protection has substantially increased in Europe and the US during the past decade mainly due to the shift towards an 'innovation economy' which resulted from outsourcing of manufacture to cheaper destinations. Nowadays this is reflected in at least a threefold increase in the size of the patent portfolio of many large firms and in the substantial growth of patent litigation. To cope with the ever increasing volume of patent data in the public domain, PatAnalyse Ltd has developed revolutionary self-learning iteration techniques for patent searching and analysis. Current tools combine the power of artificial intelligence algorithms with the judgement of subject area experts. PatAnalyse is launching a new product line: in depth patent studies available to all players, large and small, for a fixed price. This novel source of evidence-based competitive intelligence can validate and complement conventional market analyses.

Firms disclose their secrets – 'patent' them in exchange for a limited monopoly. Yet the complexity of the patenting system – especially the sheer number of patents - severely diminishes the value of disclosure. A Patent Mapping study aims to restore the original intention by allowing clearer dissemination of knowledge. Thus it serves an urgent need for companies - both large corporations and SMEs - to gain access to the rich vein of technical and commercial intelligence contained in patent databases.

Patents are an exclusive and valuable source of information on recent developments in highly commercially sensitive technology areas. Patents can be considered as a topical indicator of levels of R&D effort - being one of the principal outputs of such activities - and patent data are available with at most an 18 month delay. A good overview of the activities of major players is essential for the cross-fertilisation of R&D efforts at an international level. Business intelligence derived from such knowledge frequently helps strategic decision making. Improving access to the information buried within patent databases creates huge opportunities for businesses, especially for new entrants that have yet to build up significant internal technology know-how.

The advent of free access to on-line patent databases at the turn of this century was the first big change in the IP system for many decades but this was only the first step in the 'democratisation' of the data. The benefits of free access to these vast amounts of data have been more than offset by the massive growth in the sheer volume of patent information over the last 10 years. The information needs of technology businesses now transcend the capabilities of any single end-user. Some 20 million patents have been granted with about one and a half million new patents issued each year globally. About $4.5 billion is spent by the industry every year on patent information, but much of this expenditure is wasted through inefficiency and duplication of effort.

Patent landscapes can be used to visualise patterns of technology competition on a global scale. Patent landscaping, as the process is called, is the tool increasingly used by large corporations to inform product development and technology strategies. By analysing vast amounts of data in patents databases, users can gain a significant competitive advantage. For example, patent mapping can give firms comprehensive insights into innovation trends and the position of rivals, can show gaps and opportunities, the parts of the world where specific new technologies are being developed, and so on. But current methods are notoriously difficult to automate and so they are skill and labour intensive.

While Patent Mapping is historical in its perspective, its primary value is in allowing a corporation to inform the Business strategy to define a successful path forward. Once the business become aware where its competitors are and which way they are heading, the managers receive the vital information they need to shape the strategic and tactical responses for the Product and Technology strategy. Patent Mapping is essential for modern corporations because its relatively modest investment can both minimise potential risks and identify significant opportunities.

A Patent Mapping study is a vital part of any IP 'intelligence' exercise and must be considered by each company in the context of its own business strategy, product/service planning and technology strategy.

2.2. Preventing wilful infringement exposure

There is also a special advantage of Patent Mapping for companies that are exposed to the risk of a patent infringement lawsuit in the US. These risks are considerable because damage awards can be the highest encountered in private litigation. US courts can increase damages threefold if so-called 'wilful infringement' can be proved by the patent owner. In a past, if a company encounters a patent that has a high risk of being relevant to its business the firm has a duty to obtain an expensive opinion from external counsel in order to avoid the accusation of wilful infringement.

Many US companies do encourage employees not to read other companies' patents and not to store the electronic records of such patents in internal databases. On February 2006 the USPTO conducted a public meeting with the open-source software community to discuss issues of patent quality and prior art. One of the main concerns discussed at the meeting was related to "wilful infringement danger," where developers would be reluctant to look at any patent data whatsoever for fear of becoming liable for wilful infringement.

The America Invents Act (Bill S. 23 approved by the Senate on 8th of March 2011) creates a new 35 U.S.C. § 298, which provides that the failure of an accused infringer to obtain an opinion from counsel, or to produce such an opinion during litigation, cannot be used to prove wilful infringement:

§ 298. Advice of Counsel "The failure of an infringer to obtain the advice of counsel with respect to any allegedly infringed patent or the failure of the infringer to present such advice to the court or jury may not be used to prove that the accused infringer willfully infringed the patent or that the infringer intended to induce infringement of the patent. EFFECTIVE DATE.—the amendments made by this section shall apply to any civil action commenced on or after the date of the enactment of this Act".

Nevertheless the desire of some companies to stay away from the minefield of the wilfulness infringement claims in US has been taken in consideration during preparation of the current Patent Mapping study. To resolve possible concerns of our clients the report is provided without any specific references at the level of individual patents. This way current study does not provide an 'actual notice' of particular patents. Thus subscribers are able to study the competitive landscape while avoiding a subsequent commitment to follow such a report with a set of bespoke Freedom to Operate studies.

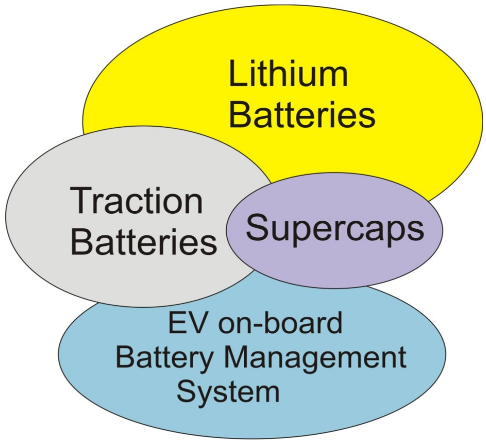
Detailed patent studies referencing individual patents can be provided under the request. If necessary, such projects can be provided under attorney-client privilege. For further details please contact PatAnalyse at info@patanalyse.com .

2.3. The focus of current study

This study is centred on a high level analysis of trends and emphasis from a huge number of relevant patents. The graphs generated are explained by informed text.

The focus of the current study is as follows.

Fig. 2.1 **Focus of current study**



This report provides an analysis of the rapidly developing related technologies of lithium rechargeable batteries, supercapacitors ie ultracapacitors, traction batteries used in electric vehicles, Battery Management Systems BMS and recharging. While the focus is electric vehicles, the analysis will also be of interest to those involved in any form of lithium battery, supercapacitor etc. and those involved in the electric vehicles themselves whether for land, water or air.

The current boom in electric vehicles is related to the impressive improvements in Lithium-Ion battery technologies, which are rapidly replacing the older and lower energy density Lead Acid and Nickel Metal Hydride (NiMH) batteries. The new high energy lithium-ion cells, however, are more vulnerable to abuse and need the support of electronic battery management systems to provide protection and ensure a long cycle life. Uniquely, the life of a lithium-ion battery is often calendar life, regardless of duty cycle. This illustrates the unusual challenges posed to those who would wish to improve them. The battery itself and on-board battery management system have become an important product differentiator, just like the engine in the contemporary cars.

2.4. Patent search strategy

The patent search strategy has been carefully developed via several rounds of iteration. A combination of about 150 Assignees + 1,100 inventors + 2,600 patent codes (including IPC, ECLA, US patent codes) and about 1,250 keywords were used to carry out the patent search. As a rule of thumb, it takes at least five years from invention to the first product on the market. In order to focus on the `hidden' R&D efforts which have not yet materialised as new products on the market, the initial study has been restricted to patents with a priority date from 2005. However because of a significant increase in the rate of patenting in this area, this initial patent portfolio contains over half of all patents with a priority from 1990 in this area.

Patent searches for Patent Mapping projects have been carried out using the DocDB and INPADOC Legal patent databases provided by the European Patent Office. In contrast to the Freedom to Operate projects, the Patent Landscaping projects are usually restricted to patent families with substantial international coverage – for instance the ones which contain either US, EP, international PCT patents, or a combination of several national patents from countries like China, Japan, Korea, and Germany. Patent families with a single patent taken out exclusively in a country like China, Japan, Korea, Germany or UK are considered as relatively unimportant for Patent Mapping studies as they do not aim to achieve monopoly rights in major international markets. Indeed, it is usual for Asian inventors to apply for patents in foreign jurisdictions for achieving a strong patent position. For instance, in the current study we found that Japanese and Korean applicants dominated both US and Chinese patent applications.

About 2,800 original Assignee names from the original bibliographic records were combined into 200 Top Assignees. The proprietary de-duplication algorithm aggregated about 12,000 simple patent families from about 40,000 national patents. Only 3% of the patent families have been left unassigned and it was further found that about 12% of the patent portfolio is assigned to small players with fewer than one invention per year. The remaining 85% of the patent portfolio is assigned to about 250 companies with about 66% of the patent portfolio assigned to the top 50 companies in terms of patenting.

2.5. Report layout

Almost a hundred Patent Maps have been provided in the report to facilitate the detailed understanding of various aspects of the patent landscape.

The report is organised in seven further chapters:

General overview of combined portfolio

Generic Lithium Batteries technologies

- Further details of Anode chemistry
- Further details of Cathode chemistry

Lithium Traction Batteries

- Traction batteries in general, their mounting and mechanical arrangement for cooling and heating
- On-board Electric Vehicle Battery Management System and external charging equipment
- Generic Supercapacitor (ultracapacitor) technologies

Accordingly, building on the marketing intelligence, the report pulls together a facts based analysis of patent filings over the years, customer relationships, and investments made by traction battery makers. It helps to answer such questions as:

- which chemistries, construction techniques etc. are prioritised by whom?
- which firms are spending heavily on new factories and gaining major sales successes but throttling back R&D so fewer patents are filed every year?
- what are the aspects prioritised by different regions, countries, companies and academia?
- which individuals are the most prolific inventors?
- which aspects receive more attention nowadays and which are increasingly ignored?

The report goes beyond the small and large scale Lithium-ion battery technology and looks at allied technologies such as on-board Electric Vehicle Battery Management Systems, EV battery charging stations, and supercapacitors (ultracapacitors). It shows the origin of work, profiles end-users of traction batteries in the automotive industry and highlights technology trends of patent filings.

We use a comprehensive set of technical categories for analysing relevant patents as listed below.

- Generic Lithium batteries technologies
  - Cathode chemistry
  - Cathode manufacturing
  - Nanotechnology for cathodes
  - Nanotechnology for anodes
  - Anode chemistry
  - Anode manufacturing
  - Electrolyte - lithium salt
  - Electrolyte - solvents, polymers
  - Battery separator
  - Mechanical construction

  - Details of anode chemistry
    - Lithium non-metal compounds
    - Germanium
    - Polymers
    - Carbon
    - Nano-form carbon
    - Graphite
    - Silicon
    - Silicon compounds
    - Silicon oxide
    - Other metal compounds
    - Tin compounds
    - Tin oxide
    - Vanadium oxide
    - Titanium oxide
    - Titanium compounds

- Details of cathode chemistry
    - Lithium iron phosphates
    - Other lithium metal phosphates
    - Lithium cobalt oxide
    - Lithium cobalt nickel oxide
    - Lithium cobalt nickel manganese oxides
    - Other lithium cobalt complex oxides
    - Lithium manganese oxides
    - Lithium nickel oxides
    - Lithium nickel manganese oxides
    - Lithium-vanadium complex oxide
    - Lithium-titanium complex oxide
    - Other metal lithium oxides
    - Lithium-sulphur
    - Other lithium compounds
    - Carbon
    - Conductive polymers

- Traction and large scale batteries in general
    - Li-based traction battery
    - non-Li traction batteries
    - Battery mounting in EV
    - Arrangement for cooling/heating
    - Supercapacitors for EV

- Generic supercapacitors technologies
    - Asymmetric supercapacitors
    - Lithium ion capacitor
    - Electrode manufacturing
    - Nanotechnology for electrodes
    - Supercap electrolyte chemistry
    - Separator for supercaps
    - Supercap construction

- On-board electric vehicle battery management system and external charging equipment
    - Battery temperature control
    - General monitoring of voltage and current
    - Battery recharging
    - Battery depth of discharge control
    - Battery or supercap balancing/redistribution
    - Battery related regenerative breaking
    - Battery safety system
    - Battery life prediction and modelling
    - Other commercial aspects of using battery in EV
    - External equipment related to battery recharging

Full list of Patent Maps:

- General overview of combined portfolio
    1. Fig 3.1. Top 50 Assignees vs Country of invention
    2. Fig 3.2. The lag between Publication year and Priority year

3. General overview of combined portfolio

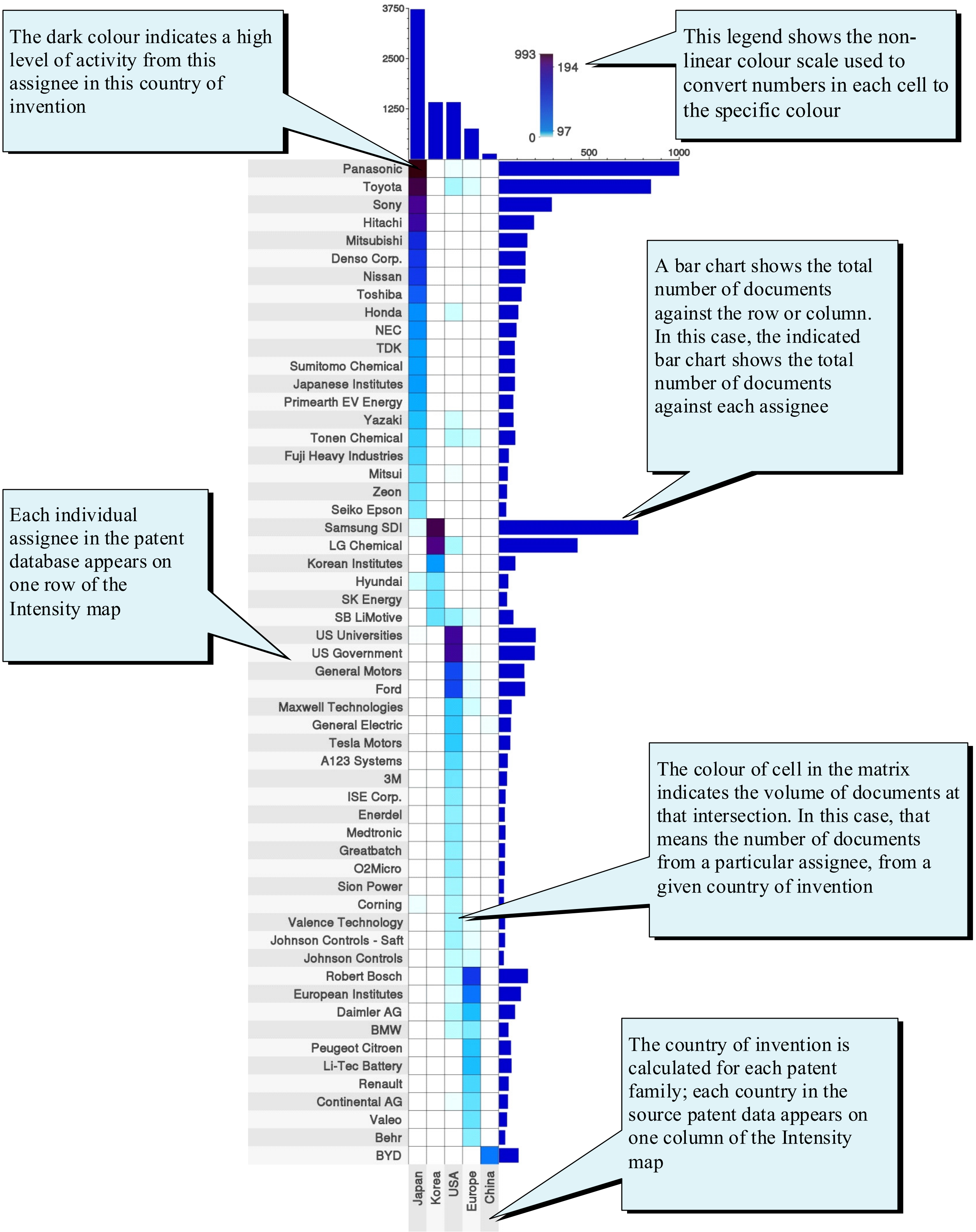
The overall portfolio contains several separate subject areas described in the details in the consecutive chapters. It combines such diverse areas as general Lithium batteries technologies, traction batteries, supercapacitors (ultracapacitors), battery management systems in electric vehicles, and external infrastructure for traction battery charging.

3.1. Top 50 Assignees vs Country of invention

Fig 3.1. Top 50 Assignees vs Country of invention

- The patent portfolio is dominated by two Japanese players - Panasonic and Toyota, and two Korean players - Samsung SDI and LG Chemical
- Japanese companies are heavily dominating the patent landscape, but even Korean companies are ahead of US; this is a rare exception in patent mapping studies. Please take into account that patents taken exclusively in Japan or Korea are not included in the study.
- The list of the second tier companies is more international. Japanese companies like Sony, Hitachi, Mitsubishi, Denso, Nissan, Toshiba, and Honda are joined by General Motors, Ford, Robert Bosch, and not surprisingly by Chinese BYD
- US activity is dominated by the governmental grant support which is reflected in the strong position of US government and US Universities on the Patent Maps

Fig. 3.1 **Top 50 Assignees vs Country of invention**



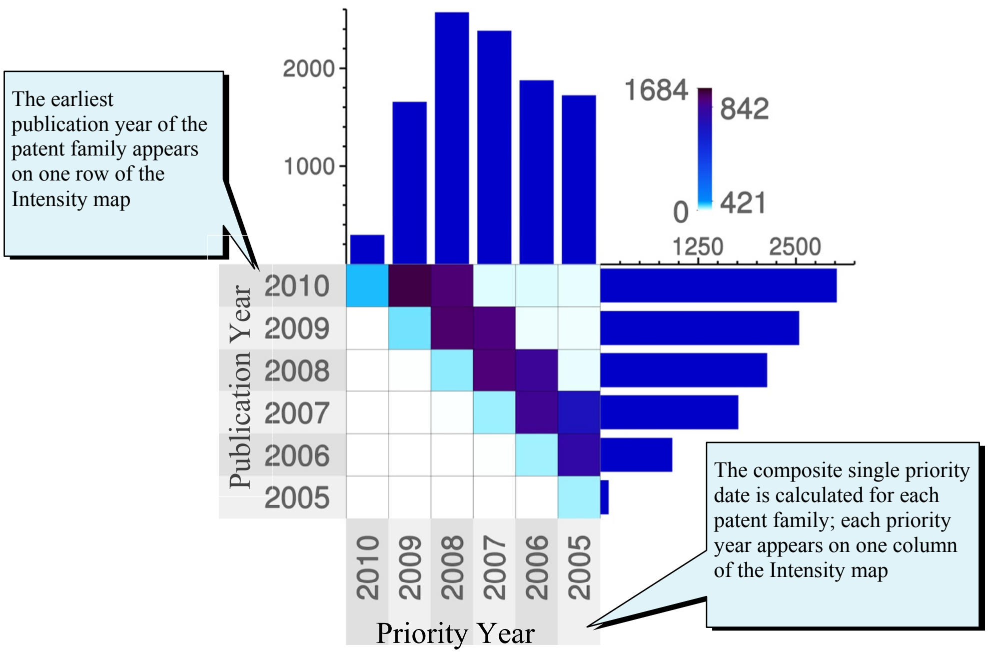
Source PatAnalyse

3.2. The lag between Publication year and Priority year

Fig 3.2. The lag between Publication year and Priority year

- Patent family might contain several patent documents taken in different national offices or the PCT (international patent office). All documents will have different publication dates and often slightly dissimilar priority information. We calculate the earliest publication date of the documents in the family and a single priority date for the whole family which reflects the date of the actual invention.
  - Quite a lot of US patents might have composite priority dates including priority dates claimed from other patent documents, which are belonging to different inventions. Our algorithm is capable to avoid such pitfalls.
- The Patent Map shows consistent lag between the actual publication date and the priority of the document. The median delay is 18 months for documents taken via PCT office and up to 24 months for patents taken to US patent office. It makes sense to ignore incomplete patent information for most recent priority years and instead to analyse timeline with a minimum delay of 20 months. For instance, it makes sense to present data for priority year 2009 for portfolio which is updated in the August 2011. Until that date our results are restricted to priority year 2008.

Fig. 3.2 **The lag between Publication year and Priority year**



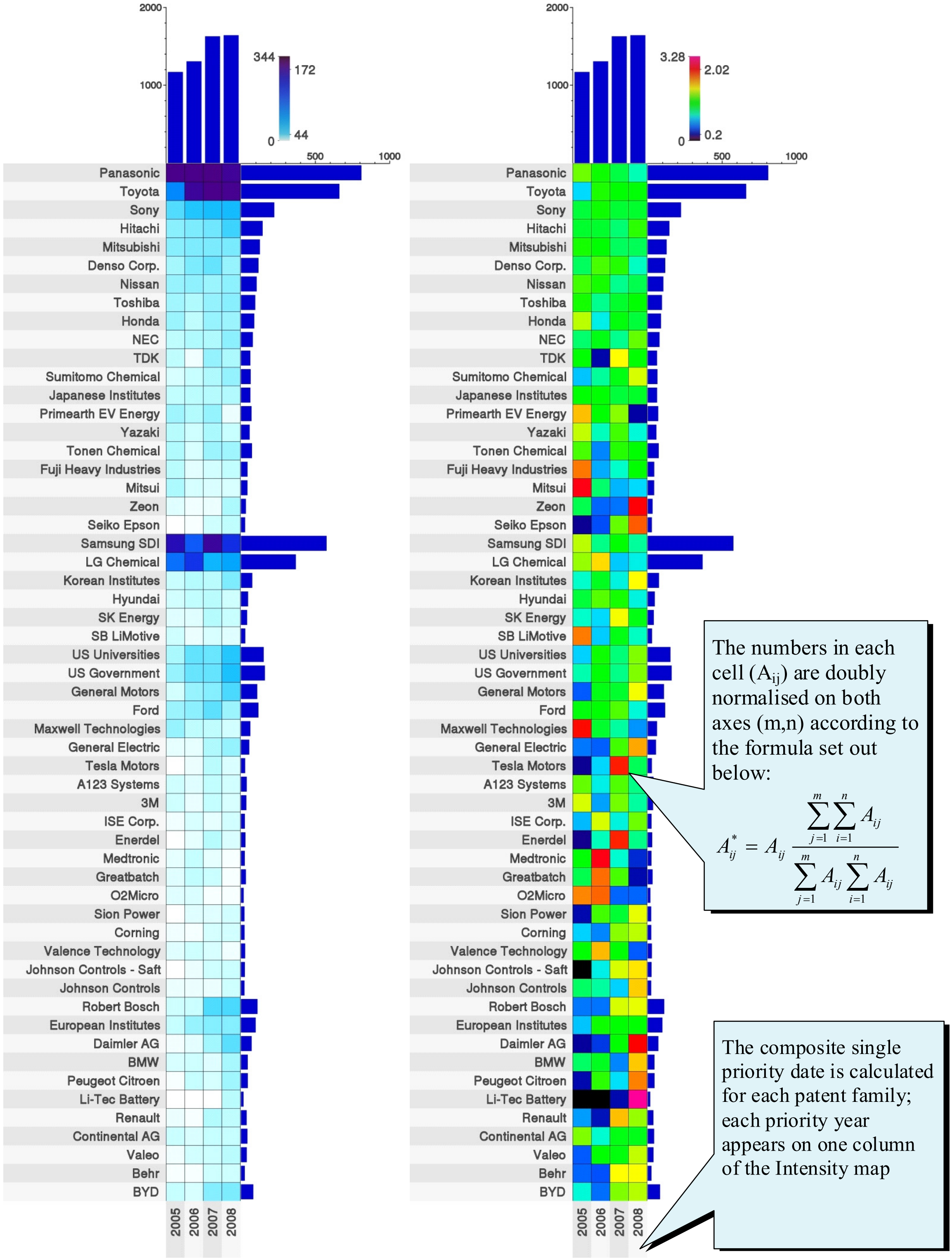
Source PatAnalyse

3.3. Top 50 Assignees vs Priority Years

Fig 3.3. Top 50 Assignees vs Priority Years

- The reasonable growth of patent applications reflects the increased maturity of lithium batteries technology including interest in developing traction batteries
- The normalised Intensity map is helpful to benchmark the performance of smaller players, whose actual trend is otherwise unclear from the absolute Intensity map. The colour scale is showing the deviation of activities of each company from the common trend. The company which follows the trend will look predominantly green (this colour is representing the value equal to one)
  - Japanese companies are mostly stable in their filing trends with Toyota slightly accelerating its overall filing rate; Sumitomo Chemical, Seiko Epson, Zeon, and SK Energy are more recent entrants to the battery business
  - Panasonic and Denso are stable in their patenting rate but overall patents are growing fast which become reflected in the reduced share for both companies
  - Samsung, LG Electronics, Hyundai, SB LiMotive, Yazaki, Mitsui, and Primearth EV Energy are reducing the rate of patenting which most probably is reflecting the cut in the R&D budgets
  - Substantial number of European and US companies are increasing their patenting activities which is a good indication of the increased R&D spend. Among other companies the growth is shown by US Universities, General Motors, General Electric, Tesla Motors, Enerdel, Sion Power, Corning, Johnson Controls – Saft, Robert Bosch, Daimler AG, Peugeot Citroen, Li-Tec Battery, Renault, Valeo, and Behr .
  - Companies like Ford, Maxwell Technologies, Valence Technology, 3M , Medtronic, Greatbatch, and O2Micro are showing a declined rate of patenting
  - The only Chinese company on the top list, BYD, is also showing a patenting growth rate above the market average

Fig. 3.3 **Timeline for top 50 Assignees – absolute and normalised**



Source PatAnalyse

3.4. Time line for different countries

Fig 3.4. Time line for different countries

- The evident growth rate in patent activities in Advanced Energy Storage is caused partially by European and US players waking up to the challenge
- It is useful to point out that Koreans are substantially outnumbered by US once all small players are taken into account
- Figure 4b is presenting Patent Map plotted in the normalised form. It is used to show the deviation of activities of each country from the common trend. The country which follows the trend will look predominantly yellow (this colour is representing the value equal to one)
  - Koreans are substantially reducing their contribution to global R&D activities with Europeans and China substantially increasing their input.
  - The finding regarding reduced R&D efforts of Korean companies is mainly related to the behaviour of LG Chemical but is also related to some degree to the similar trend from Samsung SDI, Hyundai, and SB LiMotive

Fig. 3.4 **Timeline for different countries**

Figure 3.4a. Absolute Data

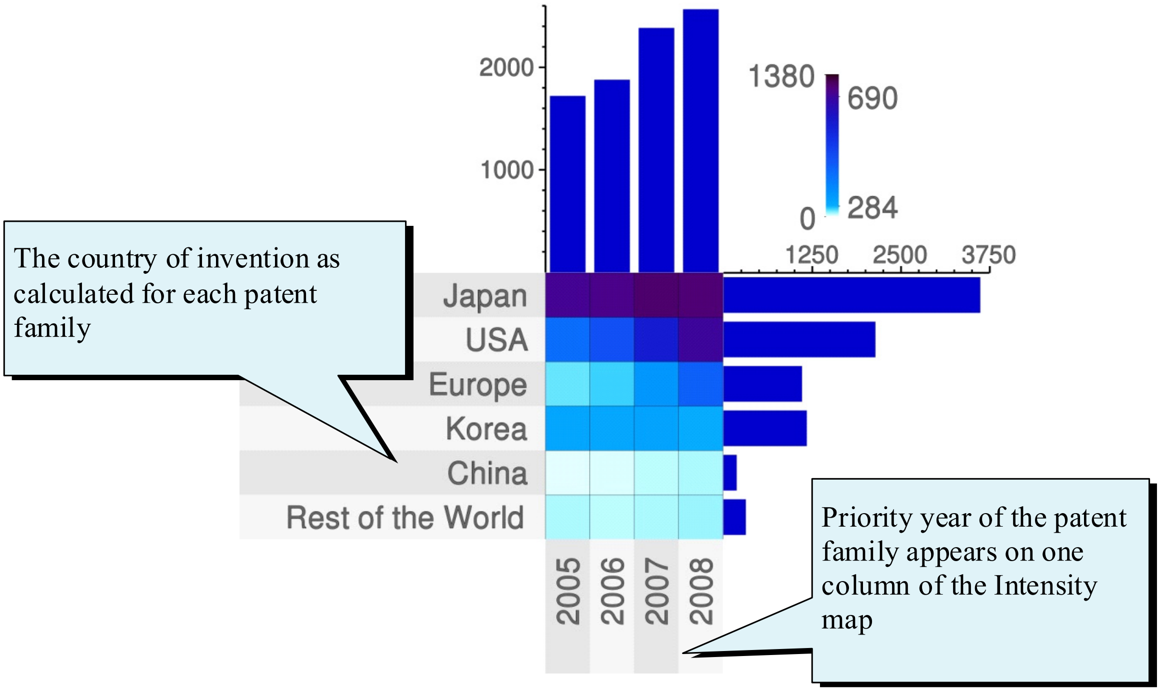
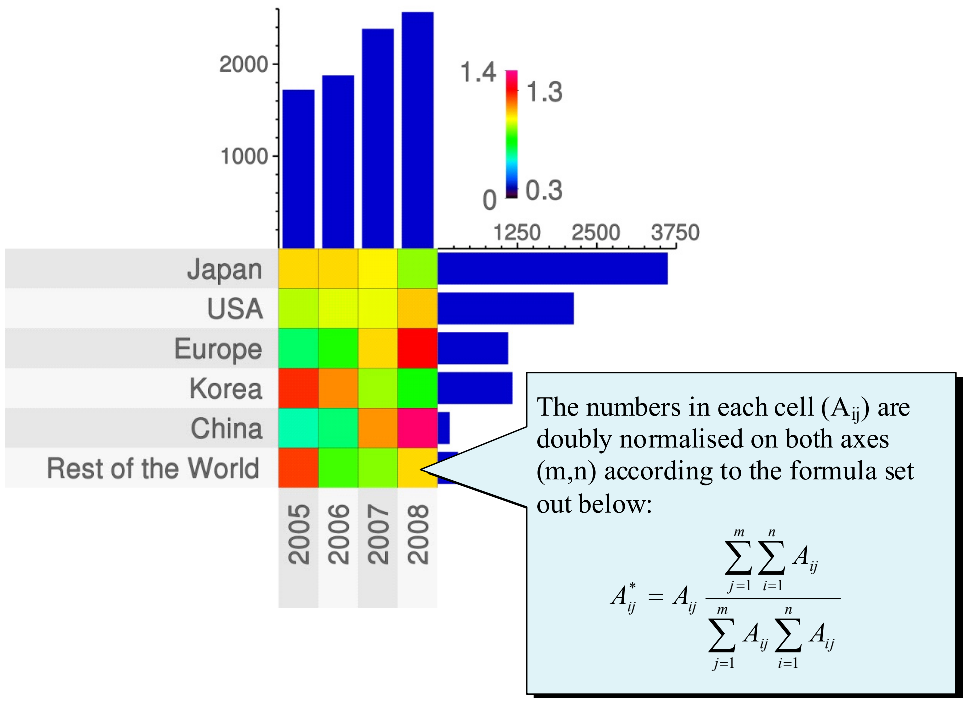


Figure 3.4b. Normalised Data



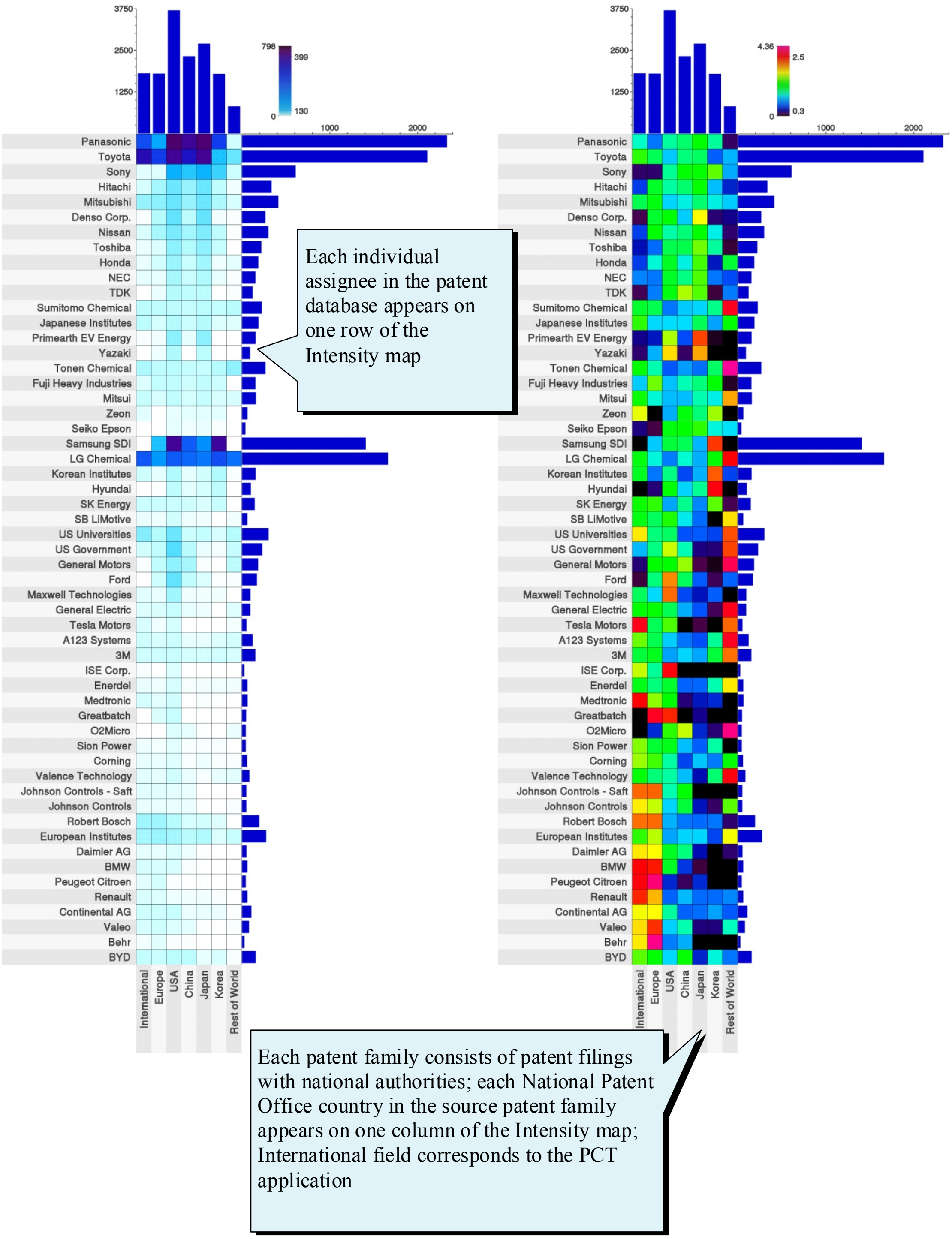
Source PatAnalyse

3.5. Top 50 Assignees and their strategy for applying to National Patent offices

Fig 3.5. Top 50 Assignees and their strategy for applying to National Patent offices

- In spite of the geography of the main players the most popular destination for patenting the inventions follow the markets – foreign patent applications are taken predominately to US, China and Europe. Patent applications in Japan and Korea are heavily dominated by the domestic companies with some added overspill from Korea to Japan and vice versa
- Substantial number of companies is ignoring the International Patent office (PCT) in their patent filings. The list includes Sony, Denso, TDK, Primearth EV Energy, Yazaki, Seiko Epson, Samsung SDI, Hyundai, General Motors, Gretbatch, and O2Micro.
- European patents are ignored by the companies like Sony, Primearth EV Energy, Zeon, Seiko Epson, Hyundai, and O2Micro
- Chinese patents are ignored by Yazaki, Tesla Motors, ISE Corp., Medtronic, Greatbatch, and Peugeot Citroen.
- Japanese and Korean patents are ignored by many US and European companies. It is interesting to note substantial amount of Korean filings in the patent portfolio of companies like A123 Systems, Enerdel, Sion Power, and Valence Technologies.

Fig. 3.5 **Top 50 Assignees and their strategy for applying to National Patent offices– absolute and normalised**



Source PatAnalyse

3.6. Country of Invention vs National Patent Office Country

Fig 3.6. Country of Invention vs National Patent Office Country

- This Patent Map aggregates both large and small players from the same country to provide an overall view of the trends
- Patent portfolio is constructed from the patent families with substantial international exposure. All families must have either a patent applied to US, EP, PCT, or have to have national patent applications covering substantial part of Asian market via Japan, China, and Korea.
- This Patent Map shows the distribution of the patents from patent families by the national patent offices.
- Already a major manufacturer of lithium ion batteries, in future China will become an even more important patent destination for foreigners due to the Chinese government financial support for promoting electric vehicles. However domestic Chinese R&D in the energy storage technologies is not yet resulting in major international patent activities
- A substantial amount of patents taken to China from Japanese and Korean companies is supported to a lesser extent by US and European companies. However both US and Europe are gradually starting to take part in the trend

Fig. 3.6 **Country of Invention vs National Patent Office Country**

Fig 3.6a. Absolute Data

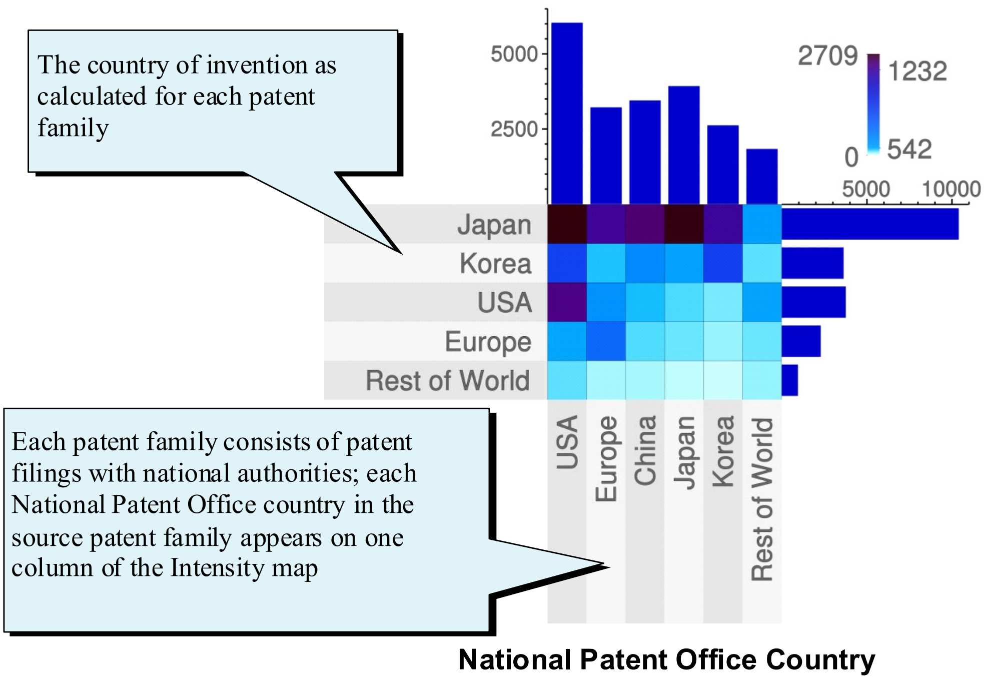
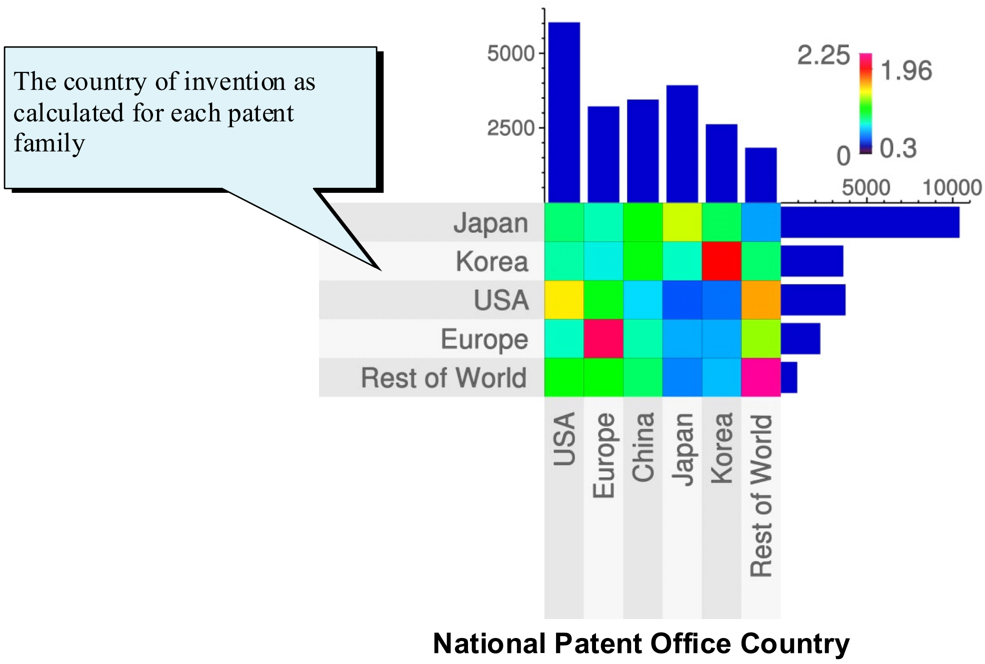


Fig 3.6b. Normalised Data



Source PatAnalyse

3.7. Citation links between Top Assignees

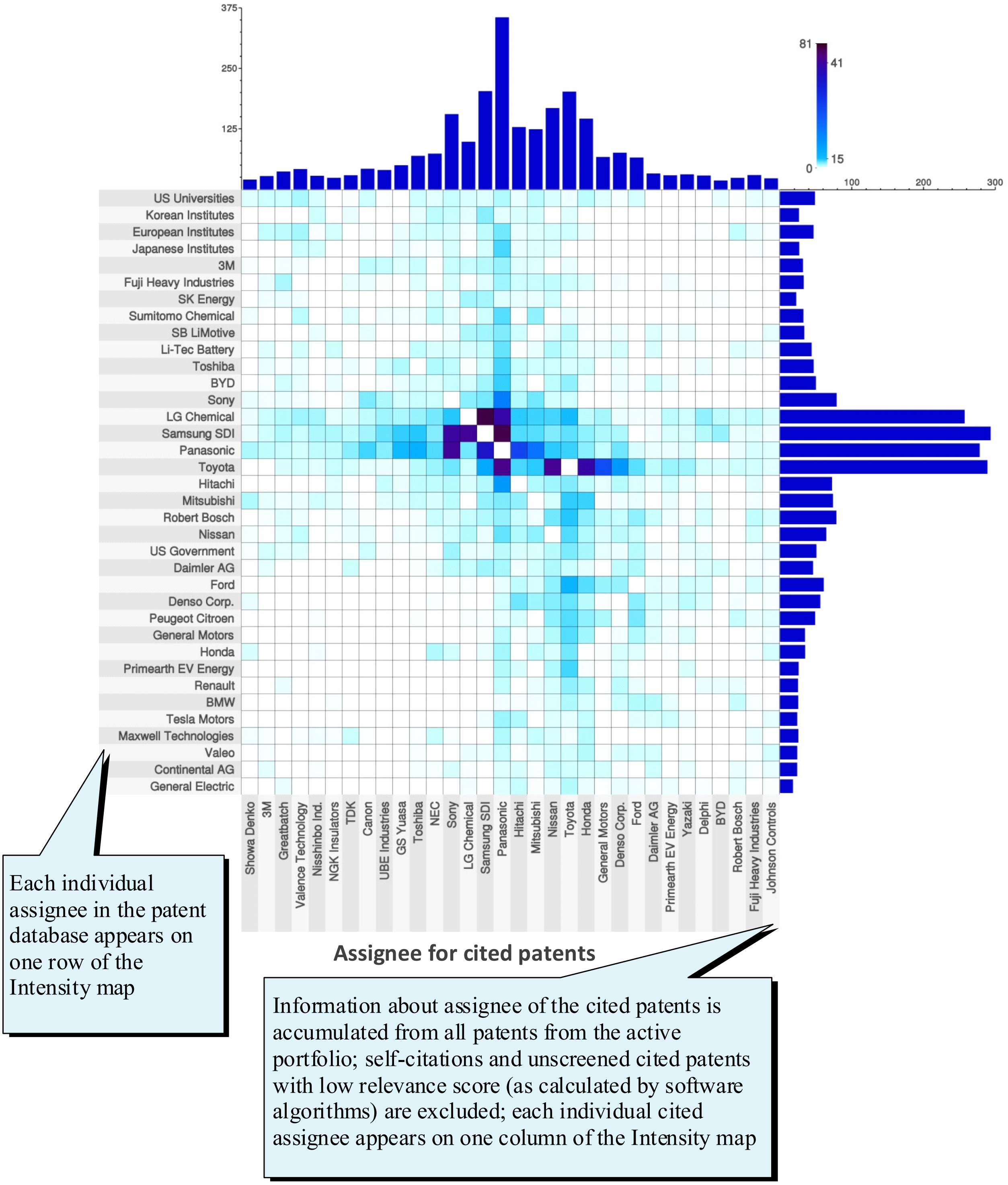
Fig 3.7. Citation links between Top Assignees

On this Map the citation links from patents are used as a measure of the international visibility of the R&D efforts of different companies. In order to correct the otherwise biased citation pattern, the self-citations (citations from one patent to another patent of the same Assignee) are ignored. Some apparent white spots in the busy areas on the Patent Map can be related to such removed self-citations.

Cited patents have been counted only if they are already included in the active patent portfolio of the current study or if they have a high relevance core to such patent portfolio.

- The citation network analysis shows the reduced dominance of the main four players. As a result LG Chemical has even dropped out from the list of the first tier players

Fig. 3.7 **Citation links between Top Assignees**



Source PatAnalyse

- Apart from Samsung SDI, Panasonic, and Toyota the refreshed list of first tier players contains names like Sony, Hitachi, Nissan, Honda, and Mitsubishi
- Second tier players are including LG Chemical, NEC, Toshiba, General Motors, Denso Corp., and Ford
- Not surprisingly the clustering of the Map shows the clear split of major players between the one related more to the electric vehicle markers and another one related to battery makers.
- The group of Japanese companies like Panasonic, Mitsubishi, Hitachi, Nissan, and Toyota has emerged on the Citation Link Map as an impressively integrated companies with substantial overlapping in the EV and lithium battery development space
  - Both Toyota and Panasonic have stronger preference towards either EV or lithium=m battery technologies an represent a clear boundary for this vertically integrated cluster of companies

3.8. Most prolific Inventors as a measure of aggressive patent strategies

Fig 3.8. Most prolific Inventors as a measure of aggressive patent strategies

The major four players Panasonic, Toyota, Samsung SDI, and LG Chemical have a relatively similar number of patents in the project portfolio. From the analysis of the most prolific inventors from these four companies it is obvious that all four first-tier players have most aggressive and rather questionable patent strategies. For instance, LG Chemical has 65% of its patent portfolio authored by most prolific inventors. For other companies this figure is slightly lower:

- LG Chemical 65%
- Panasonic 53%
- Samsung SDI 45%
- Toyota 34%

The lower percentage number for Toyota is most probably related to the substantial increase in the Toyota's patent activities during the timeline of the study. As a result of this change in the Toyota's focus some inventors have started their patenting activities with a substantial delay, and thus have failed to accumulate enough patents in the project's patent portfolio.

Most other companies will have much lower part of their portfolio underpinned by the most prolific inventors. Typical company will have just one or two prolific inventors. As a result, the share of the patent portfolio authored by such inventors is much smaller; for instance, the following figures can be shown for the second-tier Japanese players:

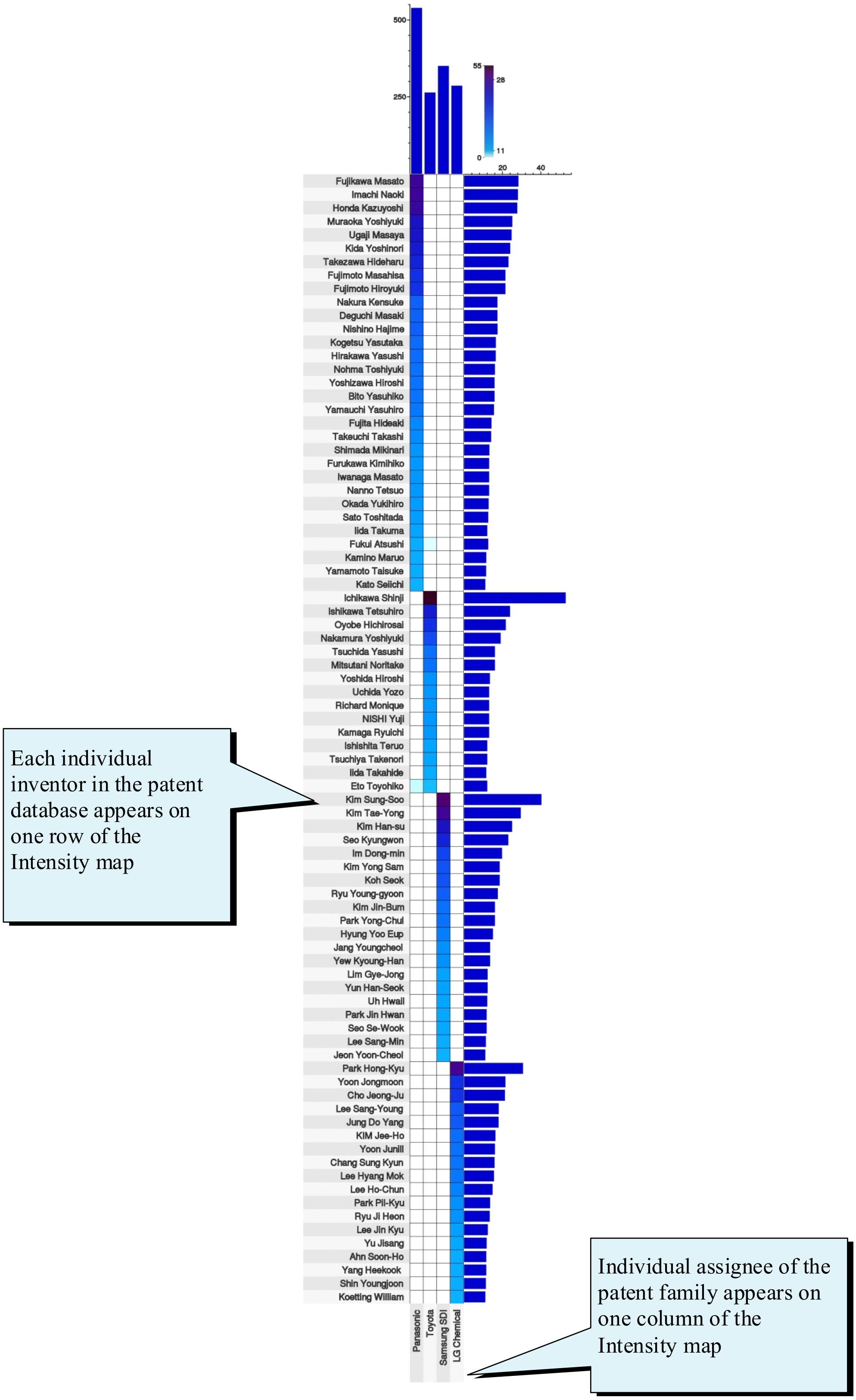
- Denso 19%
- Hitachi 15%
- Honda 14%
- Mitsubishi 0%

It is worth to emphasise some further peculiarities related to LG Chemical patent portfolio:

- LG Chemical has the most aggressive patent strategies with the patent portfolio heavily dominated by prolific inventors (see Fig 8)
- LG Chemical patent portfolio is rarely cited by its competitors (see Fig 7) which provides an evidence for below the average quality of most patents in the LG Chemical portfolio
- LG Chemical has substantially reduced its patent filings during last several years (see Fig 2)

It seems that LG Chemical is at threat of losing its leading position in lithium battery market due to reduced focus on developing its future position in the rapidly changing technology landscape.

Fig. 3.8 **Most prolific Inventors as a measure of aggressive patent strategies**



Source PatAnalyse

4. Generic Lithium Battery technologies

4.1. Introduction

A list of technical categories was created with a view of facilitating Patent Maps visualisation of general technology trends in lithium batteries R&D landscape.

Two broad categories related to the chemistry of anode and cathode are the subject of the separate detailed analysis in the two consecutive chapters. As a general trend, nanotechnology is emerging as a new pacing technology for the development of better anode and cathode materials. Improved mesoporous/nanoporous physical structure of electrodes allows for faster recharging of the battery – the process in which lithium is extracted from the cathode and moved as the cations Li^+ through the electrolyte to become intercalated into the bulk of the anode via a redox reaction. Nanoporous materials can increase the speed of the redox reaction and to reduce mechanical deformation of the lattice of the host electrode material. Most patents related to the nanotechnology are describing material system for anode (about 70%) due to the fact that most promising anode material systems like $Li_{4.4}Si$ or $Li_{4.4}Sn$ are subject to huge volume variation during the lithium insertion/extraction cycle and so might suffer from the pulverization of the electrode and very rapid capacity decay. Thus such materials should be used in a specially engineered nanocomposite form.

For the purpose of introduction to this chapter we will focus more on the technical development in electrolytes and separators technologies.

Electrolytes can be classified as

- Liquid electrolyte
- Gel electrolyte

- Polymer electrolyte
- Ceramic electrolyte

Polymer electrolytes have only cationic conductance, which serves as a substantial advantage in comparison to the liquid and gel electrolytes; the latter are characterised by both cationic and anionic conductance. As a result, liquid and gel electrolytes are used with an additional separator between electrodes; polymer electrolytes have a functionality of a separator on their own but they typically add a gel for low temperature performance. In the early days, common liquid electrolytes were creating a flammable hazard during the thermal runoff of the battery; their safe operation has been improved by developing separators with a built-in thermal shutdown mechanism.

Most patents related to the separator technologies are focused on physical form-factor properties for reducing strain during thermal cycling, improved electrical breakdown strength, etc. Chemical composition is mentioned in the patents aiming at developing a build-in thermal shutdown mechanism. Combination of different polymers is frequently used to allow appropriate functionality in the normal regime of operation with the additives mainly responsible for the safe battery functionality in the extreme regime.

A clear emerging trend in the separator technology is related to the direct integration of the electrode material onto the separator layer or alternatively to using barrier coating with well defined separator properties directly on the surface of the electrode. Such highly integrated electrodes have a controlled active interface between the electrode and the separator and thus provide a more robust and reproducible manufacturing method especially useful for traction batteries due to the reduced volume.

Liquid electrolytes are typically based on organic solvent with dissolved lithium salts. The range of salts varies from the standard one like $LiPF_6$; $LiAsF_6$; $LiSbF_6$; $LiClO_4$ and $LiBF_4$ to more specialised like:

$LiPF_5CF_3$; $LiPF_4(CF_3)_2$; $LiPF_3(CF_3)_3$; $LiPF_2(CF_3)_4$; $LiPF(CF_3)_5$; $LiP(CF_3)_6$
LiBOB ; $LiB(C_2O_4)_2$; $LiB(C_6H_5)_4$; $LiAlCl_4$; LiAlCl3 ; $LiAlF_3$,
$Li_{3.3}PO_{3\,.\,9}N_{0.1}$; $LiPF_2(C_2O_4)_2$; $LiC(SF_5)_3$; $LiN(CN)_2$; LiSCN
Li_2SO_3 ; Li_2CO_3 ; $LiCH_3CO_2$; $LiCF_3CO_2$; $LiCF_3CF_2(CF_3)_2CO$
$LiCH_3SO_3$; $LiCF_3SO_3$; $LiCF_3CF_2SO_3$; $LiCF_3(CF_2)_3SO_3$; $LiCF_3(CF_2)_7SO_3$; $LiCH(CF_3SO_2)_2$; $LiC(CF_3SO_2)_3$
LiBr ; LiCl ; LiI ; Li_3P;
$Li\text{-}NH_2$; $LiNO_3$; $LiN(SO_2)_2$; $LiN(SO_2C_2F_5)_2$; $LiN(SO_2CF_3)_2$; $LiN(CF_3CF_2SO_2)_2$; $LiN(FSO_2)_2$

A popular subject for patent applications for lithium battery electrolyte technology is related to chemical additives. Such additives can be used to improve physical parameters like electric conductivity, density, viscosity, and lithium salt solubility. The combination of the physical/chemical properties of the additives can also be used to improve the battery safety during the overcharging, as well as to improve the flame retardation or to achieve an explosion proof battery system.

Additives can be also used to improve the temperature range and optimise electrochemical process by neutralising emitted gases (for instance by using cyclic carbonate). General stabilisation of the electrolyte is achieved by preventing thermal decomposition in liquid electrolytes using such additives as sulfocompounds and carboxylic salts. In gel electrolytes the amines are additionally used as a "proton collection" vehicle.

As a new trend in liquid lithium electrolytes, some patents are describing ionic liquids. Ionic liquids are based on liquid compositions (salts) with complex organic anions and nonorganic (lithium) cations. There is no problem in dissolving large amount of lithium in such ionic liquids, which allows achieving high concentration of lithium ions and consequently a high conductivity. The main drawback is related to the unwanted process of washing-out the lithium ions from the electrodes and substantial number of patents is aiming to develop solution to this problem. The commercialisation of the ionic liquid technology is restricted mainly because of the high cost of ionic liquids and the common issue related to a limited temperature stability of most practical ionic liquids.

It is possible to identify several trends in the technical development for polymer electrolytes.

- First trend is related to the physical form-factor. In such approach polymer electrolyte is considered almost as a separator. Its physical properties are improved using nanotechnology including lithium salt nanofibers, nano-domains, mesoporous structures, etc.
- Second trend is related to the various approaches aimed to enhancing the temperature range for lithium batteries. The focus is equally split between the lower temperature range (below -20 degree) and higher temperature range (above 80 degree).
- Third trend is related to the additives, specifically to the one which provides the optimisation of electrochemical process. Main issue is related to the controlled and uniform formation of the solid electrolyte interphase (SEI) film on the surface of the anode. Such SEI film prevents electrolyte decomposition by blocking unwanted side chemical reactions on the surface of the anode without reduction in the ionic conductivity. This in turn improves cycle characteristics of a lithium battery, and prevents cycle deterioration. Quite a lot of patents are also describing additives for gas neutralisation or a free radical capture in the polymer electrolytes.

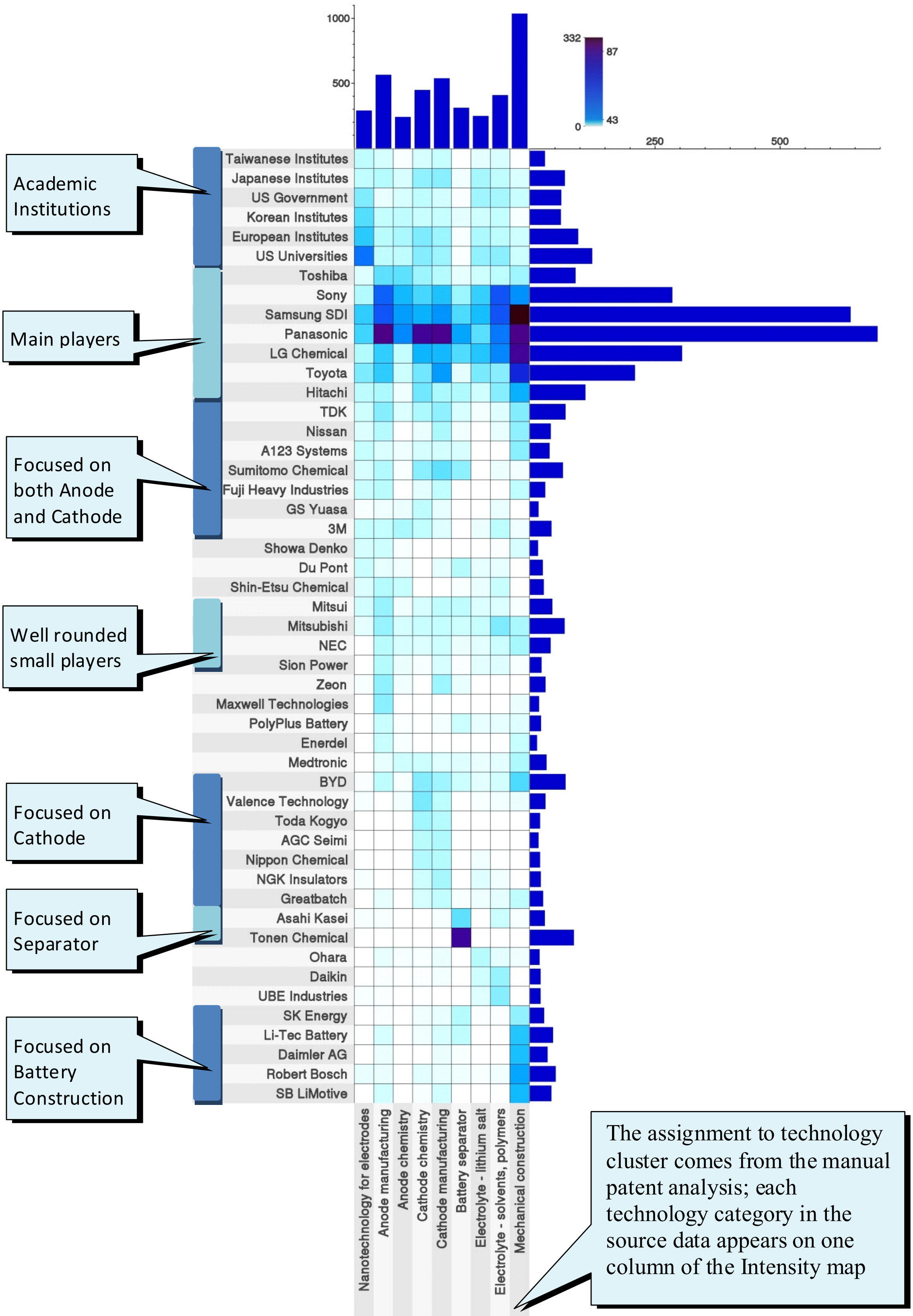
It is clear that there is still quite lot of potential in developing a better polymer electrolyte system however all simple ideas are mostly patented by now. In seeking to meet the market need of higher energy density, notably for longer pure electric range, some attention is therefore now turning to inorganic solid electrolytes in what are commonly called third generation lithium-ion traction batteries.

4.2. Top 50 Assignees vs Technical categories

Fig 4.1. Top 50 Assignees vs Technical categories

- The list of main players is dominated by Panasonic and Samsung SDI. Sony, LG Chemical, and Toyota are forming a list of second-tier players.
- 30% of patenting activities in the separator technologies are related to a single company – Tonen Chemical.
- 45% of patenting activities in nanotechnology are directly related to academic efforts. Another 30% are related to the first and second tier players. This provides an indication that such technologies are gradually changing their status from being just an academic emerging technology to become a pacing technology widely accepted by the whole industry.
- Equal attention is provided to four main subgroups in the portfolio:
  - Anode
    - Nanotechnology in electrode manufacturing (mainly related to anode), anode manufacturing and anode chemistry
  - Cathode
    - Cathode manufacturing and cathode chemistry
  - Electrolyte and separator
    - Electrolyte – lithium salts, electrolyte – additives, solvents and polymers, battery separators
  - Mechanical construction and packaging of the battery.
- Mechanical construction and packaging is an important focus of most companies involved in the traction lithium batteries technologies

Fig. 4.1 **Top 50 Assignees vs Technical categories**



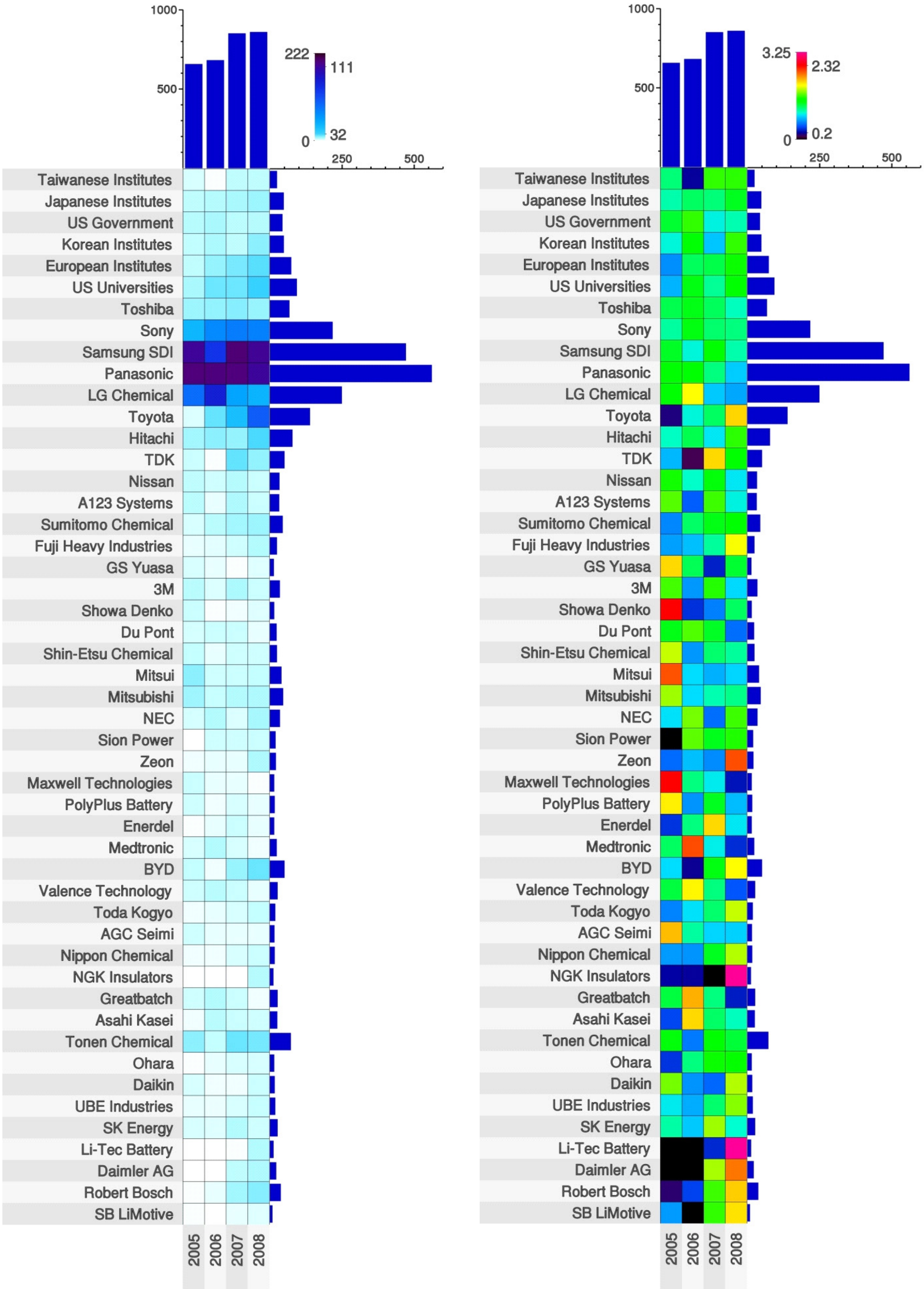
Source PatAnalyse

4.3. Top 50 Assignees vs Priority Years

Fig 4.2. Top 50 Assignees vs Priority Years

- Substantial amount of companies are accelerating their patent filing rate. The list of such companies is dominated by Toyota, which is showing an impressive rate of growth. Other companies on a list are including BYD, TDK, Fuji Heavy Industries, Zeon, UBE Industries, Nippon Chemical, NGK Insulators, Li-Tec Battery, Daimler AG, Robert Bosch, and SB LiMotive.
- Surprisingly, substantial number of companies is reducing their patenting activities. The most dramatic reduction is shown by LG Chemical, but quite visible reduction is showing by the first tier players like Panasonic and Samsung SDI. The list of smaller companies includes PolyPlus Battery, Medtronic, Valence Technology, AGC Semi, A123 Systems, Greatbatch, and Mitsui

Fig. 4.2 **Top 50 Assignees vs Priority Years– absolute and normalised**



Source PatAnalyse

4.4. Technical categories vs Priority Years

Fig 4.3. Technical categories vs Priority Years

- Overall patenting rate is increased by 40% during just 4 years. This is substantial growth unknown in mature industries.
- There is no growth rate in subject areas related to electrolytes and anode manufacturing, as a result these areas looks as declining in popularity on the normalised graphs.
- Nanotechnology has attracted a 100% growth in 4 years which most probably shows that this subject area has a clear commercial potential in the very near future.

Fig. 4.3 **Technical categories vs Priority Years**

Fig 4.3a. Absolute Data

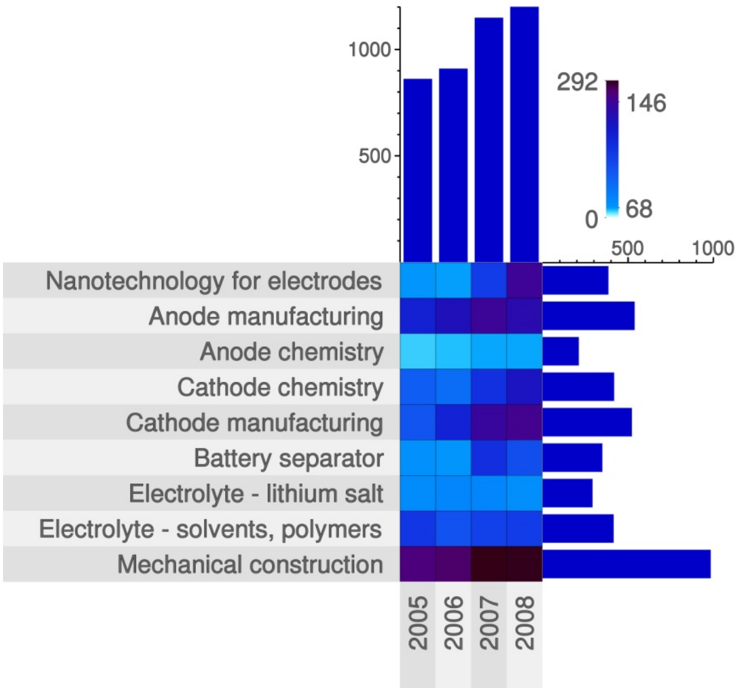
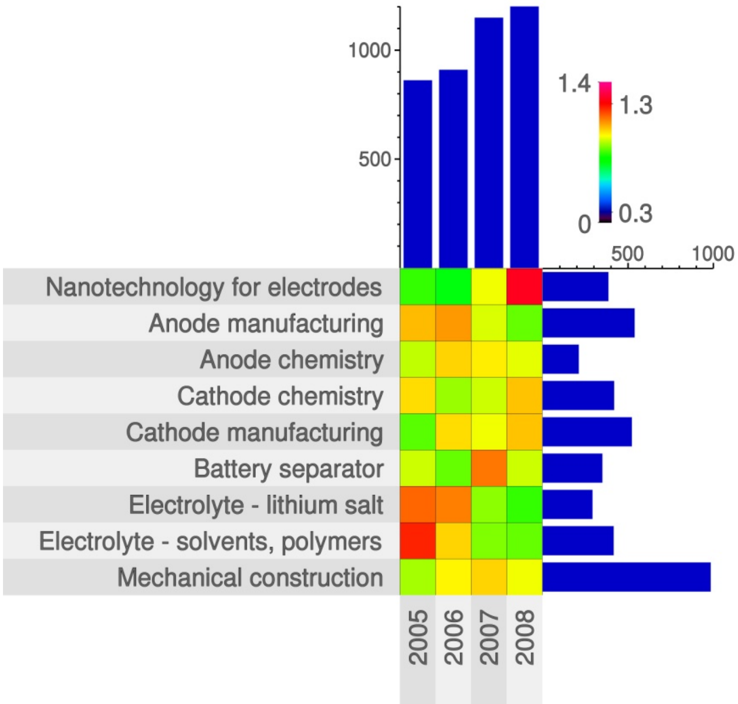


Fig 4.3b. Normalised Data



Source PatAnalyse

4.5. Countries of origin vs Priority Years

Fig 4.4. Countries of origin vs Priority Years

- On this Patent Map patent activities originated in US are well behind not only the Japanese one (who is ahead of US by a shocking 150%) but also behind Koreans.
- European and Chinese patent activities are well behind the Japanese, Koreans, and US one but are growing much faster than the global patent portfolio. Europe has shown fourfold increase in the patent activities which allowed it to become comparable to the US and Koreans patent activities in year 2008. If this trend to continue, Europe might overtake US and Korea in the coming years.
- Korea has shown the slight decline in the patenting rate in spite of the general growth in the global patent portfolio

Fig. 4.4 **Countries of origin vs Priority Years**

Fig 4.4a. Absolute Data

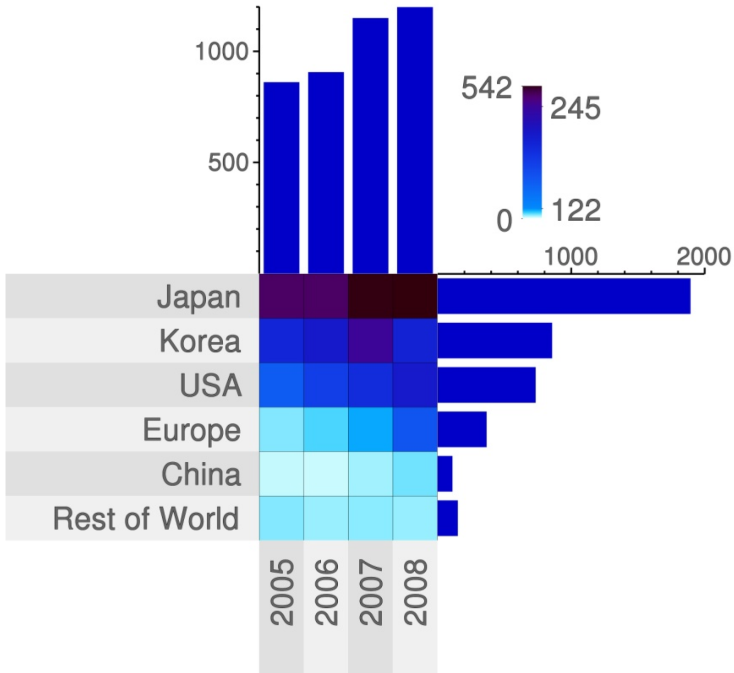
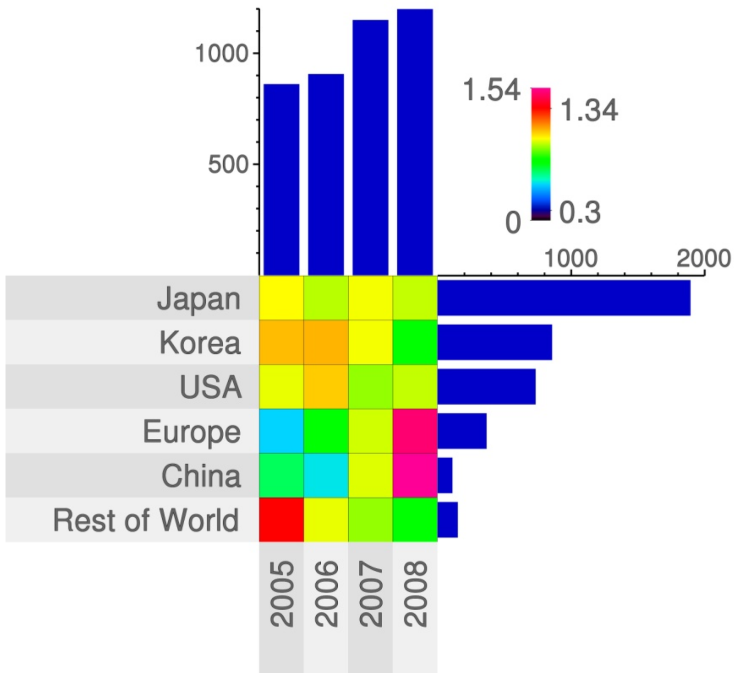


Fig 4.4b. Normalised Data



Source PatAnalyse

4.6. Technical categories vs Countries of origin

Fig 4.5. Technical categories vs Countries of origin

- Nanotechnology is a strong focus for patent activities originated in US and to a lesser degree to European patent activities. This is consistent with the government policies in US and Europe which are heavily supporting commercialisation of nanotechnologies.
- Japan has the strongest dominance in the patent activities related to manufacturing of anodes and cathodes
- Main focus of Samsung SDI and LG Chemical is in mechanical construction, this is reflected in the results aggregated for the whole Korea.

Fig. 4.5 **Technical categories vs Countries of origin**

Fig 4.5a. Absolute Data

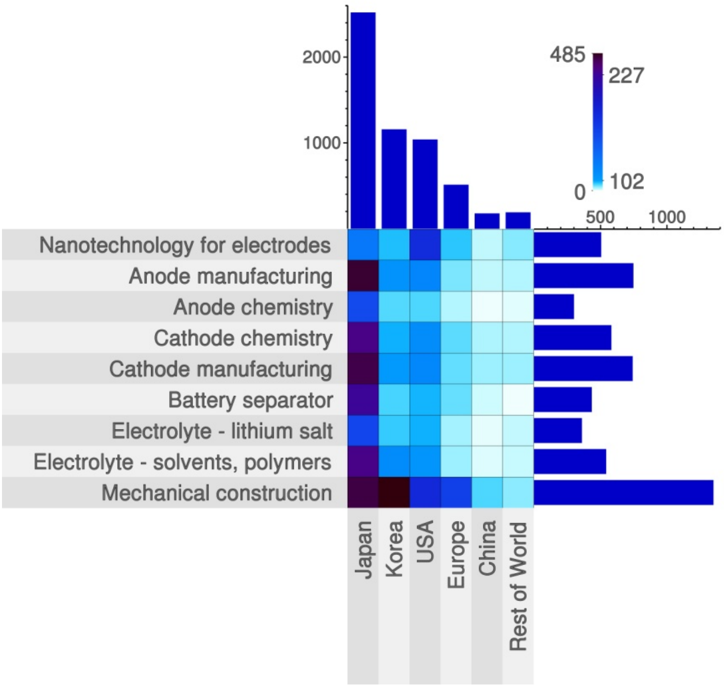
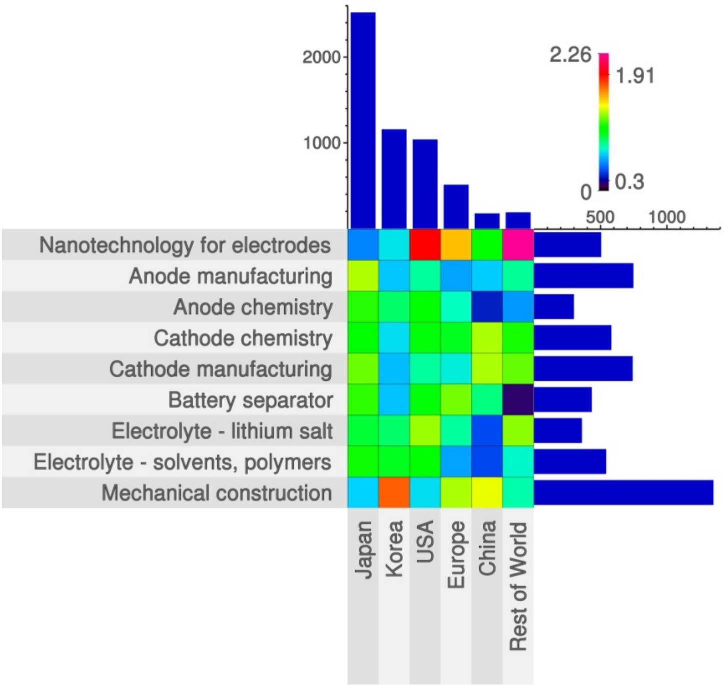


Fig 4.5b. Normalised Data



Source PatAnalyse

4.7. Technical categories vs National Patent Office Country

Fig 4.6. Technical categories vs National Patent Office Country

- National patent filings are following major markets.
  - China has a similar number of national patent applications if compared to Japan and Korea, but almost all Chinese patent applications have been invented outside of China ;
  - US patent filings are ahead of everyone else, however most of these patents are invented in Japan and Korea (see Fig 6 for comparison)
- Nanotechnology related patents are filed predominantly in US, and this subject area is most pronouncedly under-represented in China.
- Anode manufacturing and anode chemistry is a substantial specialisation of Asian national patent filings with most patents invented in Japan

Fig. 4.6 **Technical categories vs National Patent Office Country**

Fig 4.6a. Absolute Data

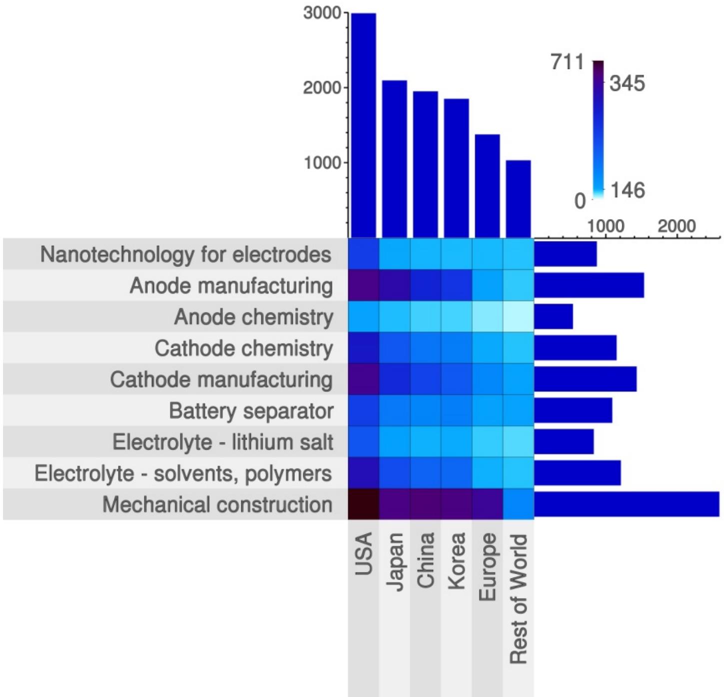
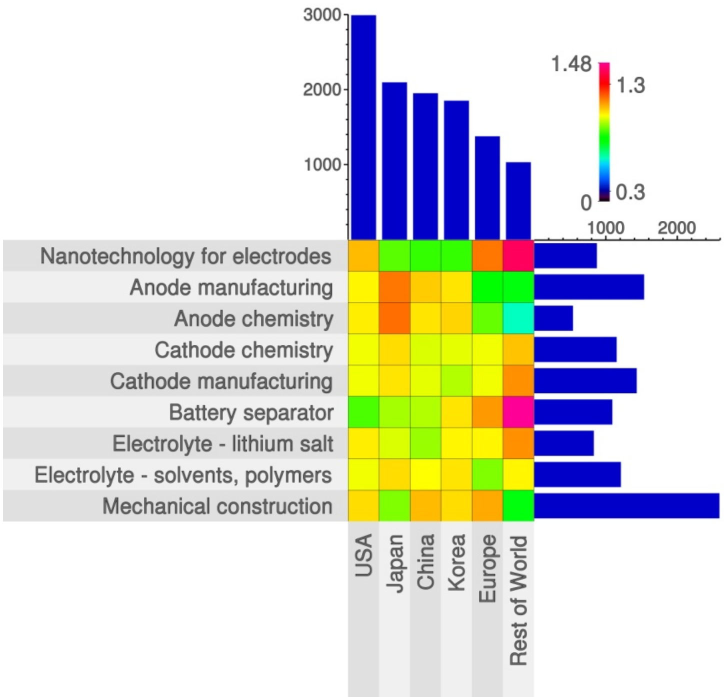


Fig 4.6b. Normalised Data



Source PatAnalyse

4.8. Further details of Anode chemistry

In many ways, though the cathode largely controls cost and performance, the anode is the weakest part of the battery cell due to the possible breakdown of the thin passivating Solid Electrolyte Interface/Interphase (SEI) layer on the anode.

The deposition of the SEI layer is an essential part of the formation process when the cells take their first charge. The electrolyte reacts vigorously with the anode material during the initial formation charge and a thin passivating SEI layer builds up moderating the charge rate and restricting current. The SEI layer increases the cell internal impedance and reduces the possible charge rates as well as the high and low temperature performance. The thickness of the SEI layer is not homogeneous and increases with age, increasing the cell internal impedance, reducing its capacity and hence its cycle life.

Excessive heat can cause the protective SEI barrier layer to breakdown allowing the anode reaction to restart releasing more heat leading to thermal runaway. The initial overheating may be caused by excessive currents, overcharging or high external ambient temperature.

Lithium titanate anodes do not depend on an SEI layer and hence can be used at higher charge/discharge rates. However lower anode reactivity means that cell voltage is substantially reduced which results in 25% to 30% lower energy density hence bulkier battery cells.

The anode is typically based on various material variations of carbon and its compounds. Substantial emphasis is given to developing the mesoporous/nanoporous carbon based structures at the surface of the anode in order to increase the recharging rate and to reduce the deformation of the lattice of the host active material related to the intercalation of lithium.

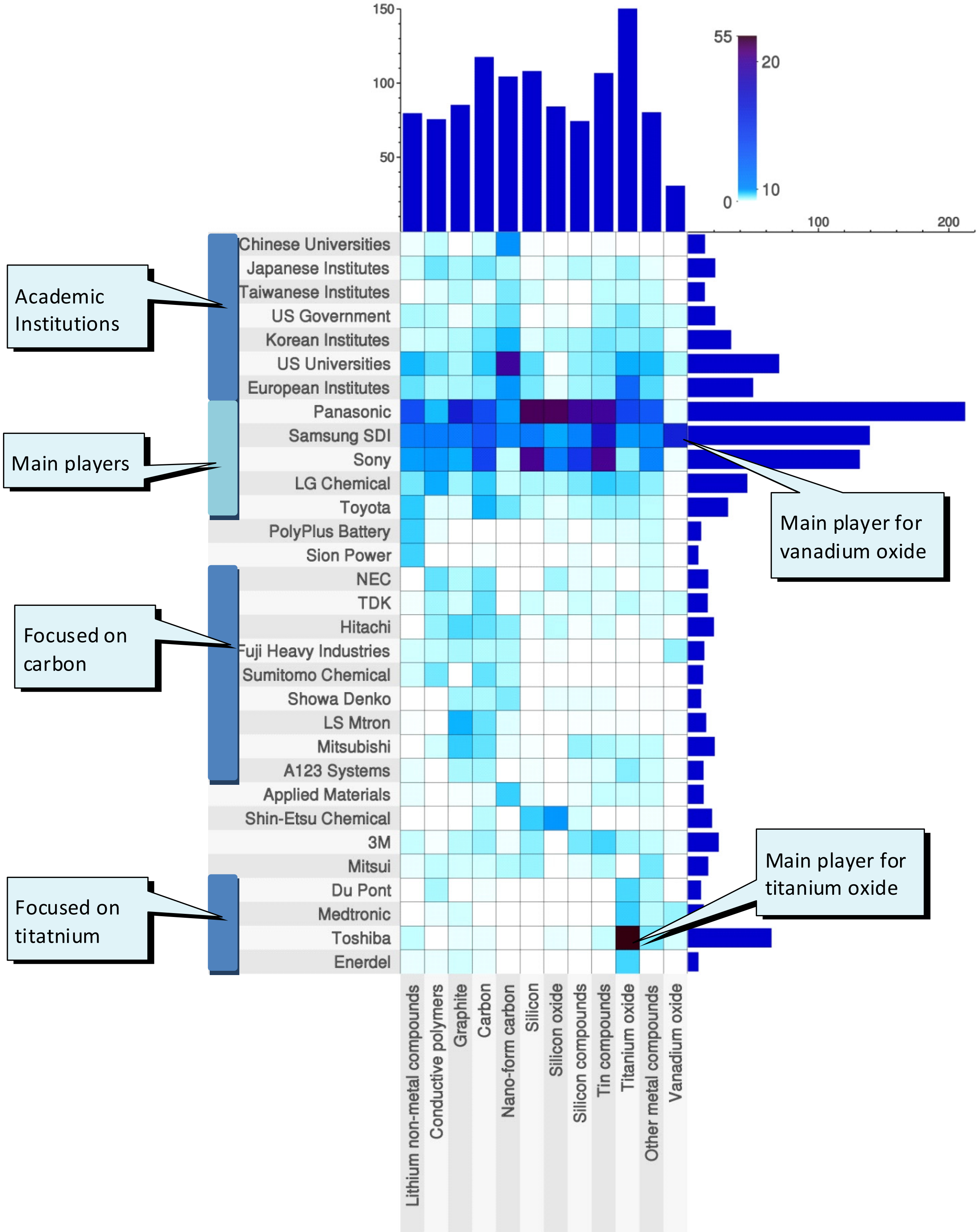
The current trend in patent activities is related to using various active materials embedded in the carbon host structure. Some patents are discussing the usage of conductive polymers as a way of increasing the conductivity of the anode, but most efforts are related to using compounds of silicon, tin, and titanium oxide as an active material. Many patent applications are describing the method of embedding the nanoparticles of the active material inside the carbon mesoporous shell. Some patents goes a step further by describing novel systems which are not using carbon matrix and are fully based on the non-carbon nanocomposite active materials like aluminosilicate, silicon oxide, titanium oxide, etc.

4.9. Top 50 Assignees vs Technical categories

Fig 4.7. Top 50 Assignees vs Technical categories

- Top companies developing anode technology are Panasonic, Samsung SDI, and Sony
  - Samsung SDI has specific focus in vanadium oxide but has a gap in silicon based material systems
  - Sony has a clear gap in using nanotechnology and in developing titanium oxide material system
- Toshiba is showing quite strong focus in titanium oxide material system
- LG Chemical is working with conductive polymers
- High level of patent activities of academic institutions is focused on nano-form carbon; it is further supplemented with few other areas of interest like conductive polymers and titanium oxide

Fig. 4.7 **Top 50 Assignees vs Technical categories**



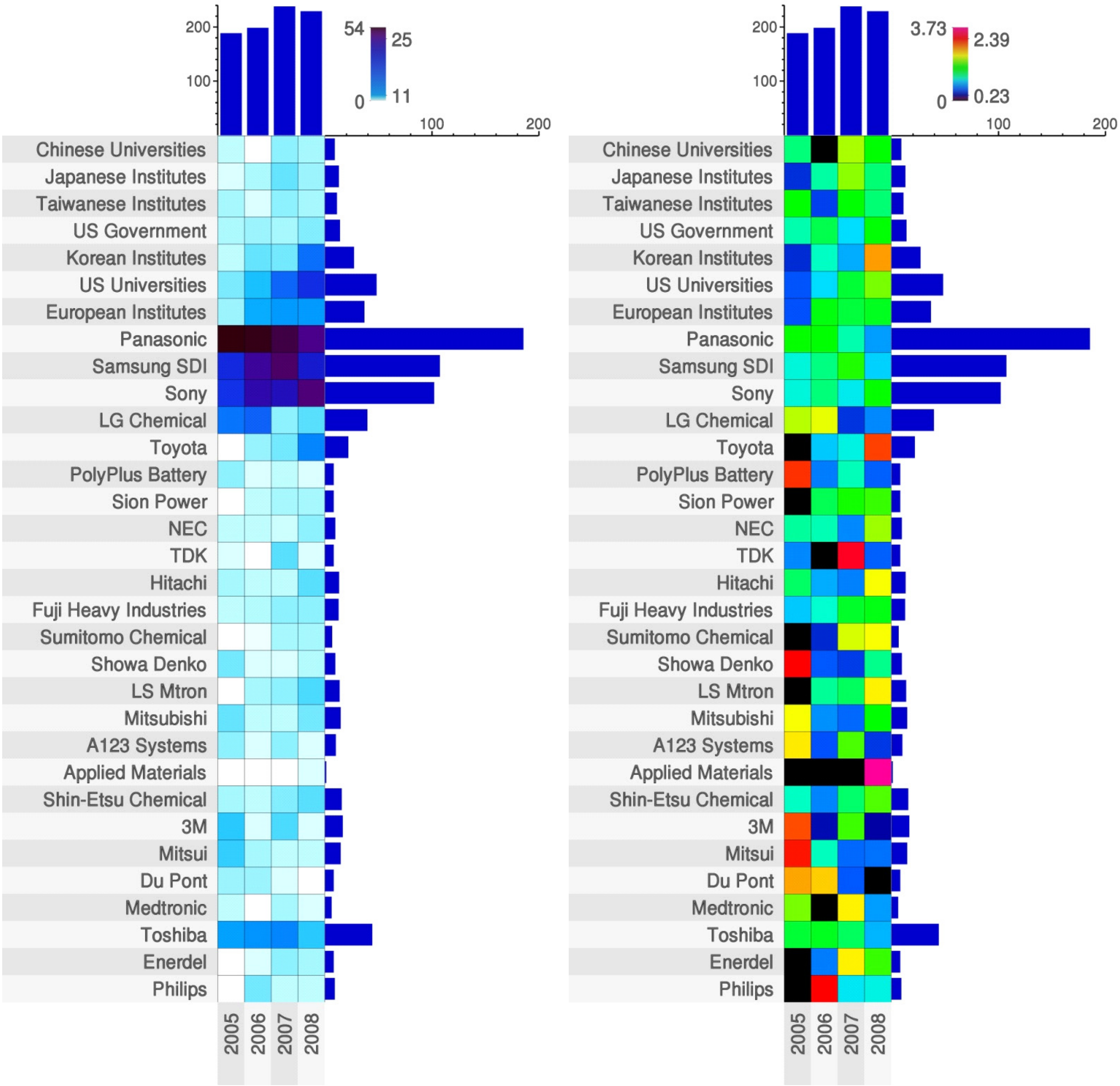
Source PatAnalyse

4.10. Top 50 Assignees vs Priority Years

Fig 4.8. Top 50 Assignees vs Priority Years

- The list of players showing the growth in patent activities includes Toyota, Sion Power, Sumitomo Chemical, LS Mitron, Enerdel, Philips, and academic players like Korean Institutes, US universities, and European Institutes
- A substantial decline in patent activities is demonstrated by LG Chemical, PolyPlus Battery, 3M‹ Mitsui, DuPont, Panasonic, Samsung SDI, and Toshiba
- It is very unusual to have a Patent Map showing the overall growth of patent activities against the substantial decline of patent activities of major players. The reduced activities of major players are substituted with a growing activity of small players and academic institutions. Most probably this reflects the second wave of innovation occurring now in the industry. Current technology for lithium batteries for mobile applications is reaching a maturity stage, the new growth is related to traction batteries, where many technical challenges might be related specifically to the anode chemistry
    - The result of such new wave of innovation might challenge the status quo in the industry and might lead to a number of forced acquisitions of small innovative companies by larger players in the near future.

Fig. 4.8 **Top 50 Assignees vs Priority Years– absolute and normalised**



Source PatAnalyse

4.11. Technical categories vs Priority Years

Fig 4.9. Technical categories vs Priority Years

- There is a clear trend of increasing the patent filing in the area related to the nanotechnology.
- Titanium oxide looks as an area of future growth in spite of reduced patent filings from Toshiba – the single largest proponent of this material system
- It also seems that carbon is not going to give up the top spot in the list of active anode materials. Patent activities for using carbon based material system are just increasing right now.

Fig. 4.9 **Technical categories vs Priority Years**

Fig 4.9a. Absolute Data

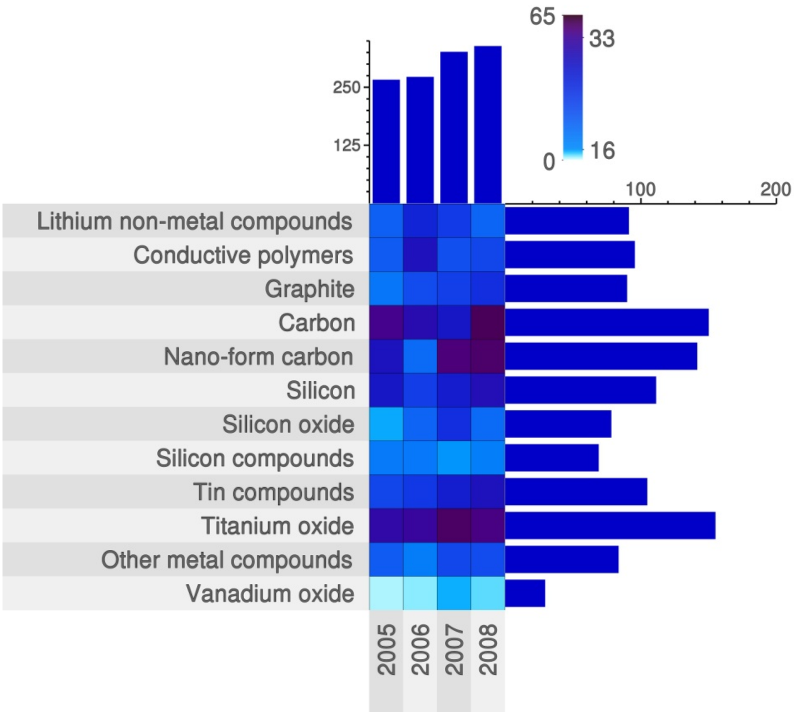
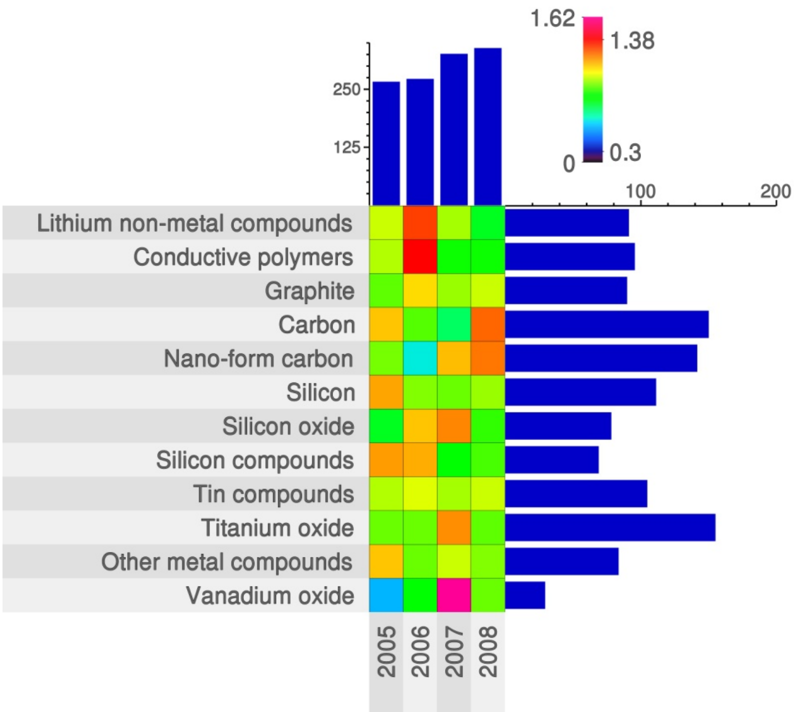


Fig 4.9b. Normalised Data



Source PatAnalyse

4.12. Countries of origin vs Priority Years

Fig 4.10. Countries of origin vs Priority Years

- Unlike on the Patent Map for overall lithium battery technologies, US is well ahead of Korea. This is related to a major focus on mechanical construction for the main Korean player - Samsung SDI
- Both China and Europe are increasing their contribution to R&D in the anode chemistry and manufacturing. However Chinese contribution is still disproportionately small

Fig. 4.10 **Countries of origin vs Priority Years**

Fig 4.10a. Absolute Data

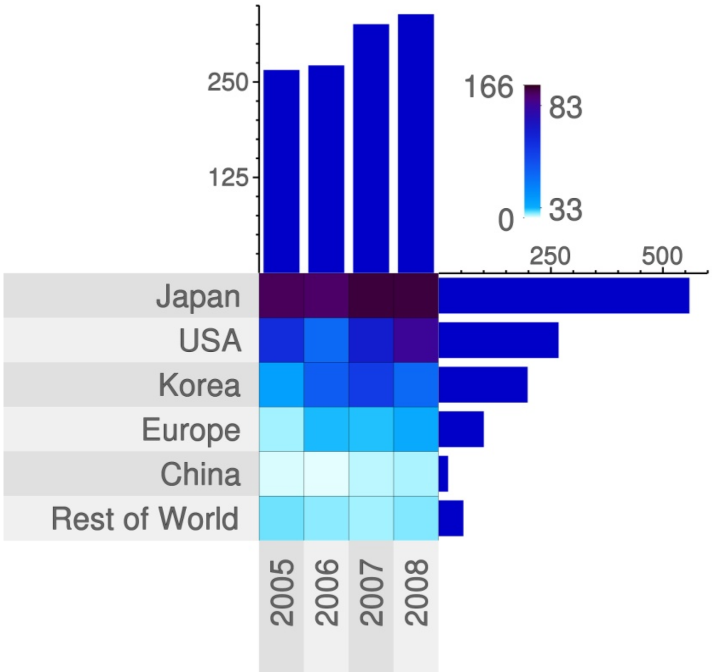
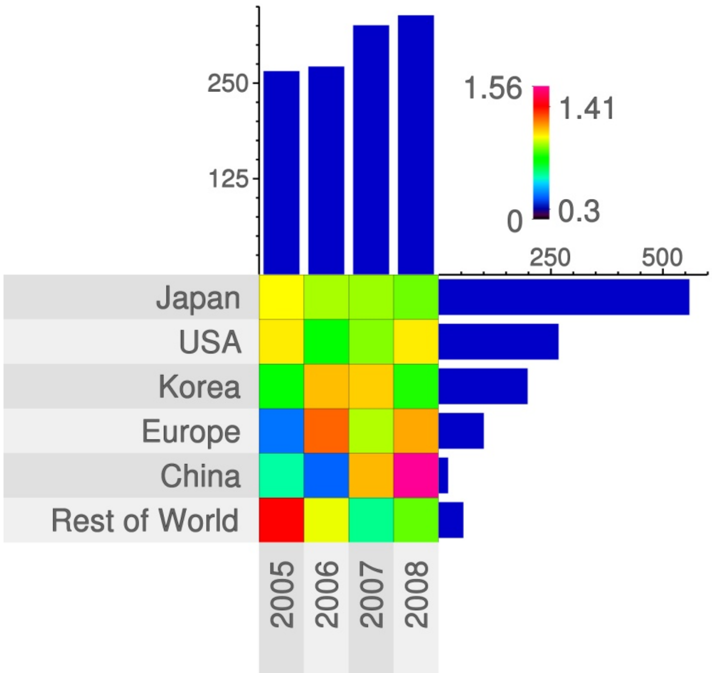


Fig 4.10b. Normalised Data



Source PatAnalyse

4.13. Technical categories vs Countries of origin

Fig 4.11. Technical categories vs Countries of origin

- Silicon, silicon oxide, silicon compounds, tin compounds, and graphite – are mainly a Japanese activity
- Titanium oxide, nano-form of carbon, carbon, and Lithium non-metal compounds are strong activities in US

Fig. 4.11 **Technical categories vs Countries of origin**

Fig 4.11a. Absolute Data

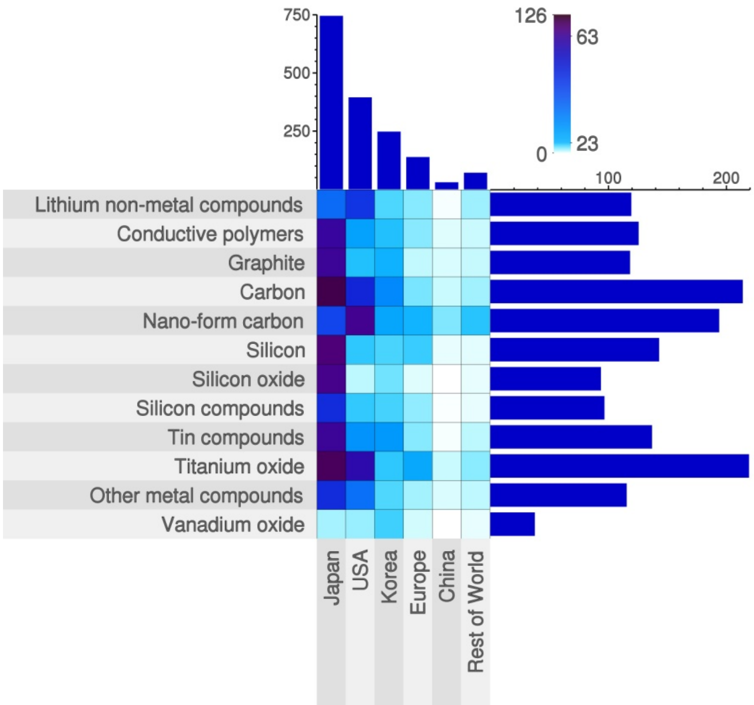
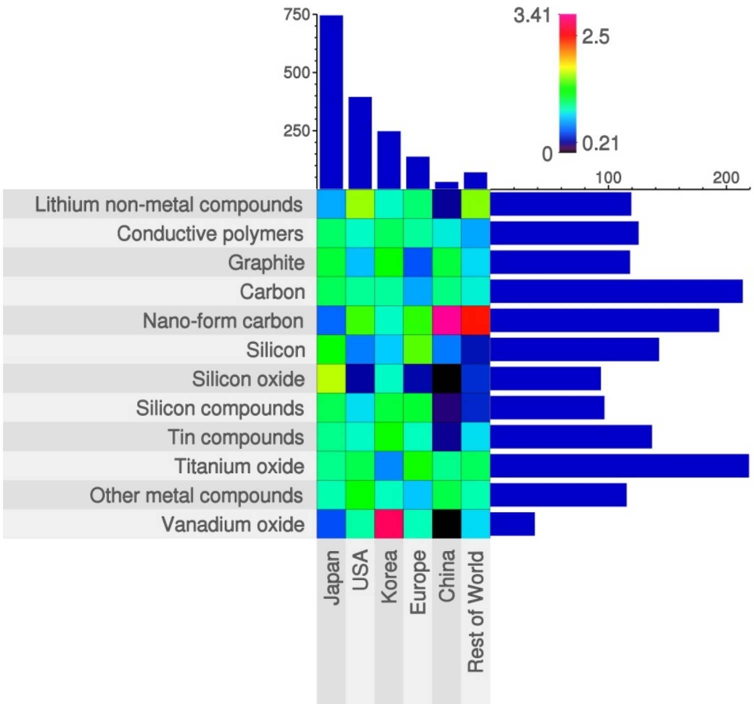


Fig 4.11b. Normalised Data



Source PatAnalyse

4.14. Technical categories vs National Patent Office Country

Fig 4.12. Technical categories vs National Patent Office Country

- China is a very popular destination for National patents invented in Japan, Korea and to some degree in US
- Japanese companies are actively patenting material systems related to silicon, silicon oxide, silicon compounds, tin compounds, and graphite in Korea and China. As a result this group of material systems is overrepresented in the Asia
- Nanotechnology patents are underrepresented in Asian countries
- Titanium oxide material systems are more actively patented in US and Europe compared to other material systems
- Vanadium oxide technology – patent activity originated from Korea – is taken to other countries but its share of European filings is slightly larger than it might be expected normally

Fig. 4.12 **Technical categories vs National Patent Office Country**

Fig 4.12a. Absolute Data

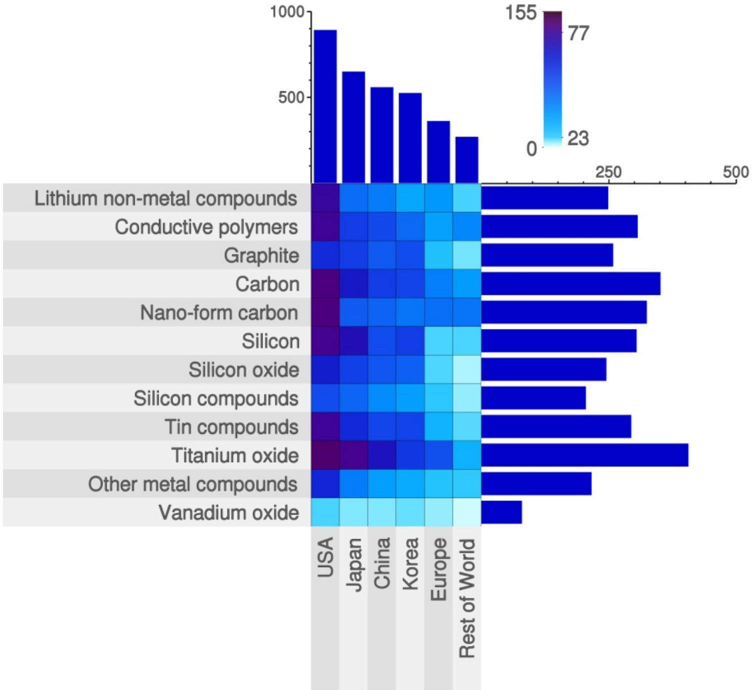
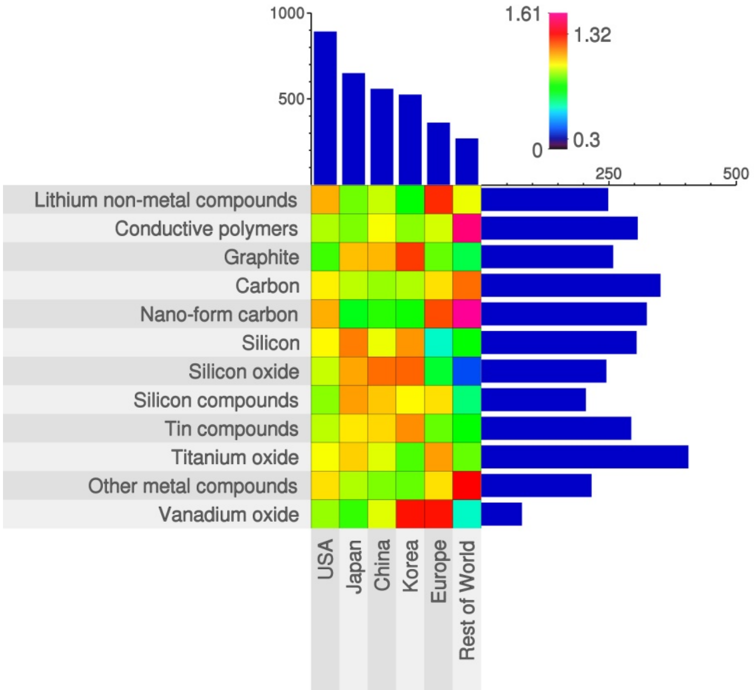


Fig 4.12b. Normalised Data



Source PatAnalyse

4.15. Further details of Cathode chemistry

Numerous variants of the basic Lithium-ion cell chemistry have been developed. Lithium Cobalt and Lithium Manganese were the first to be produced in commercial quantities but Lithium Iron Phoshate is taking over for high power applications because of its improved safety performance.

Lithium Iron Phosphate cathodes do not break down with the release of oxygen until 300°C with Lithium Cobalt breaking down at 170°C. The reason is that the Oxygen molecules in the Phosphate material have a much stronger valence bond to the Phosphorus and this is more difficult to break and when they do, much less energy is released. Lithium phosphate cells are incombustible in the event of mishandling during charge or discharge, they are more stable under overcharge or short circuit conditions and they can withstand high temperatures without decomposing. When abuse does occur, the phosphate based cathode material will not burn and is not prone to thermal runaway. Phosphate chemistry also offers a longer cycle life. The use of Lithium Iron Phosphate chemistry is the subject of patent disputes and some manufacturers are investigating other chemistry variants mainly to circumvent the patent on the $LiFePO_4$ chemistry.

Lithium (NCM) Nickel Cobalt Manganese - $Li(NiCoMn)O_2$ - has an improved safety compared to Cobalt oxide (oxygen break down at 250°C) and has much lower cost without compromising the energy density. Different manufacturers may use different proportions of the three constituent elements.

Lithium Manganese has slightly higher temperature performance compared to Lithium Nickel Cobalt Manganese. This chemistry is more stable than Lithium Cobalt technology and thus inherently safer but the trade off is lower potential energy densities. Manganese is also much cheaper than Cobalt, and is more abundant.

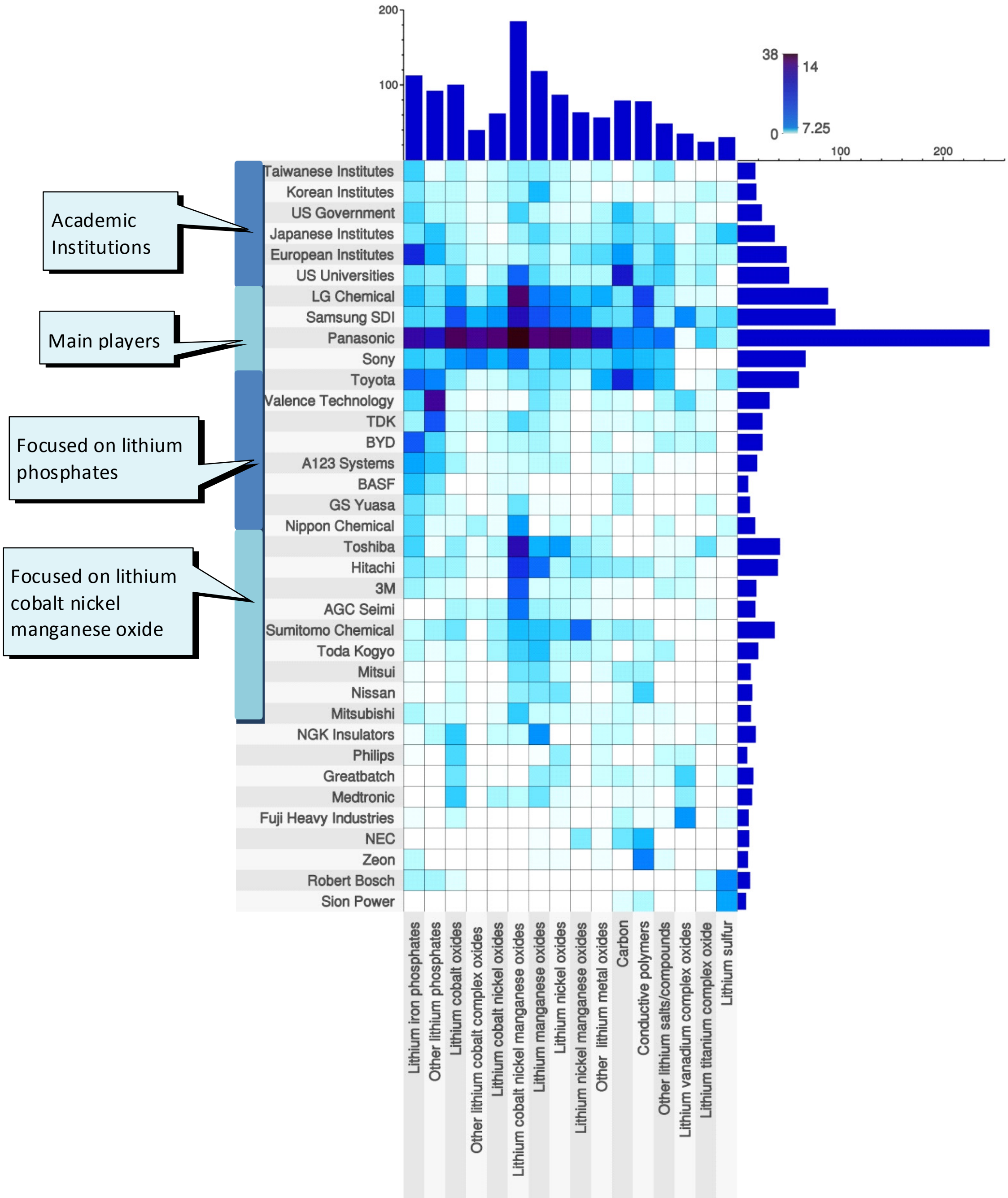
4.16. Top 50 Assignees vs Technical categories

Fig 4.13. Top 50 Assignees vs Technical categories

- Panasonic is an absolute leader in developing cathode material technologies
- The list of second tier players includes LG Chemical, Samsung SDI, Sony, Toyota, Toshiba, Hitachi, Sumitomo Chemical, and academic institutions in Europe and US.
- Lithium (NCM) Nickel Cobalt Manganese is a focus of most second tier players excluding Toyota and European Institutes
- The proponents of Lithium Iron Phosphate material systems are Panasonic, Toyota, BYD, and European Institutes. TDK, Toyota, and Valence Technology are developing non-Iron Lithium Phosphate technologies.
- Lithium Manganese Oxide and Lithium Nickel Oxide technologies are well represented with top players like Panasonic, LG Chemical, Samsung SDI, Hitachi, and Toshiba

- The usage of conductive polymers is under development by LG Chemical, Panasonic, Samsung SDI, Sony, Toyota, NEC and Zeon
- Carbon – mainly as a mesoporous/nanoporous host material for nanoparticles of the active material (like lithium iron phosphate) is under development by US Universities and Toyota. LG Chemical, Panasonic, Samsung SDI, and Sony have their own established development activity in this area.

Fig. 4.13 **Top 50 Assignees vs Technical categories**



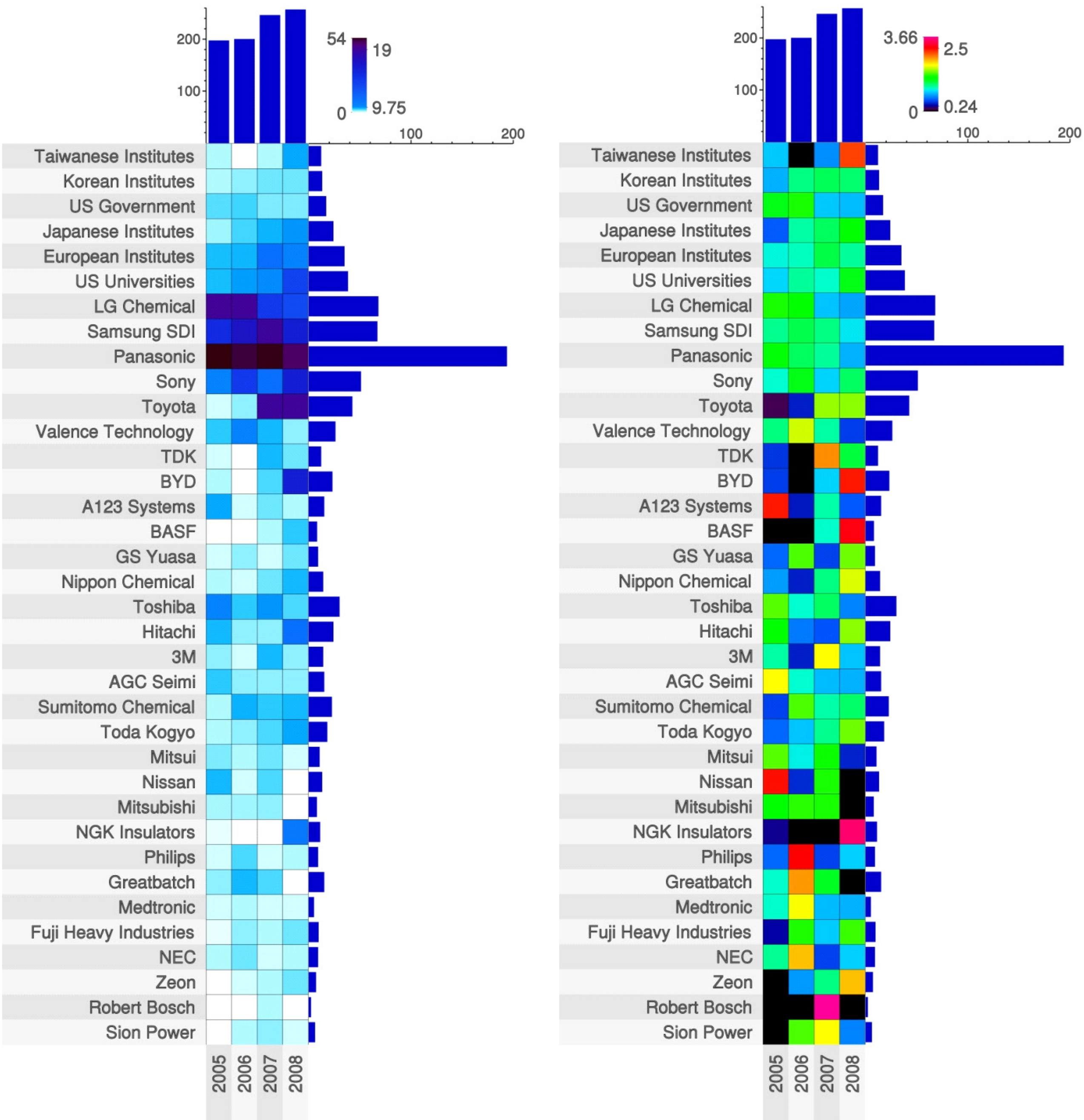
Source PatAnalyse

4.17. Top 50 Assignees vs Priority Years

Fig 4.14. Top 50 Assignees vs Priority Years

- The list of companies increasing their patenting activities is headed by Toyota and followed by BYD, TDK, BASF, Zeon, and Sion Power (developer of lithium sulphur technologies)

Fig. 4.14 **Top 50 Assignees vs Priority Years– absolute and normalised**



Source PatAnalyse

4.18. Technical categories vs Priority Years

Fig 4.15. Technical categories vs Priority Years

- Lithium phosphate material systems are the hottest subject of patent activities. At the moment the patenting rate for lithium phosphate is similar to the lithium cobalt based material systems but it probably has overtaken cobalt based chemistries in the most recent years since 2008. As have been mentioned earlier, the phosphate based cathode material is not prone to thermal runaway and offers a longer cycle life.
- Cobalt based chemistries, especially Lithium (NCM) Nickel Cobalt Manganese are attracting steady interest in spite of being quite mature and established material systems.
- Nanotechnologies based on nano- carbon as a host material are attracting increased attention right now

Fig. 4.15 **Technical categories vs Priority Years**

Fig 4.15a. Absolute Data

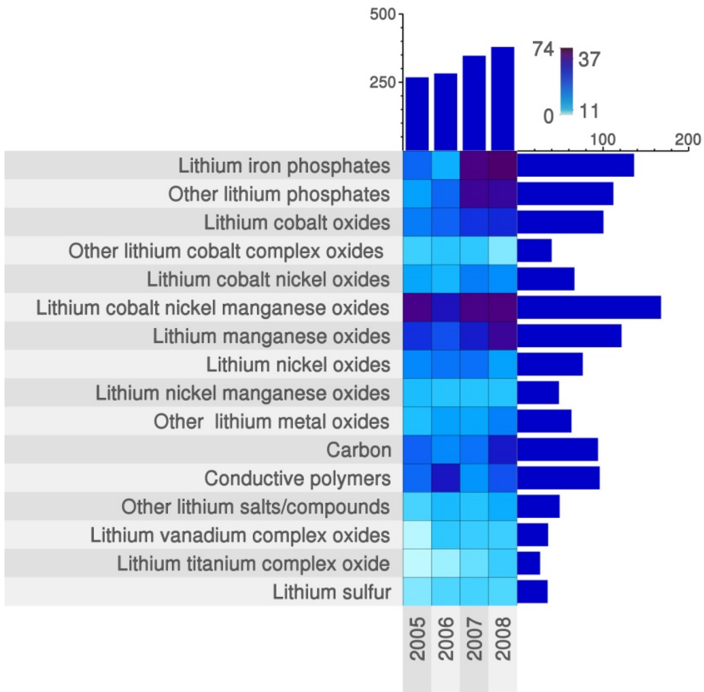
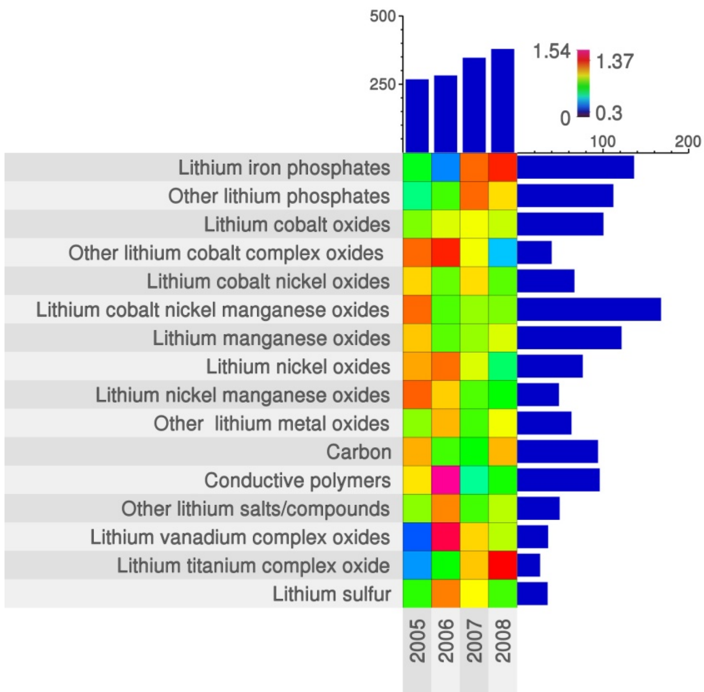


Fig 4.15b. Normalised Data



Source PatAnalyse

- The list of companies decreasing their patent activities is including Valence Technology, LG Chemical, A123 Systems, AGC Semi, Nissan, Mitsubishi, Mitsui, and Greatbatch

4.19. Countries of origin vs Priority Years

Fig 4.16. Countries of origin vs Priority Years

- It is usual to see Korean activities declining; this reflects behaviour of two major Korean players Samsung SDI and LG Chemical. However, it is quite unusual to witness a decline of patent activities originated from US
- Europe as usual shows the steep increase in patent activities, China was waking up with its own patent activities in this subject area only from 2008

Fig. 4.16 **Countries of origin vs Priority Years**

Fig 4.16a. Absolute Data

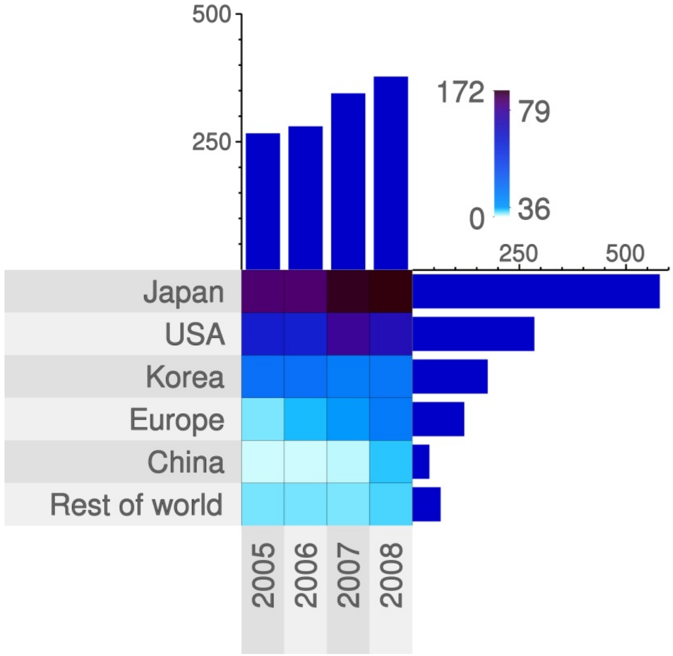
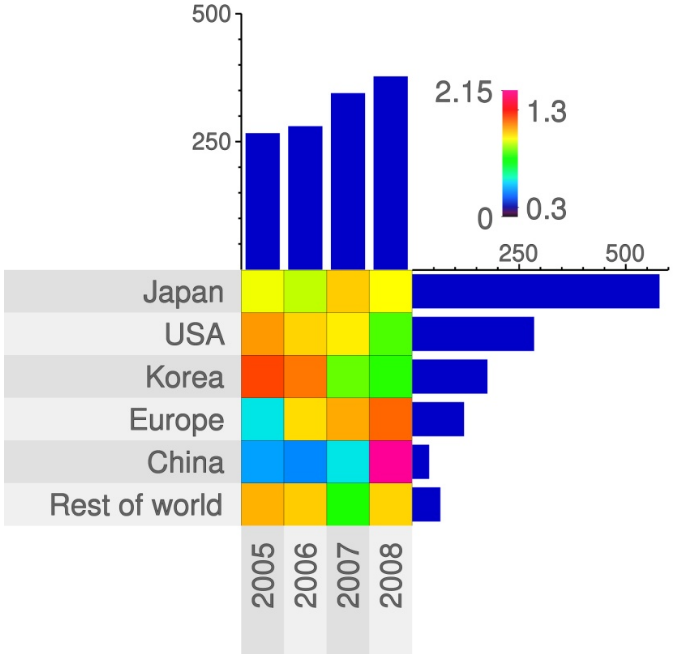


Fig 4.16b. Normalised Data



Source PatAnalyse

4.20. Technical categories vs Countries of origin

Fig 4.17. Technical categories vs Countries of origin

- Lithium Iron Phosphate is not a pure Asian technology; in fact it is under represented in Japan and is a focus of US and European patent activities
- Lithium (NCM) Nickel Cobalt Manganese is a good example of Asian technology, with the US lagging behind Korea and Japan
- US is a strong proponent of Lithium Sulfur and Vanadium Oxide material systems. Vanadium oxide is a '3 – 4 V' battery material and is thus capable of high power and energy densities. However substantial volume changes during lithium intercalation are leading to serious cathode pulverization. Vanadium Oxide nanostructured battery electrodes could circumvent these problems. Outside of US these material system is under development by NEC and Samsung SDI (refer to Fig. 21)

Fig. 4.17 **Technical categories vs Countries of origin**

Fig 4.17a. Absolute Data

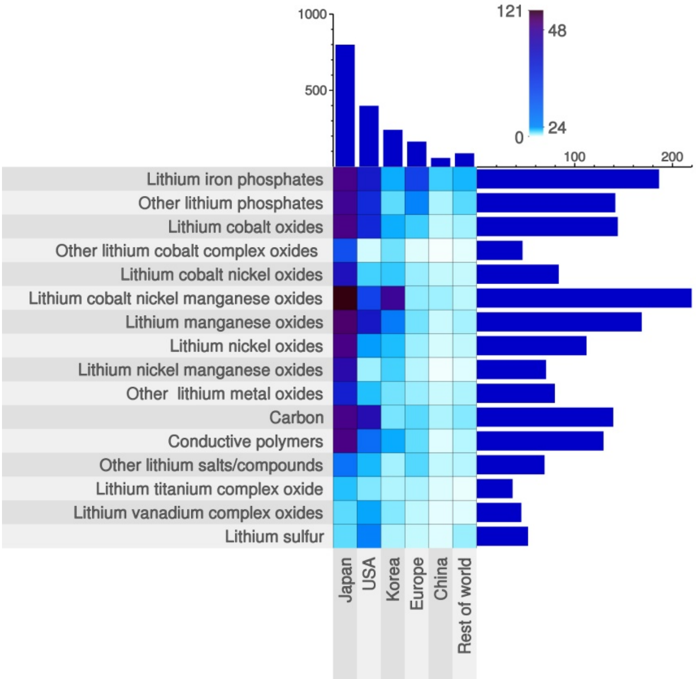
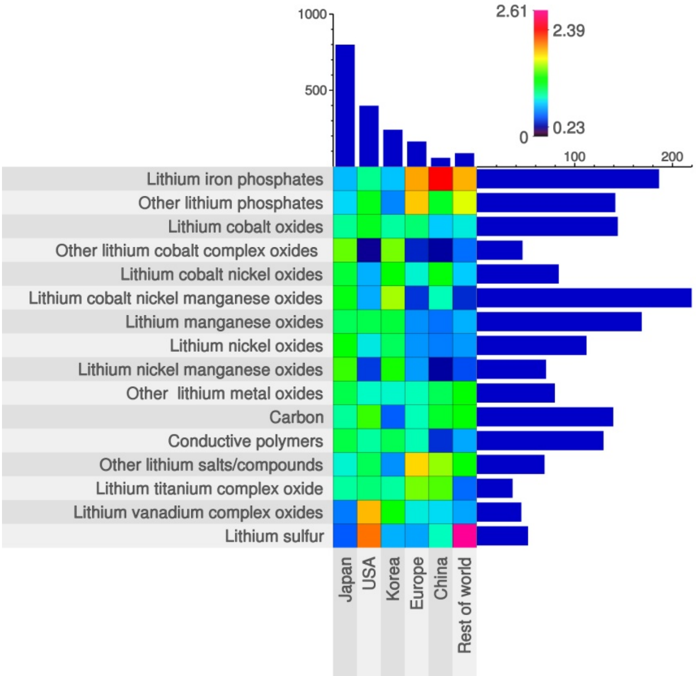


Fig 4.17b. Normalised Data



Source PatAnalyse

4.21. Technical categories vs National Patent Office Country

Fig 4.18. Technical categories vs National Patent Office Country

- Cobalt based materials and lithium spinel (lithium manganese oxide and lithium nickel oxide) are remaining as Asian activities.
- A niche material technology – lithium titanium oxide – used typically as a coating for other spinel materials is originated from Japan (by Panasonic and Toshiba) and is taken mainly to US and China
- Nano-form Carbon and conductive polymers are biased towards US patent filings

Fig. 4.18 **Technical categories vs National Patent Office Country**

Fig 4.18a. Absolute Data

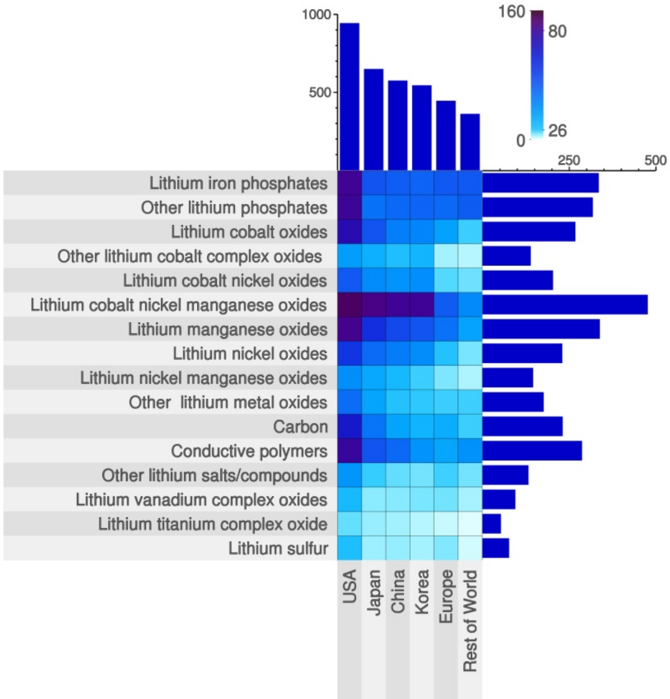
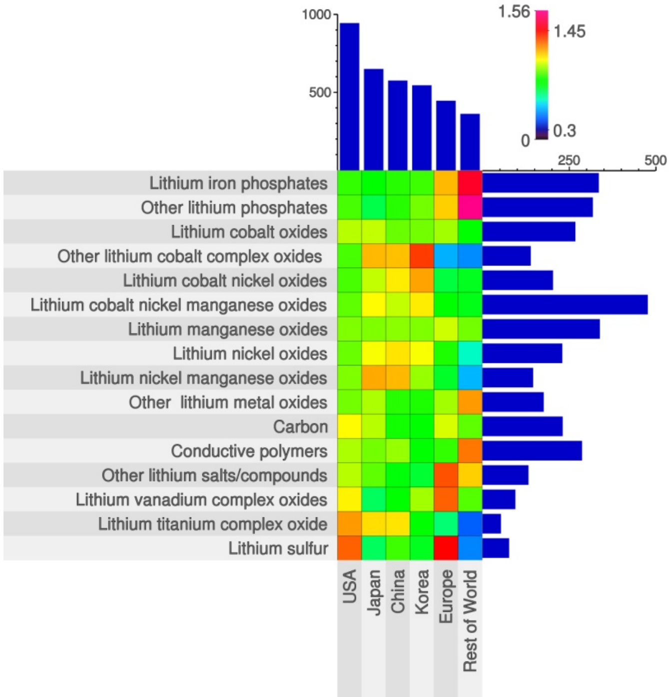


Fig 4.18b. Normalised Data



Source PatAnalyse

5. Lithium Traction Batteries

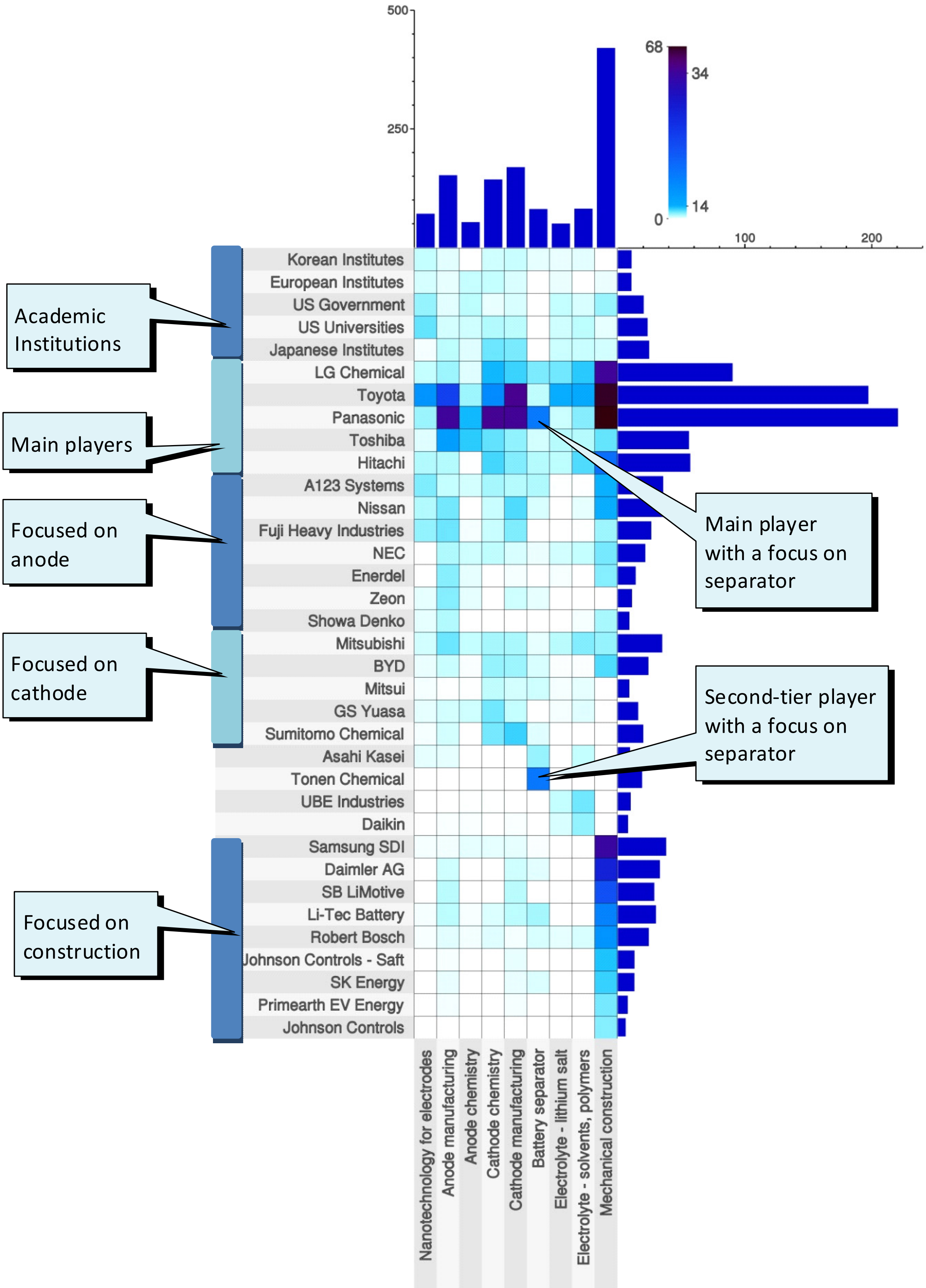
This section is analysing a sub-portfolio of the General Lithium Batteries section for patents which are clearly mentioning traction battery applications. Not surprisingly, this section is dominated by the mechanical construction and packaging category. Battery management system, which might be an integral part of the lithium traction battery, is discussed in the separate section.

5.1. Top 50 Assignees vs Technical categories

Fig 5.1. Top 50 Assignees vs Technical categories

- Panasonic and Toyota are two leaders in the Lithium Traction Batteries market
  - Main activities for Panasonic and Toyota are centered around manufacturing of Anode and Cathode, and Mechanical construction and packaging of the battery cell pack
  - Panasonic has substantially outweighed Toyota in the chemistry of Anode and Cathode materials, as well as in Separator technologies
  - Toyota has substantially outweighed Panasonic in nanotechnology and electrolytes
- The list of second-tier players includes LG Chemical, Toshiba, and Hitachi. The third echelon is listing companies like Nissan, A123 Systems, Mitsubishi, Samsung SDI, Daimler, SB LiMotive, Li-Tec Battery, and Robert Bosch.

Fig. 5.1 **Top 50 Assignees vs Technical categories**



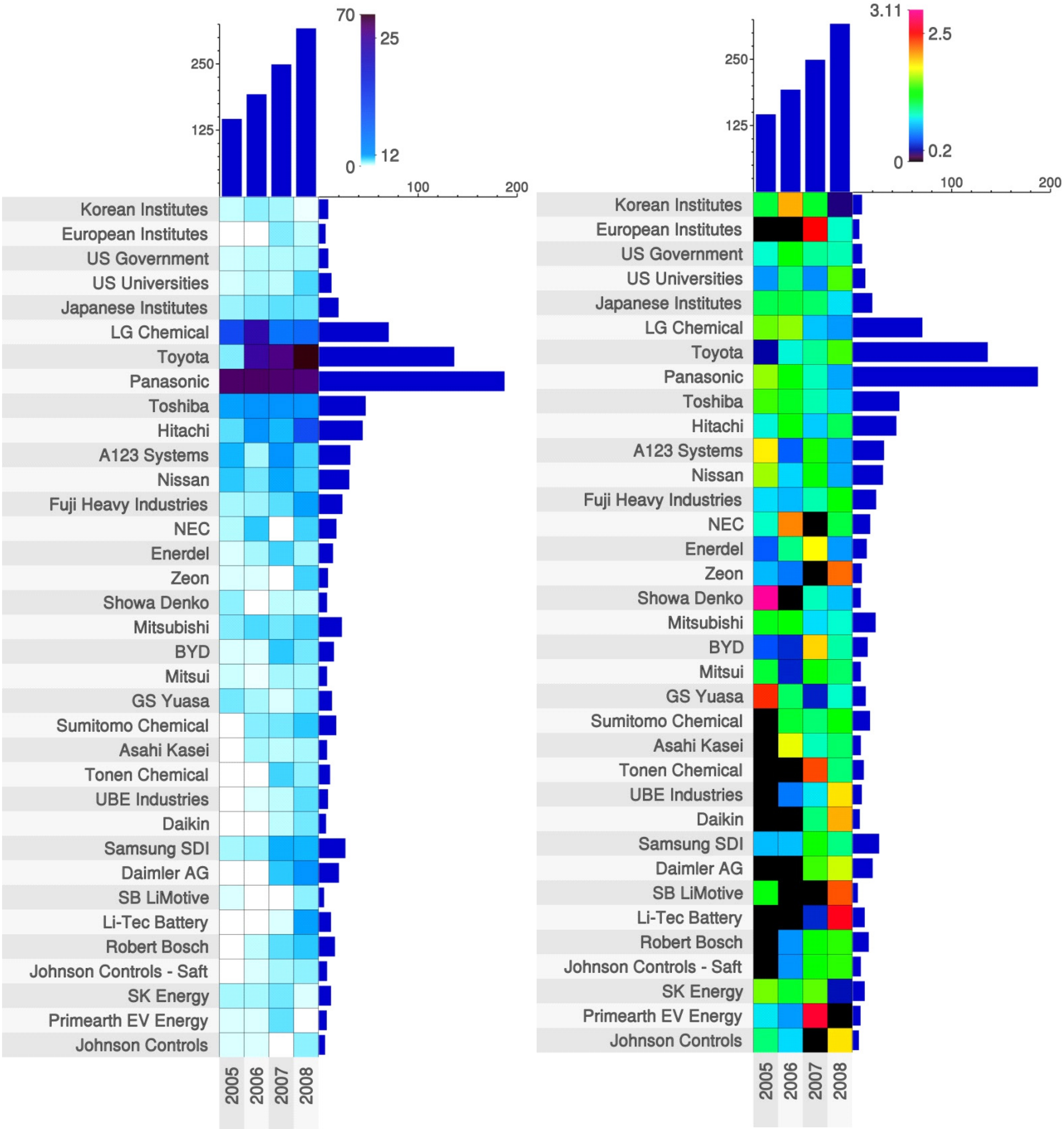
Source PatAnalyse

5.2. Top 50 Assignees vs Priority Years

Fig 5.2. Top 50 Assignees vs Priority Years

- The 100% growth in patenting activities during just 3 years is very impressive.
- In spite quite strong overall growth, some companies like LG Chemical, Panasonic, Toshiba, A123 Systems, Nissan, and Mitsubishi are staying flat or even actually reducing their patenting activities
- Most other players are showing the growth in the patent activities. The growth is headed by Toyota, which on-going patenting activities have overtaken Panasonic since 2008.
- Quite a lot of companies on the top companies list are actually newcomers – they did not have any patent activities in 2005, and some started filing patents only since 2007

Fig. 5.2 **Top 50 Assignees vs Priority Years– absolute and normalised**



Source PatAnalyse

5.3. Comparison of Profiles for top companies in Lithium Traction batteries

Fig 5.3. Comparison of Profiles for top companies in Lithium Traction batteries

Four Patent Maps with a fixed colour scale for Panasonic, Toyota, LG Chemical, and Toshiba are presented for the patents relating to Lithium Traction Batteries. It is easy to see that:

- Toyota has shown an aggressive growth by being the new but bold entrant to the area since late 2006
  - Nanotechnology is one of the strong growth areas for Toyota
- Panasonic has demonstrated a steady activity. The activities in separator technologies has been recently dropped
- LG Chemical is showing a declining level of patent activities especially in the aspects related to mechanical packaging which most probably reflects a reduced development budget for the new generation of lithium traction batteries
  - It seems that LG Chemical is shifting its financial resources from R&D to manufacturing which should pay off in a short term but might become quite a risky strategy in the long run
- Patent filings by Toshiba show flat behaviour over last years. The recent increase in the patent filings in the mechanical construction and packaging might signal some increase focus on manufacturing away from pure R&D.

Fig. 5.3 **Comparison of Profiles for top companies in Lithium Traction batteries**

Fig 5.3a. Toyota

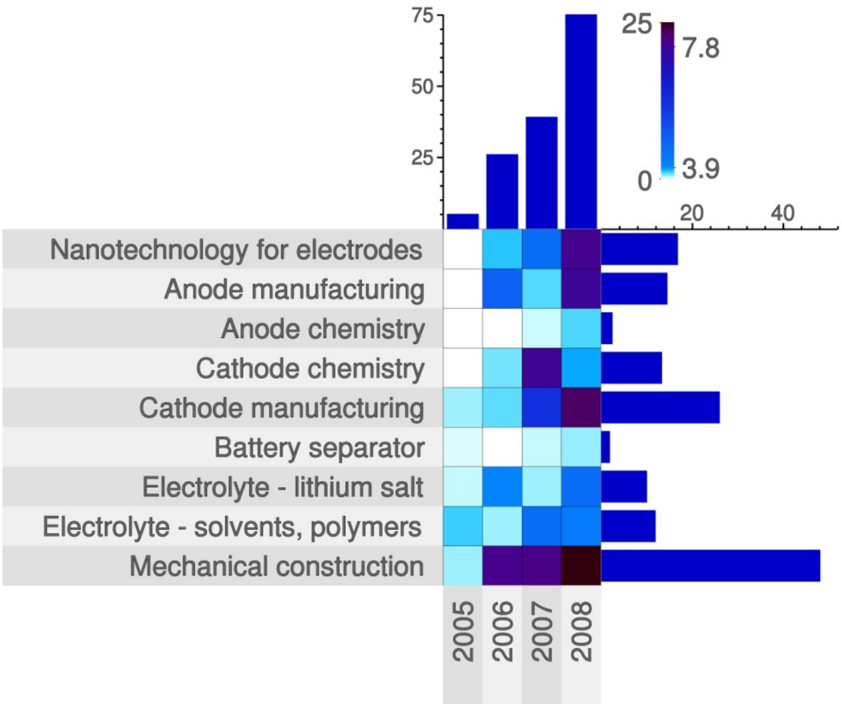
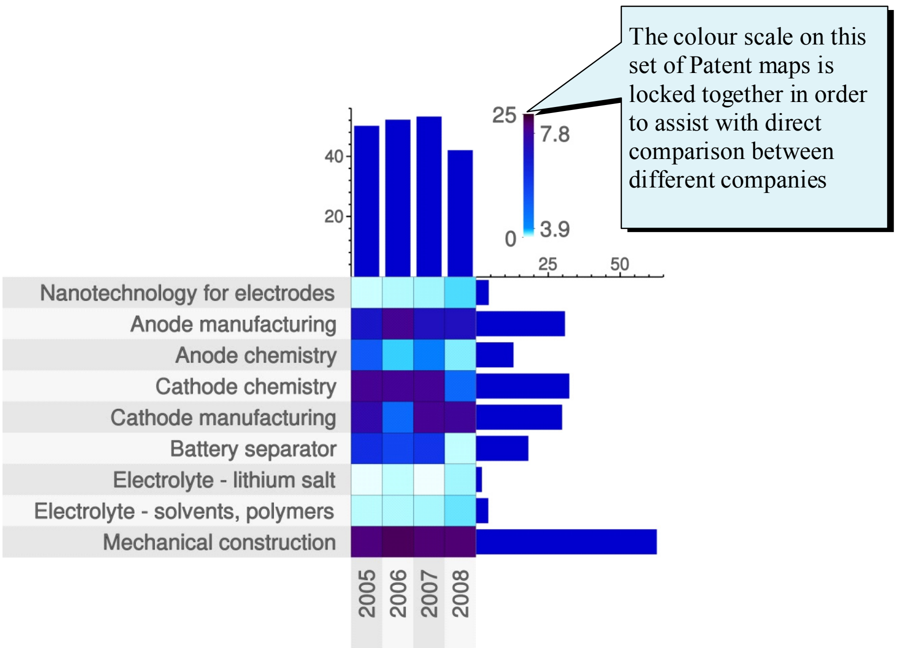


Fig 5.3b. Panasonic



Source PatAnalyse

Fig 5.3c. LG Chemical

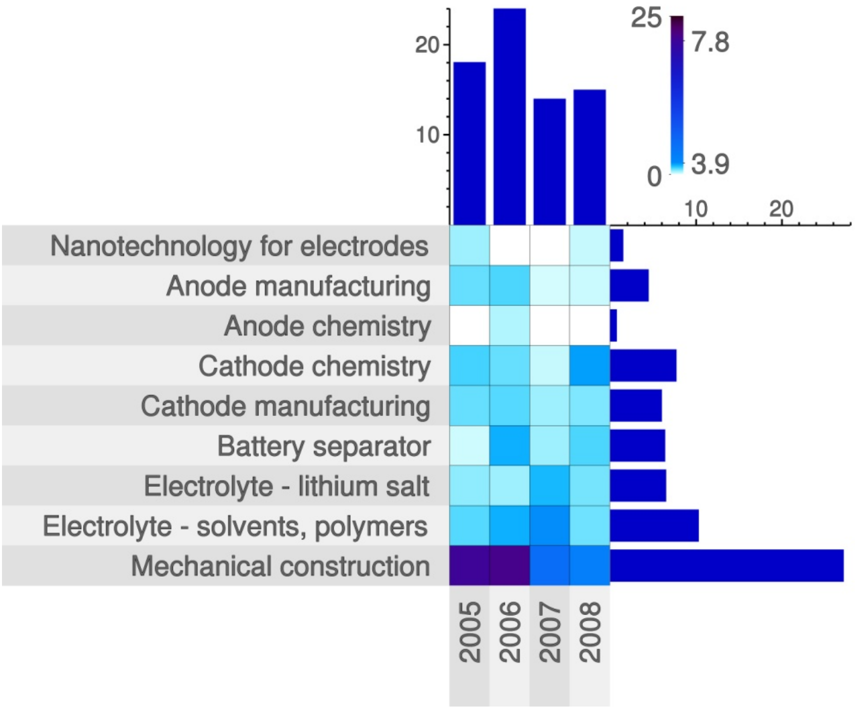
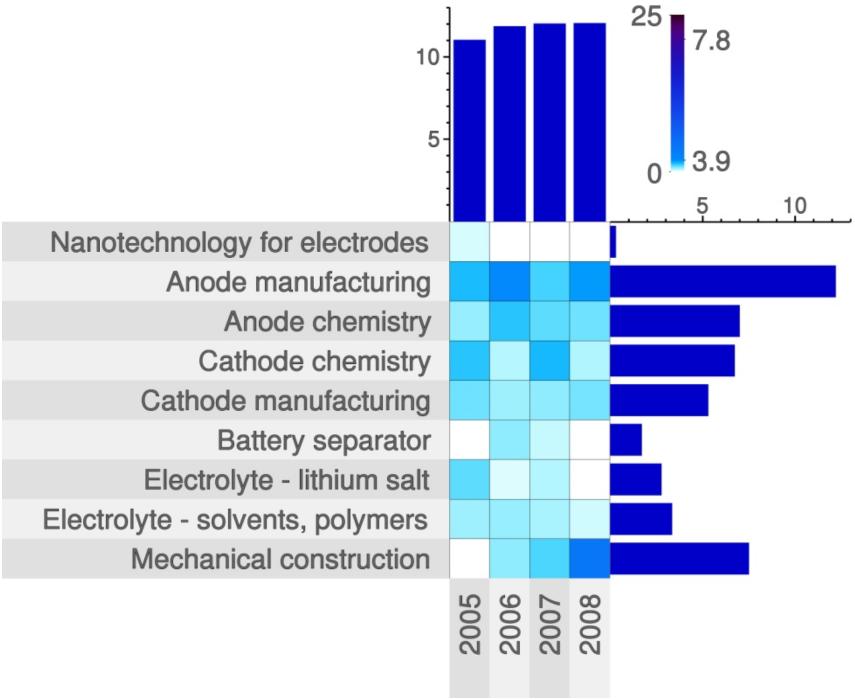


Fig 5.3d. Toshiba



Source PatAnalyse

5.4. Technical categories vs Priority Years

Fig 5.4. Technical categories vs Priority Years

- Mechanical construction and packaging of the traction battery is not only the main focus but also the area of growth above the average
- Another areas of growth are related to nanotechnology and cathode manufacturing
- Other categories shows the absolute growth which is below the average

Fig. 5.4 **Technical categories vs Priority Years**

Fig 5.4a. Absolute Data

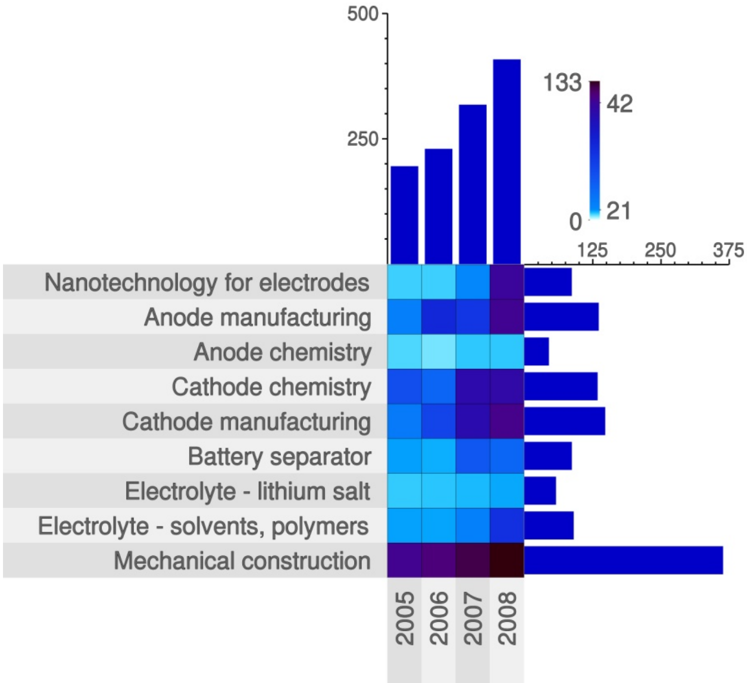
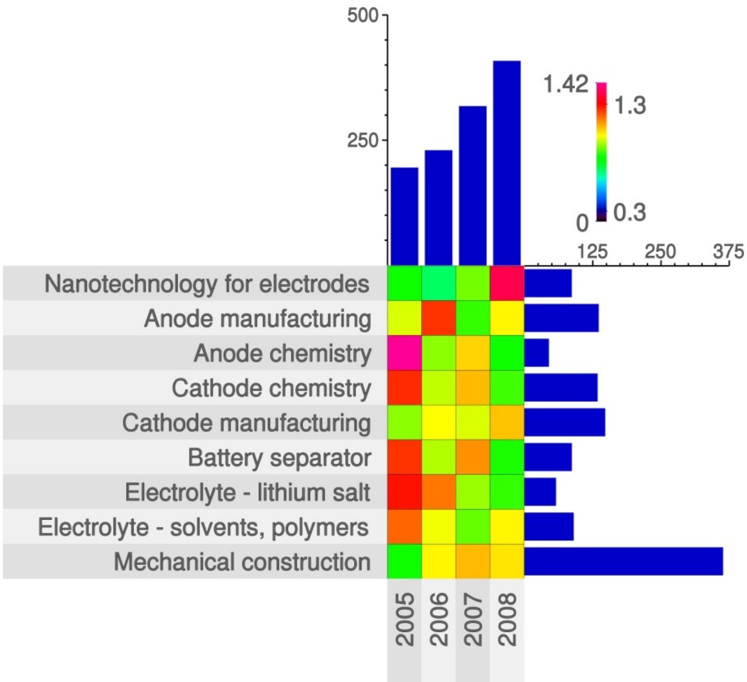


Fig 5.4b. Normalised Data



Source PatAnalyse

5.5. Countries of origin vs Priority Years

Fig 5.5. Countries of origin vs Priority Years

- Lithium Traction Battery is a Japanese technology. Japan is too big in comparison with everyone else. Partially this is reflected by the fact that both two first-tier players – Toyota and Panasonic – are Japanese companies.
- Europe is a late entrant to the Lithium Traction Battery market; however in 2008 Europe has already overtaken Korea and had almost caught up with US

Fig. 5.5 **Countries of origin vs Priority Years**

Fig 5.5a. Absolute Data

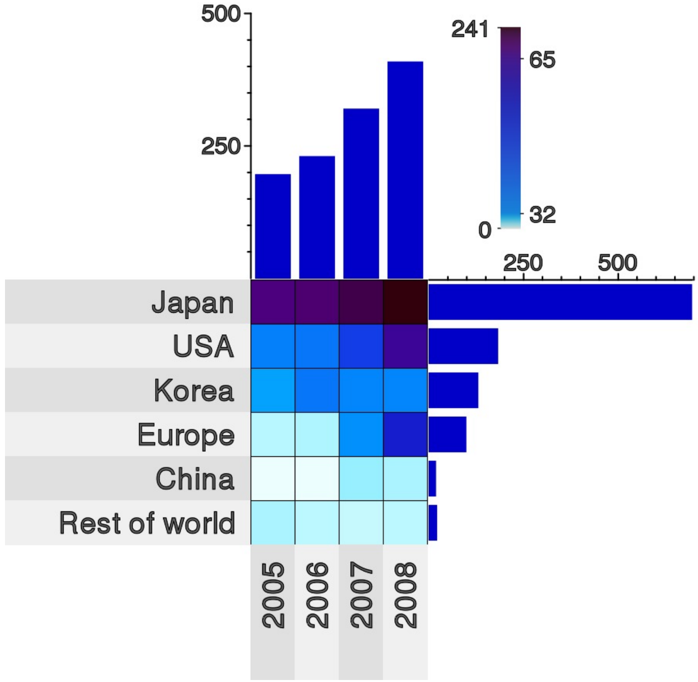
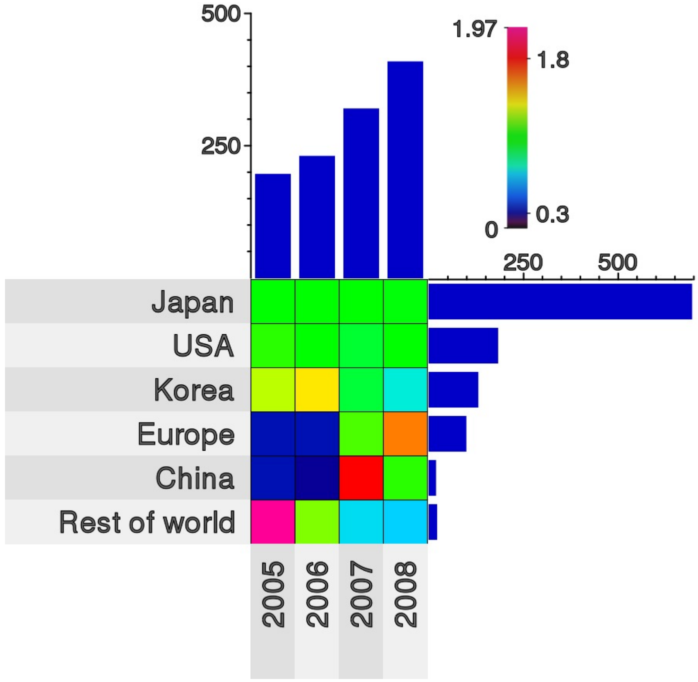


Fig 5.5b. Normalised Data



Source PatAnalyse

5.6. Technical categories vs Countries of origin

Fig 5.6. Technical categories vs Countries of origin

- Nanotechnology is the only category in which Japan is not dominating the market – in spite of the big support from Toyota
- Korea and Europe are strong in mechanical construction and packaging and are weak in most other areas, however Europe has higher than average contribution to nanotechnology

Fig. 5.6 **Technical categories vs Countries of origin**

Fig 5.6a. Absolute Data

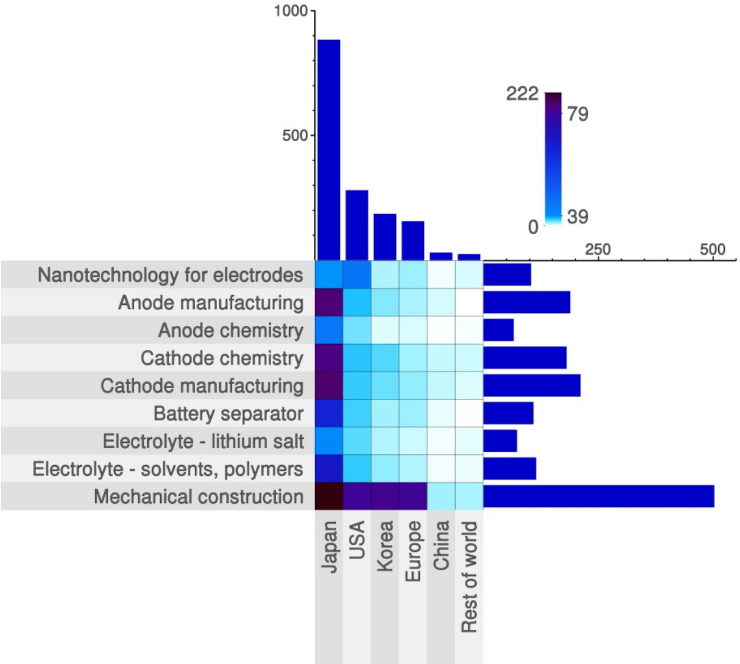
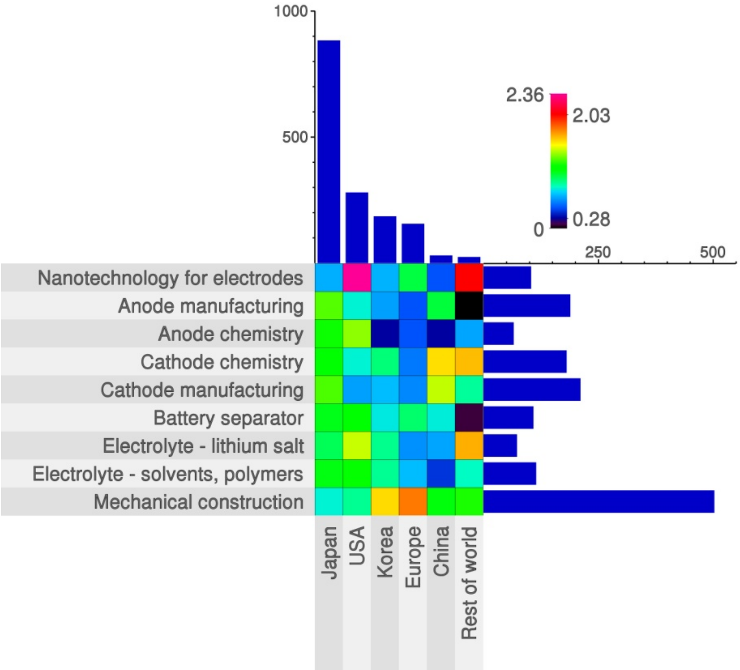


Fig 5.6b. Normalised Data



Source PatAnalyse

5.7. Technical categories vs National Patent Office Country

Fig 5.7. Technical categories vs National Patent Office Country

- More than 60% of National patents represented on this Patent Map have originated in Japan; Japanese companies are taking more patents in China if compared to Korea or Europe
- Nanotechnology and Mechanical construction are overrepresented in Europe which is reflecting the original European patent filings in this subject areas
- Categories related to Manufacturing and Chemistry of anodes and cathodes were especially dominated by Japanese companies; as a result these activities are still overrepresented in Japanese National filings

Fig. 5.7 **Technical categories vs National Patent Office Country**

Fig 5.7a. Absolute Data

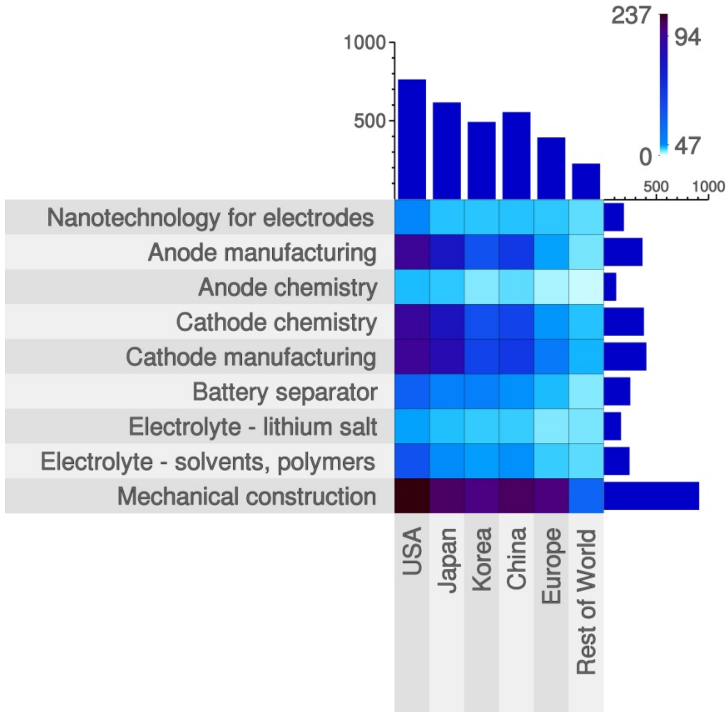
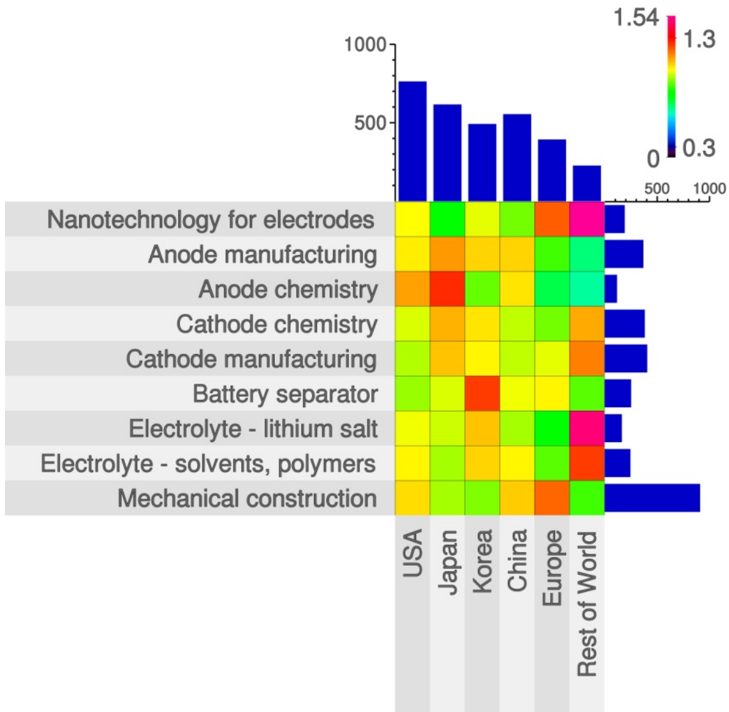


Fig 5.7b. Normalised Data



Source PatAnalyse

6. Traction batteries in general

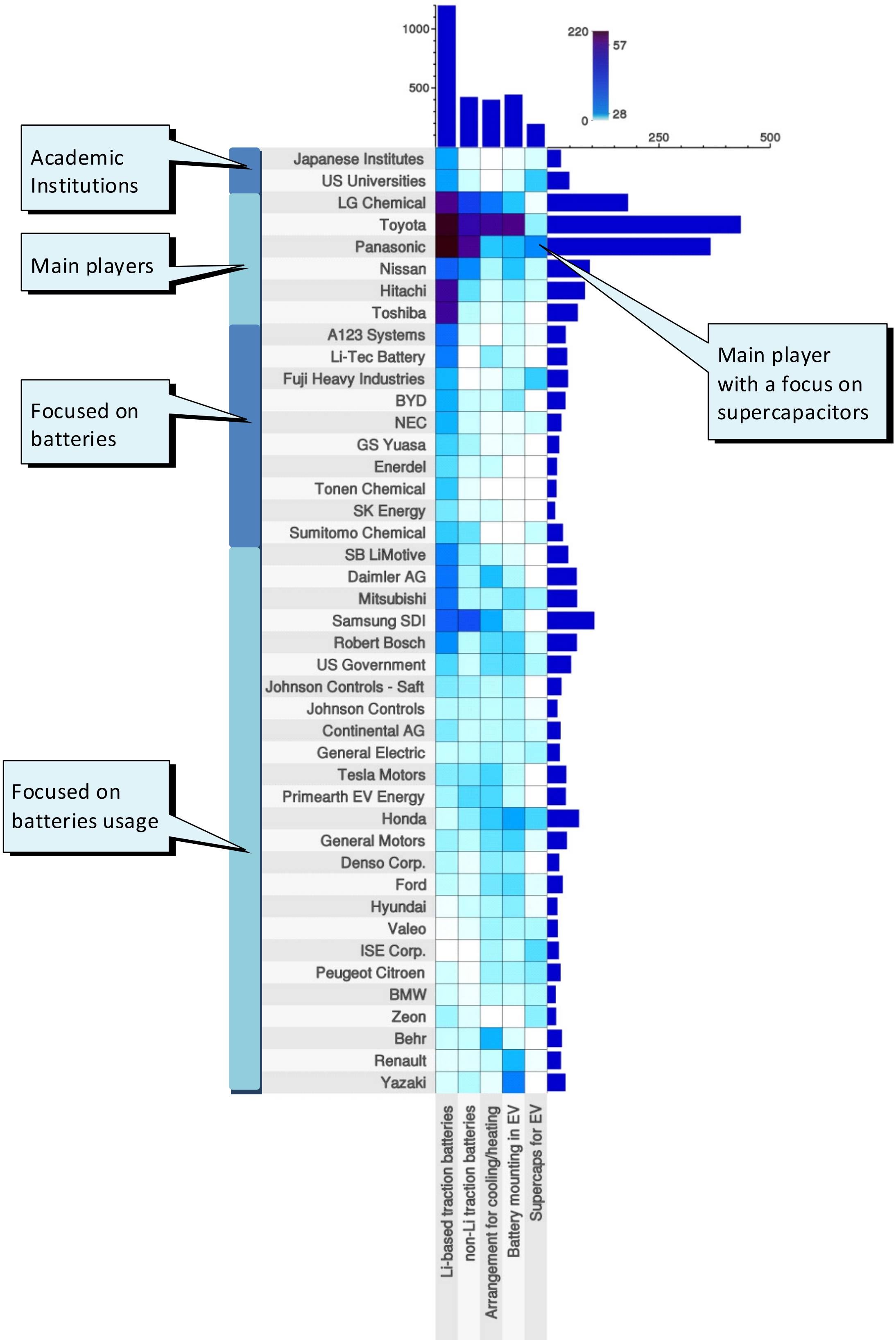
The previous section – Lithium Traction Batteries – is one of the categories of the Patent Maps presented in this section

6.1. Top 50 Assignees vs Technical categories

Fig 6.1. Top 50 Assignees vs Technical categories

- Panasonic and Toyota remains at the top of the game. However LG Chemical is much closer to these two rivals compared to the previous Lithium Traction Battery Patent Maps.
  - Toyota has stronger emphasis on the mechanical aspects like mounting battery pack in the EV or arranging mechanical system for cooling or heating the battery pack
  - Panasonic has stronger focus in developing supercapacitors for EV
- There are several new second-tier players including Honda and Nissan.

Fig. 6.1 **Top 50 Assignees vs Technical categories**



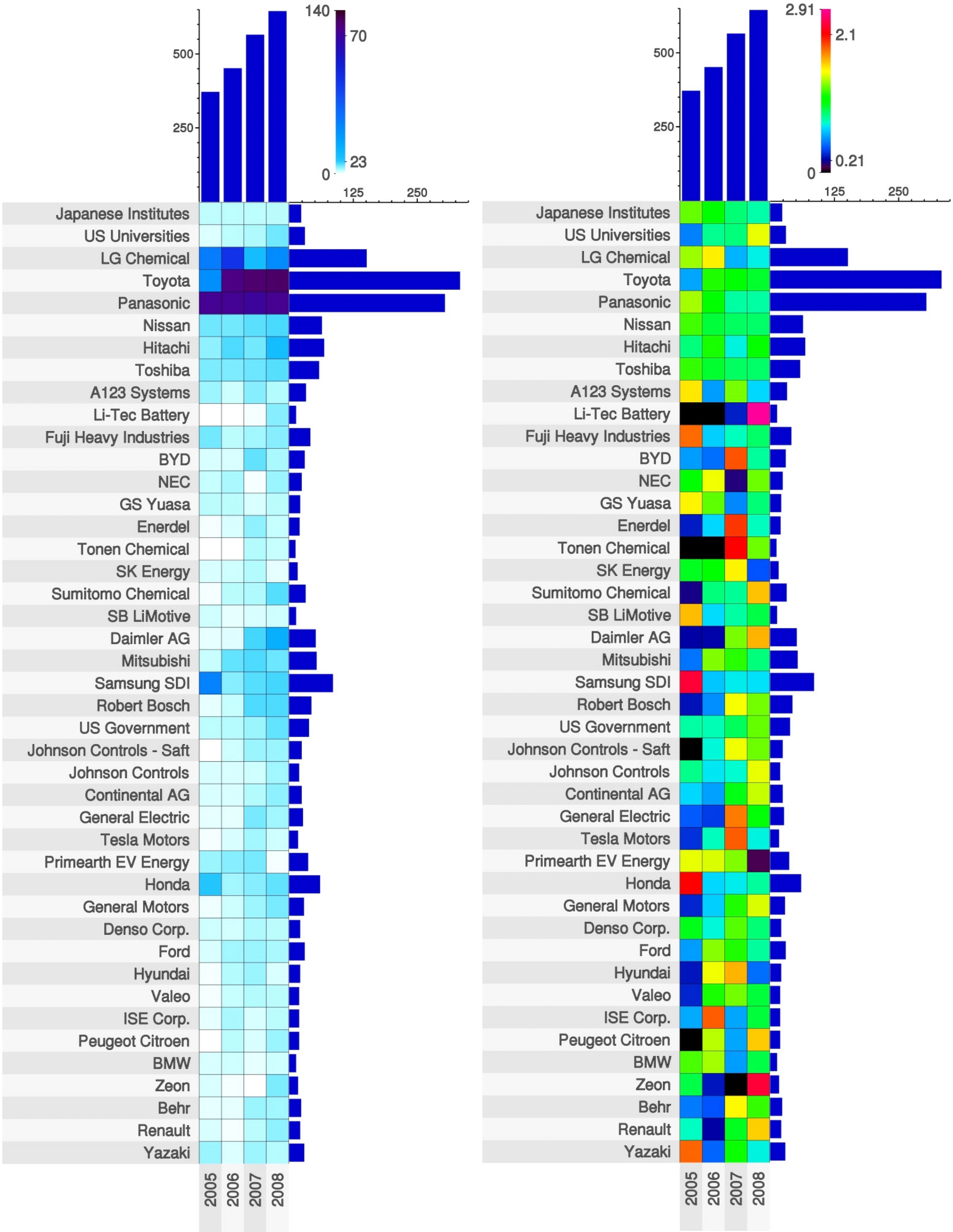
Source PatAnalyse

6.2. Top 50 Assignees vs Priority Years

Fig 6.2. Top 50 Assignees vs Priority Years

- The overall growth is modest if compared to the phenomenal growth of the patent activities in Lithium Traction Batteries
- Toyota has entered this market in 2006 and is growing on a par with the rest of the market since then.
- Several companies like LG Chemical and Primearth EV Energy are down; this behaviour just reflects their overall exit from R&D activities
- Quite a lot of newcomers (since 2006 or later) from the automotive industry are evident on the Patent Maps. The list includes such names as Behr, Renault, Peugeot Citroen, Hyundai, Ford, General Motors, Tesla Motors, General Electric, Continental AG, Robert Bosch, Mitsubishi, BYD, and Daimler AG

Fig. 6.2 **Top 50 Assignees vs Priority Years– absolute and normalised**



Source PatAnalyse

6.3. Comparison of Profiles for top companies in Traction batteries

Fig 6.3. Comparison of Profiles for top companies in Traction batteries

- Toyota has entered this market at late 2005 with initial equal emphasis on the Lithium Traction Batteries and their usage in the EV - like battery mounting in EV and mechanical arrangements for heating and cooling. It seems that since 2008 Toyota has made a strategic decision to focus mainly in developing its own product in Lithium Traction Batteries and has substantially scaled down other activities.
- Panasonic shows steady activities in Lithium Traction Batteries and somewhat reduced interest in developing supercapacitors for EV applications. Panasonic shows somewhat unusual steady focus on non-Lithium Traction Batteries since 2006.

Fig. 6.3 **Comparison of Profiles for top companies in Traction batteries**

Fig 6.3a. Toyota

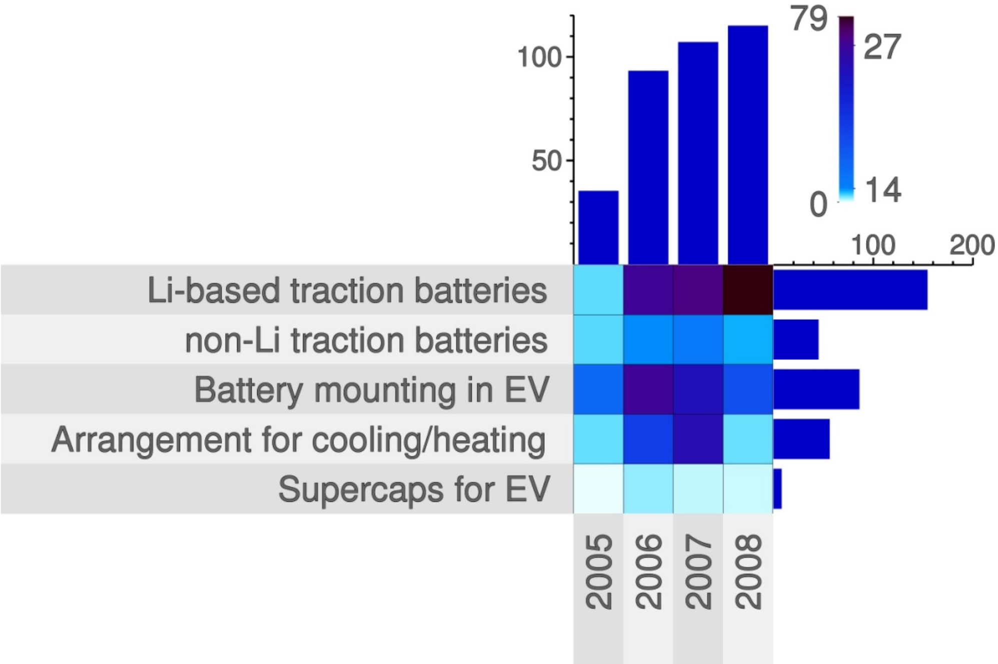
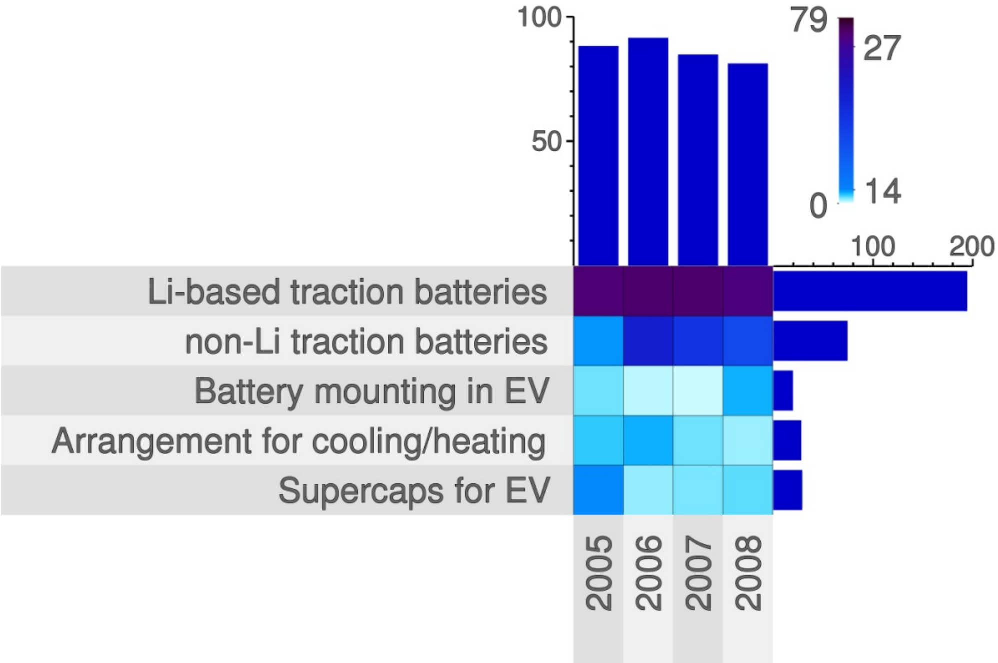


Fig 6.3b. Panasonic



Source PatAnalyse

6.4. Technical categories vs Priority Years

Fig 6.4. Technical categories vs Priority Years

- Supercapacitors for EV are down in popularity
- Lithium Traction Batteries is the most strongly growing area. Its success will determine the speed at which market will be able to move from the hybrid EV to the plug-in hybrid EV.
- All other areas are growing, but at a slightly lower rate compared to Lithium Traction Batteries

Fig. 6.4 **Technical categories vs Priority Years**

Fig 6.4a. Absolute Data

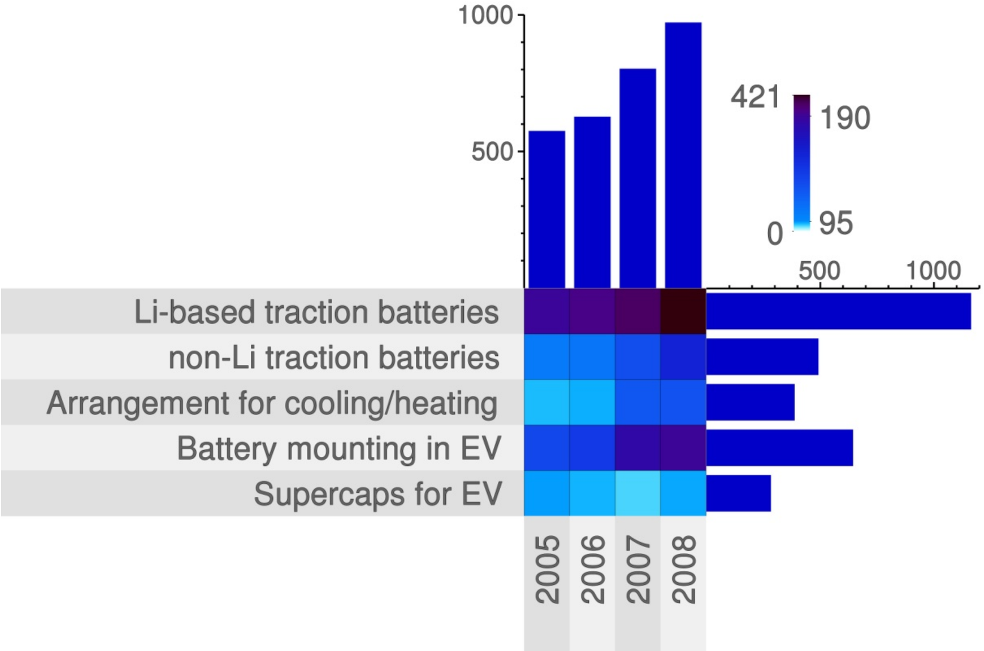
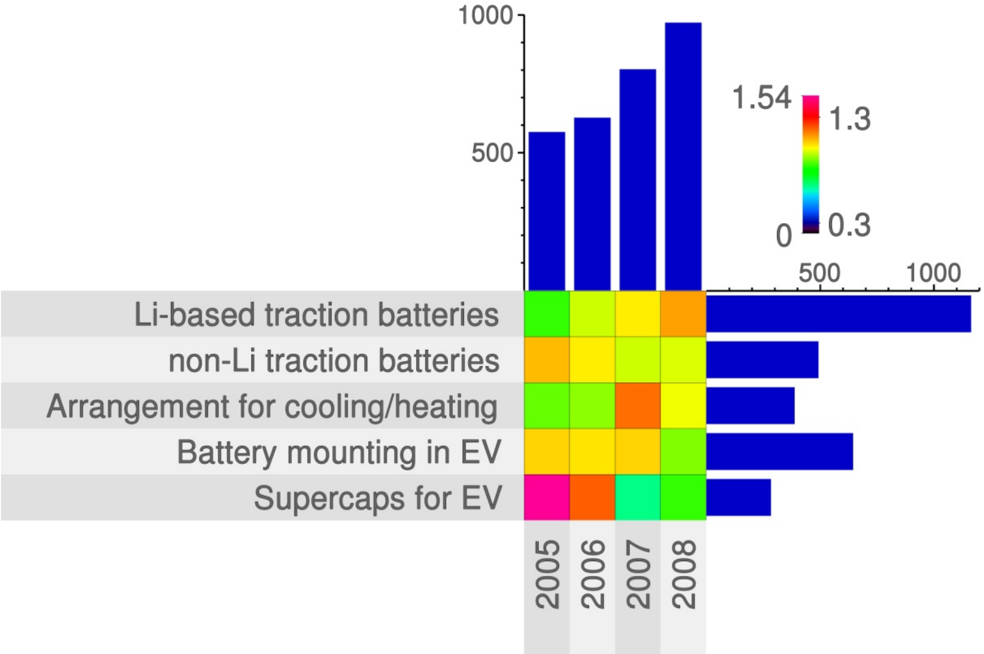


Fig 6.4b. Normalised Data



Source PatAnalyse

6.5. Countries of origin vs Priority Years

Fig 6.5. Countries of origin vs Priority Years

- Compared to the Lithium Traction Battery Patent Maps, the US has reduced the gap to Japan.
- Due to the activities of its automotive players, in 2008 Europe has almost caught up with US. However due to a substantially later start (from 2007) is still lagging behind US by the overall size of its portfolio.
- Korea is down in its activities – effected as usual by the LG Chemical
- China is growing its involvement, however Chinese activities are still relatively small

Fig. 6.5 **Countries of origin vs Priority Years**

Fig 6.5a. Absolute Data

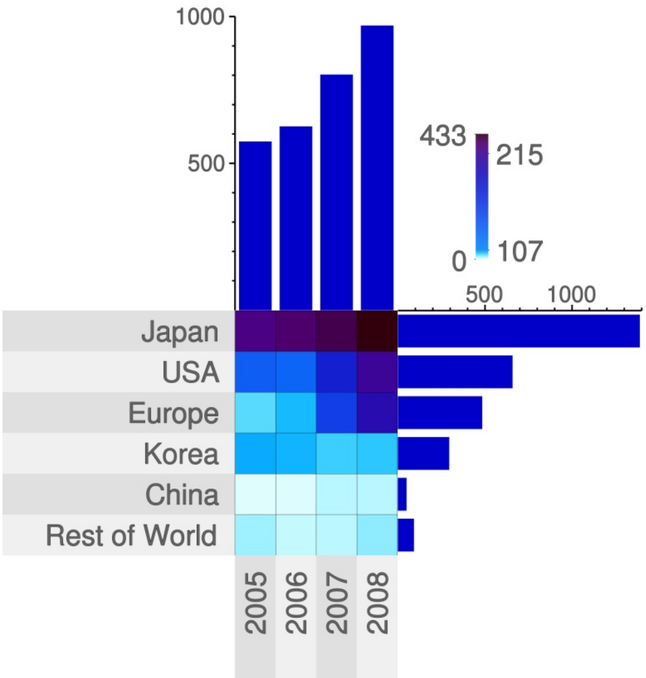
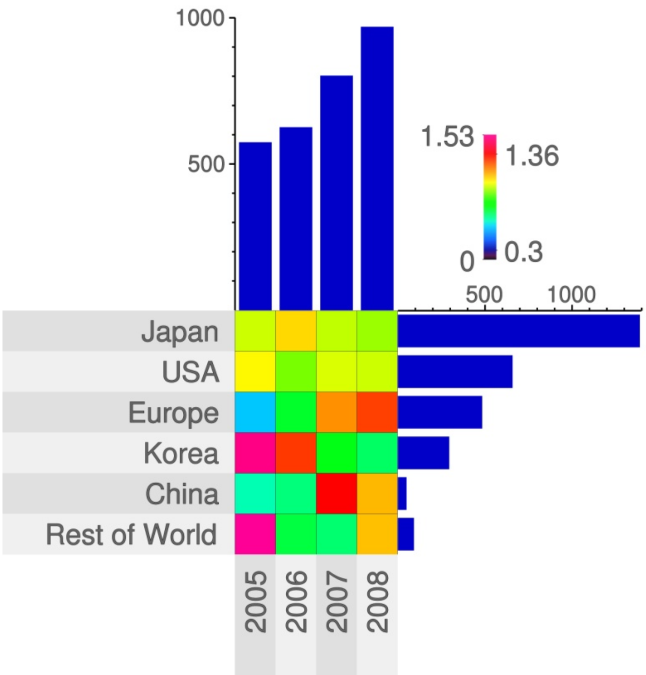


Fig 6.5b. Normalised Data



Source PatAnalyse

6.6. Technical categories vs Countries of origin

Fig 6.6. Technical categories vs Countries of origin

- European automotive players are quite strong in the technical aspects related to using Traction Batteries in EV. Such activities are represented on the Patent Maps by two categories - battery mounting in EV and mechanical arrangement for cooling and heating the battery pack. At the moment European players have accumulated patent portfolio which is on a par with US and Japan in such technical areas. Actually, since 2008 European companies have already became worldwide leaders in the development activities in these areas of using Traction Batteries in EV.
- Korea has stronger emphasis to the non-Lithium Traction Batteries technologies which is probably a risky strategy in the light of rapid growth in Lithium Traction Battery patents and market growth
- Japan and US have their contribution to developing supercapacitors technology for EV. The US share of such activities is larger than average across other activities.

Fig. 6.6 **Technical categories vs Countries of origin**

Fig 6.6a. Absolute Data

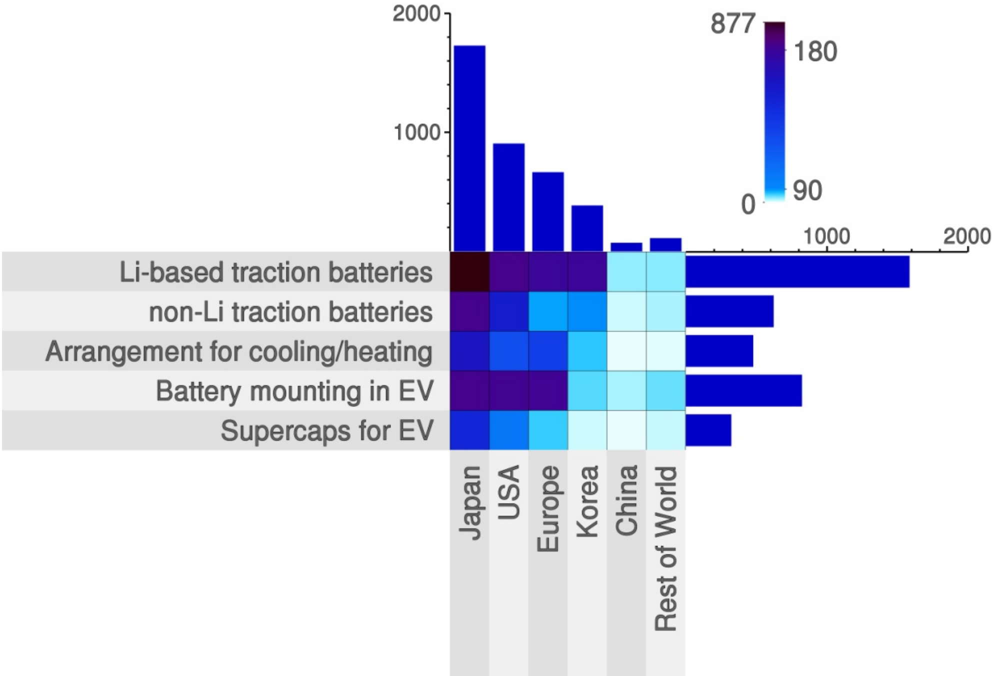
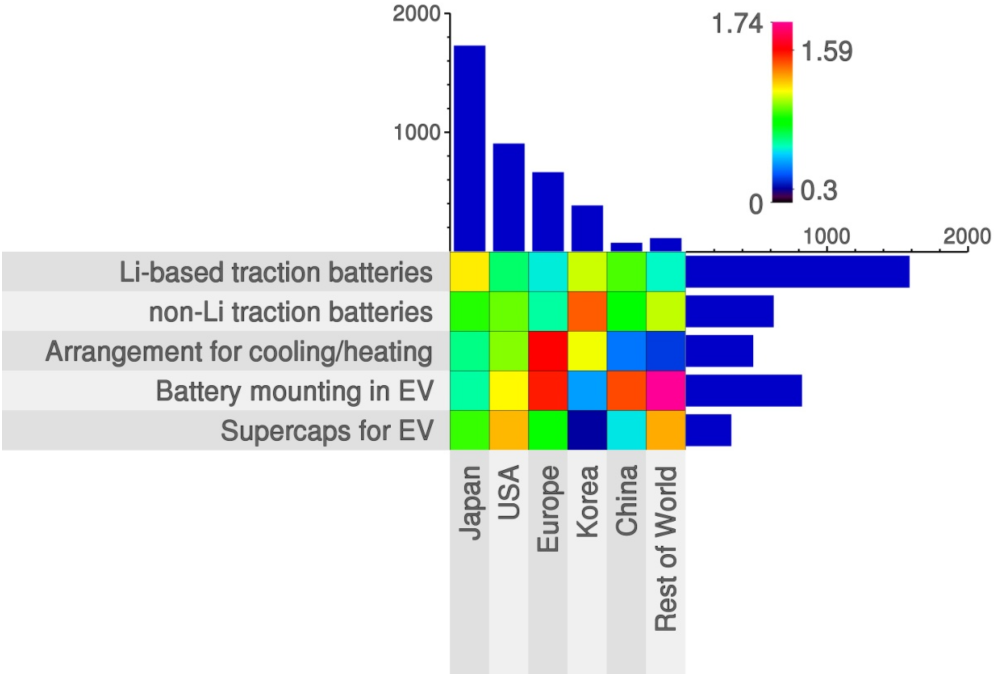


Fig 6.6b. Normalised Data



Source PatAnalyse

6.7. Technical categories vs National Patent Office Country

Fig 6.7. Technical categories vs National Patent Office Country

- Lithium Traction Batteries is an Asian activity with a substantial number of patents (605 of which originated in Japan) taken to China and Korea
- The usage of batteries in EV as well as the development of the supercapacitors for EV applications is more focused towards patent filings in Europe and US. In these categories number of patents taken to Europe is larger than the number of patents taken to Japan or China.

Fig. 6.7 **Technical categories vs National Patent Office Country**

Fig 6.7a. Absolute Data

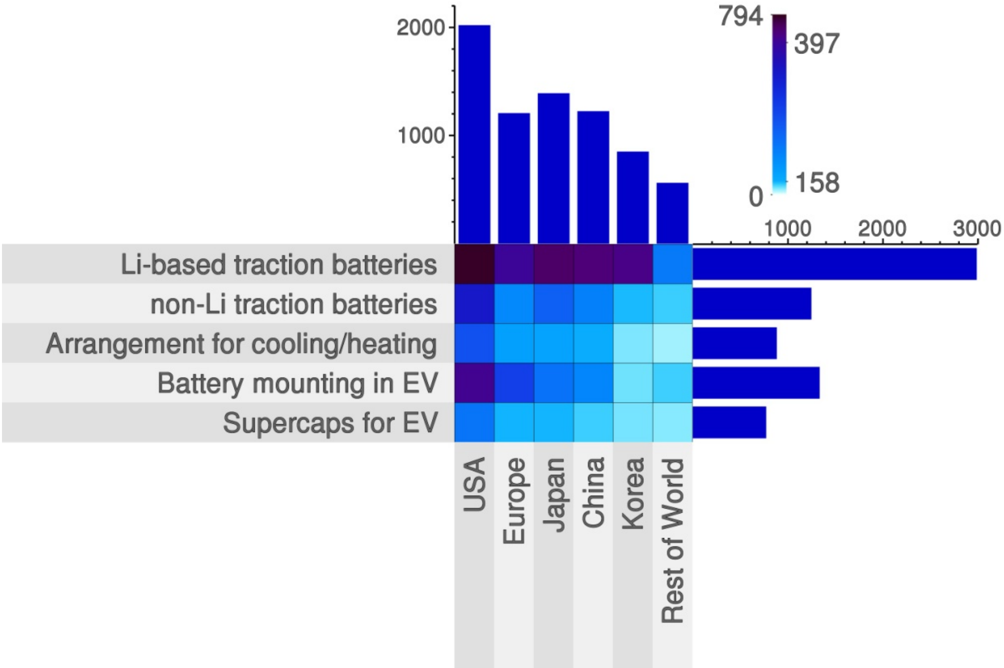
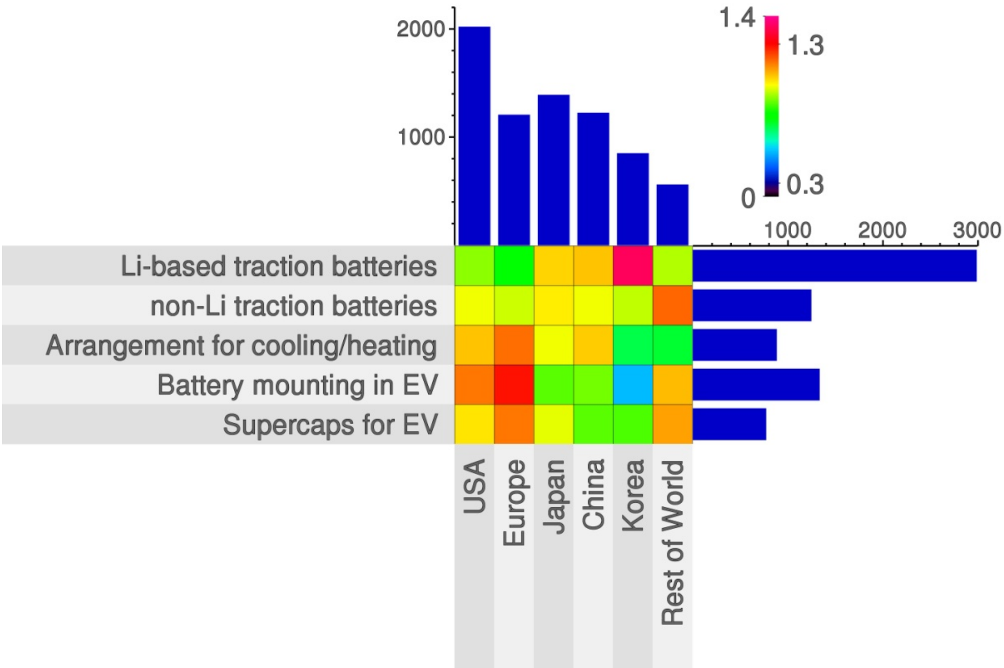


Fig 6.7b. Normalised Data



Source PatAnalyse

7. Generic Supercapacitor technologies

Supercapacitors are used in some electric vehicles in order to keep batteries within resistive heating limits and extend battery life. The ultrabattery combines a supercapacitor and a battery in one unit, creating an electric vehicle battery that lasts longer, costs less and is more powerful than current Traction Batteries. Supercapacitors have a variety of other commercial applications, mainly for the "power smoothing" and momentary-load devices.

Supercapacitor also known as an electric double-layer capacitor (EDLC), supercondenser, pseudocapacitor, electrochemical double layer capacitor, or ultracapacitor, is an electrochemical capacitor with relatively high energy density. Compared to conventional electrolytic capacitors the energy density is typically on the order of hundreds of times greater.

In a conventional capacitor, the opposite charges are separated by the relatively thick dielectric layer. Supercapacitors do not have a conventional dielectric. The supercapacitors use "plates" of opposite charges separated by the vanishingly thin (on the order of nanometers) depletion layer on the surface of the electrodes. Each "plate" layer by itself is quite conductive, but the physics at the interface where the layers are effectively in contact means that no significant current can flow between the layers. However, the double layer can withstand only a low voltage which limits their energy density.

Main advantage of supercapacitors comes from the fact that unlike batteries they don't require an ionic transport through the electrolyte. So while existing supercapacitors have energy densities that are perhaps 1/10 that of a conventional battery, their power density is generally 10 to 100 times larger.

Most commercial supercapacitors use powdered activated carbon made from coconut shells. Higher performance devices are available, at a significant cost increase.

One way of improving the energy density of supercapacitors is related to replacing one electrode with a battery-like electrode with the redox (reduction-oxidation) storage mechanism along with a high surface area.

Supercapacitors with redox electrode in which voltage is proportional to the charge are called pseudo-capacitors or asymmetric supercapacitors. Such pseudo-capacitors are typically based on ruthenium oxide. This material allows more than 10 million charge/discharge cycles. Unfortunately this material is too expensive for commercial applications. Some cheaper polymers (e.g. polyacenes and conducting polymers) have useful parameters but are not capable to withstand a large number of recharging cycling. To extend their useful life it is necessary to reduce the depth of the discharge thus reducing the utility of this approach.

The true advantage can be achieved by using a battery type redox electrode in which voltage is nearly independent of the intercalated ions charge. An example of such approach is a Lithium Ion Capacitor. In such device cathode employs activated carbon material at which charges are stored in an electric double layer which is developed at the interface between the carbon and the electrolyte. The anode of the lithium ion capacitor consists of carbon material which is pre-doped with lithium ion. This pre-doping process lowers the potential of the anode and allows a high output voltage. Typically, an output voltage is kept in the range of 3.8V to 4.0V. As a consequence, such lithium ion capacitors have a high energy density. Furthermore, the capacity of the anode is several orders of magnitude larger than the capacity of the cathode. As a result, the discharge does not lead to the substantial drop in the voltage – this along doubles the amount of stored energy.

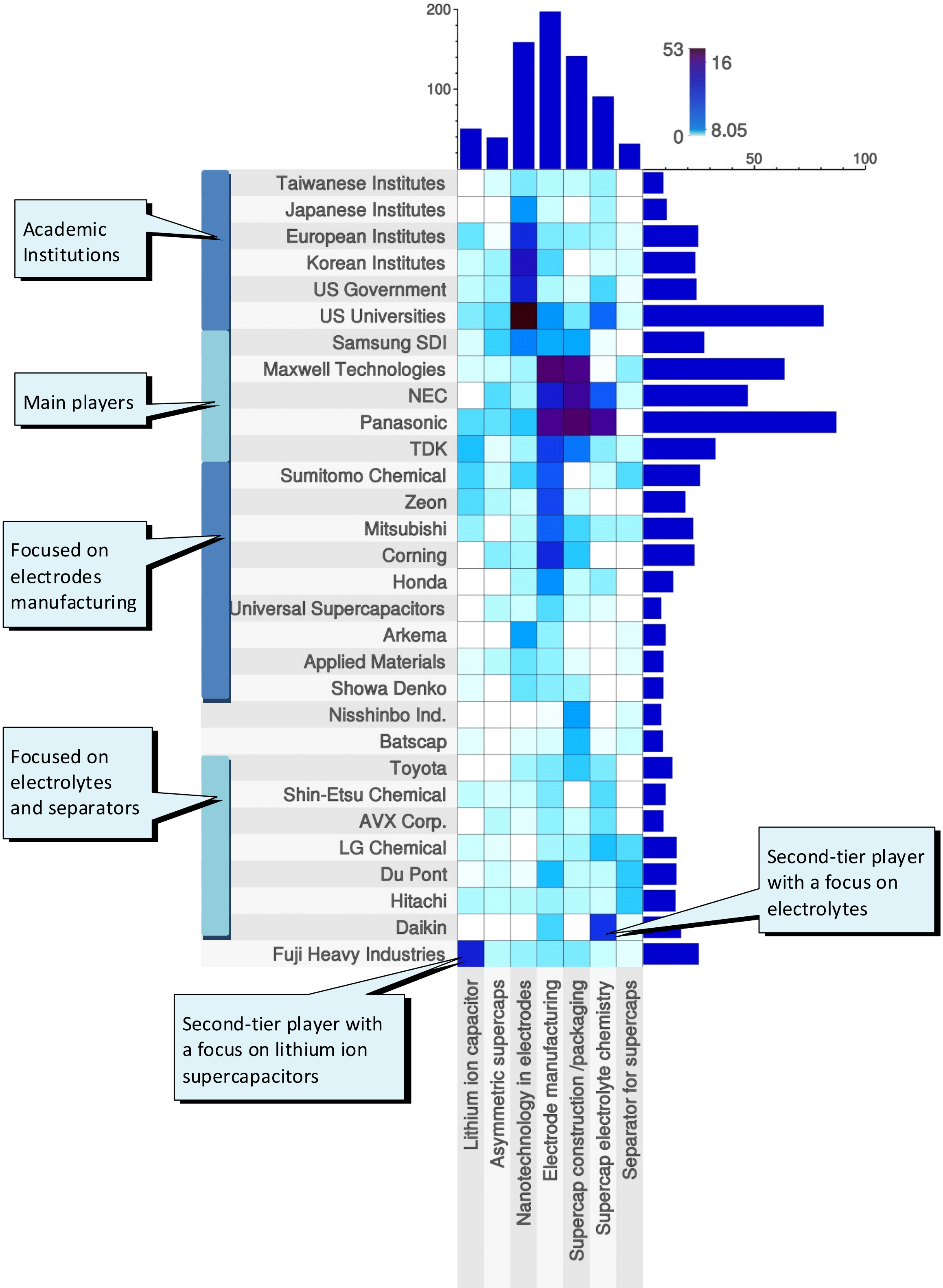
7.1. Top 50 Assignees vs Technical categories

Fig 7.1. Top 50 Assignees vs Technical categories

- It is quite unusual to find US Universities in the list of the first-tier players in the area of genuinely stagnating market. Most probably academic teams are trying to provide some evidence to the fulfillment of various promises made during the applications to various government grants related to nanotechnology projects. It is easy to create numerous patents claiming carbon nanotechnology (especially nanotubes) for manufacturing electrodes for supercapacitors, however commercial value for such patents is not clear. The evidence of commercial interest in the form of licenses for such patents can be the best indicator of their utility.
- Another players in the top list include Maxwell Technology, NEC, and Panasonic
  - Main focus for commercial players is in the technologies related to electrodes manufacturing and to mechanical construction and packaging of the supercapacitors packs
  - Panasonic, NEC, and US Universities have additional focus on electrolyte chemistry
- The list of second-tier players includes Samsung SDI, TDK, Sumitomo Chemical, Zeon, Mitsubishi, Corning, Fuji Heavy Industries, and Daikin

- Most companies on the list of second-tier and first-tier players have some cautious R&D activities in nanotechnologies, however still on a lower scale – typically not exceeding just a couple of patents.

Fig. 7.1 **Top 50 Assignees vs Technical categories**



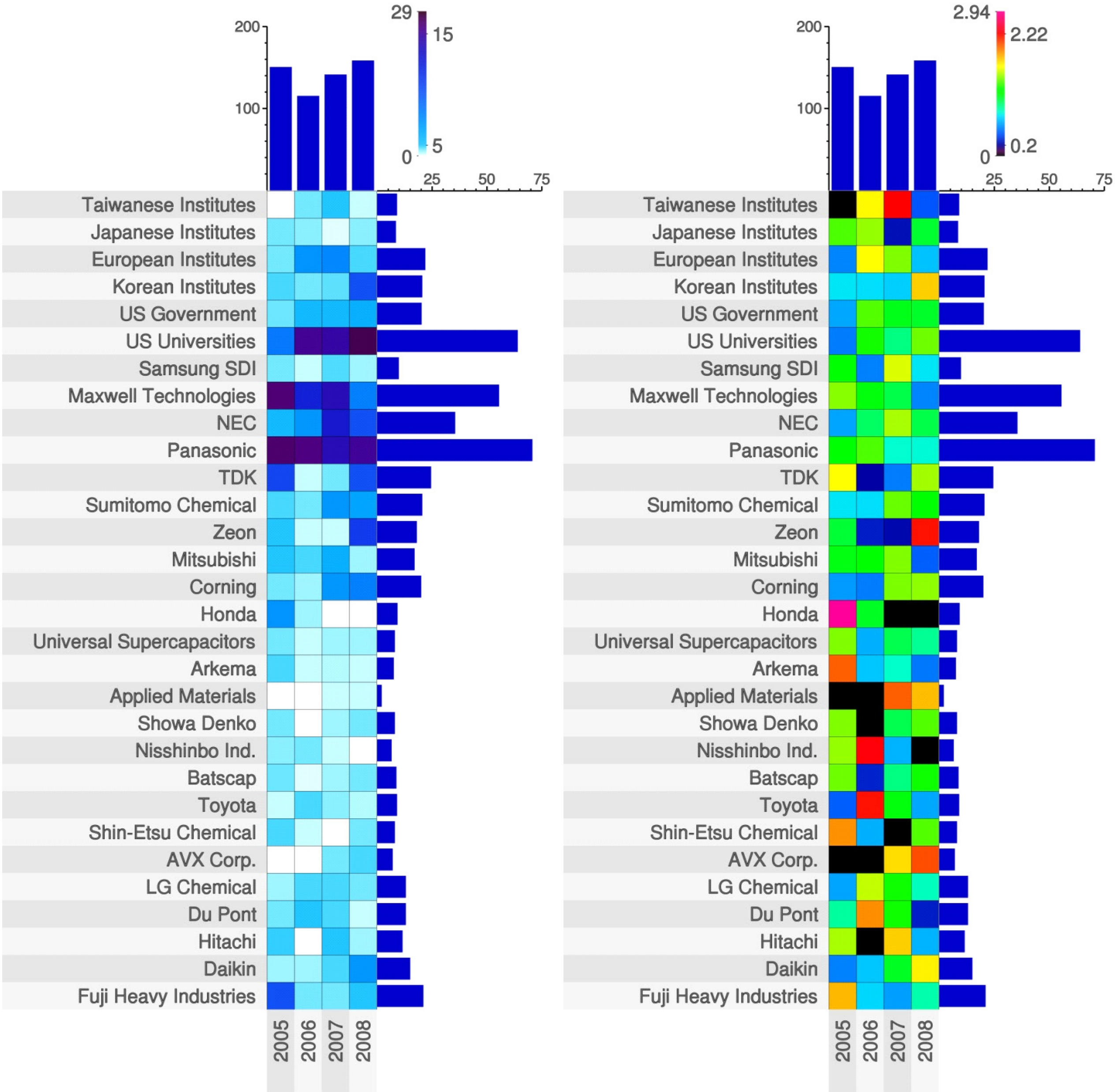
Source PatAnalyse

7.2. Top 50 Assignees vs Priority Years

Fig 7.2. Top 50 Assignees vs Priority Years

- Several players like US Universities, NEC, Corning, Sumitomo Chemical, Daikin, and AVX Corporation are increasing their patent activities.
- Panasonic activities are relatively steady
- Several companies are clearly reducing their filing efforts. The list includes companies like Fuji Heavy Industries, Honda, Maxwell Technologies, etc.

Fig. 7.2 **Top 50 Assignees vs Priority Years– absolute and normalised**



Source PatAnalyse

7.3. Technical categories vs Priority Years

Fig 7.3. Technical categories vs Priority Years

- Technical development in lithium ion capacitors, asymmetric supercapacitors, and nanotechnology is growing well above the average.
  - Lithium ion capacitor was a strong focus to Fuji Heavy Industries and now is supported by the modest activities at Panasonic, TDK, Sumitomo Chemical, and Zeon
- More commercially focused activities related to the electrodes manufacturing, supercapacitors mechanical construction and packaging, and to electrolyte chemistry are gradually declining

Fig. 7.3 **Technical categories vs Priority Years**

Fig 7.3a. Absolute Data

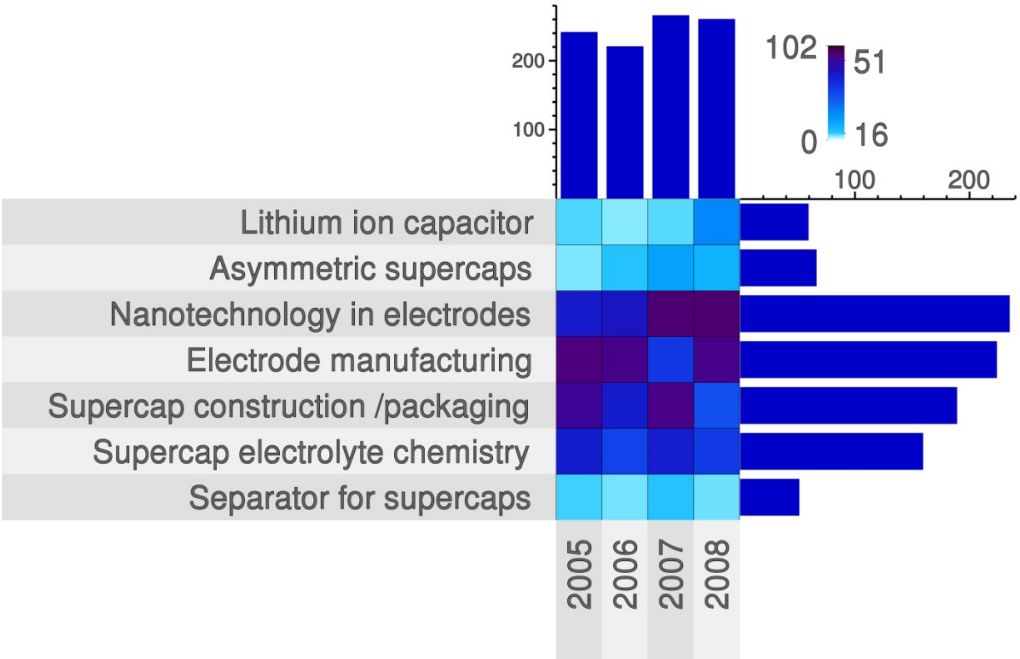
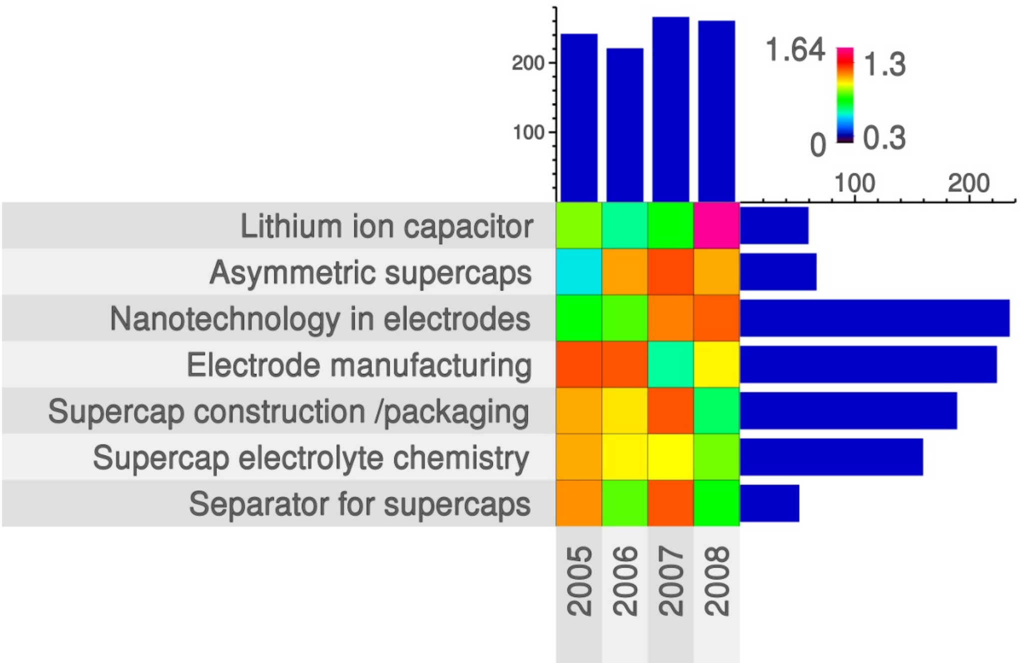


Fig 7.3b. Normalised Data



Source PatAnalyse

7.4. Countries of origin vs Priority Years

Fig 7.4. Countries of origin vs Priority Years

- US patent activities are quite close to the patent activities of Japan
- European and Korean activities are growing, however from a relatively low level
  - This is the only Patent Map showing patent growth in Korea

Fig. 7.4 **Countries of origin vs Priority Years**

Fig 7.4a. Absolute Data

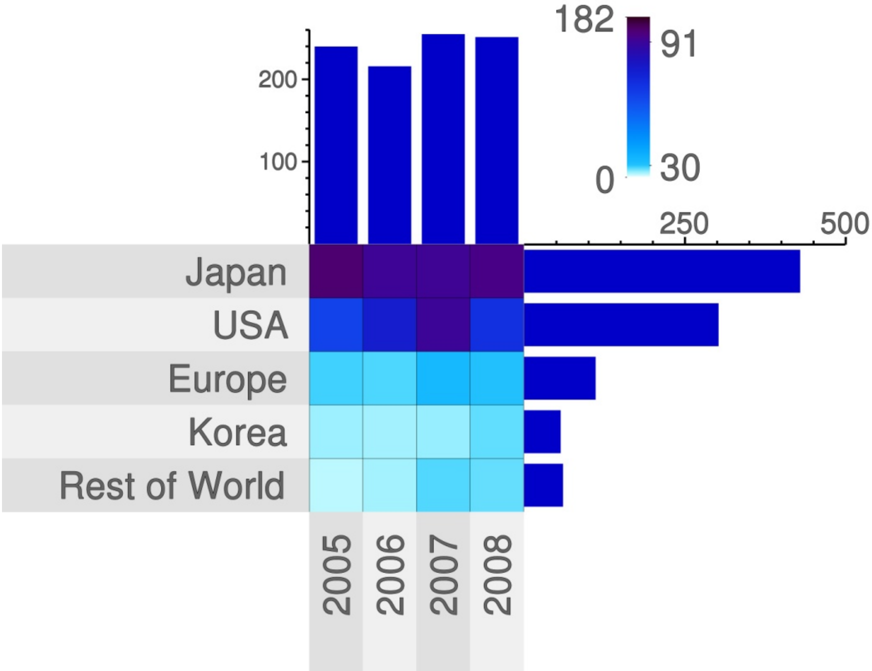
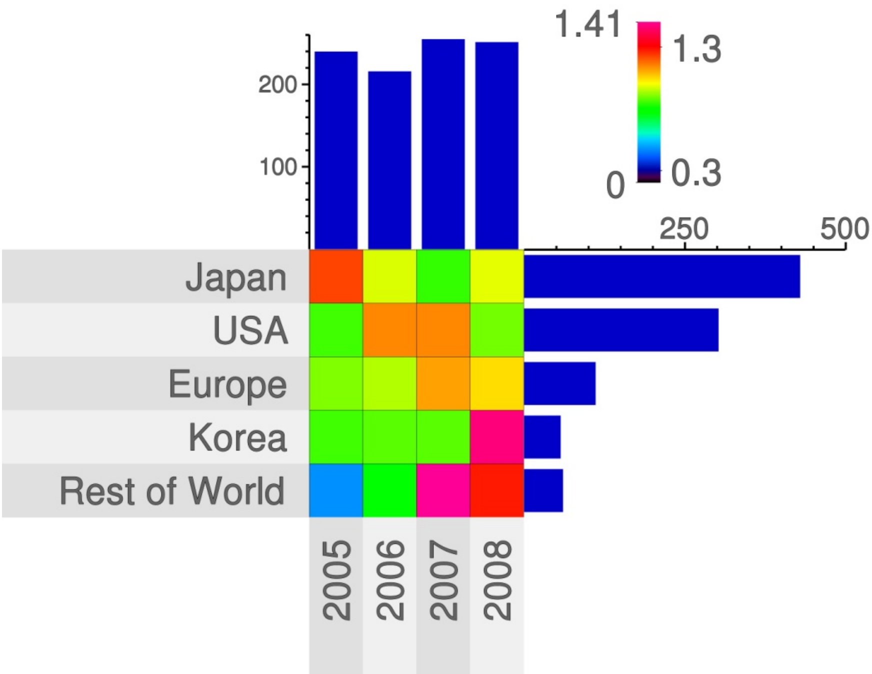


Fig 7.4b. Normalised Data



Source PatAnalyse

7.5. Technical categories vs Countries of origin

Fig 7.5. Technical categories vs Countries of origin

- Japan is on a second place (after US) in the nanotechnology related patent filings. However in comparison to other categories Japan seems to be ignoring opportunities provided by the nanotechnology.
- Japan has very strong focus in lithium ion capacitors and to a less degree in electrolyte chemistry and electrode manufacturing
- Apart from nanotechnology Europe has substantial activities in supercapacitors manufacturing and packaging

Fig. 7.5 **Technical categories vs Countries of origin**

Fig 7.5a. Absolute Data

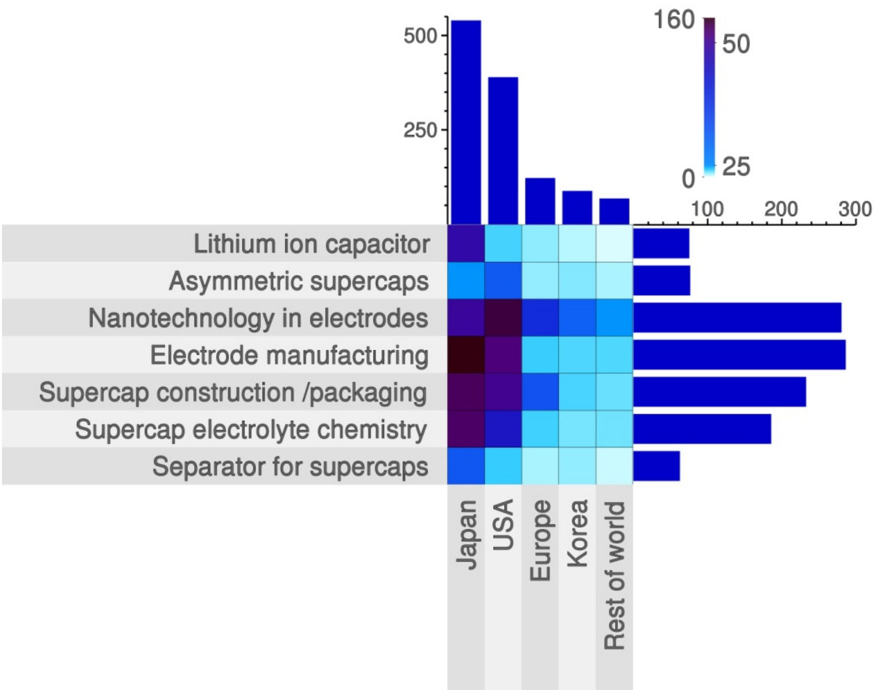
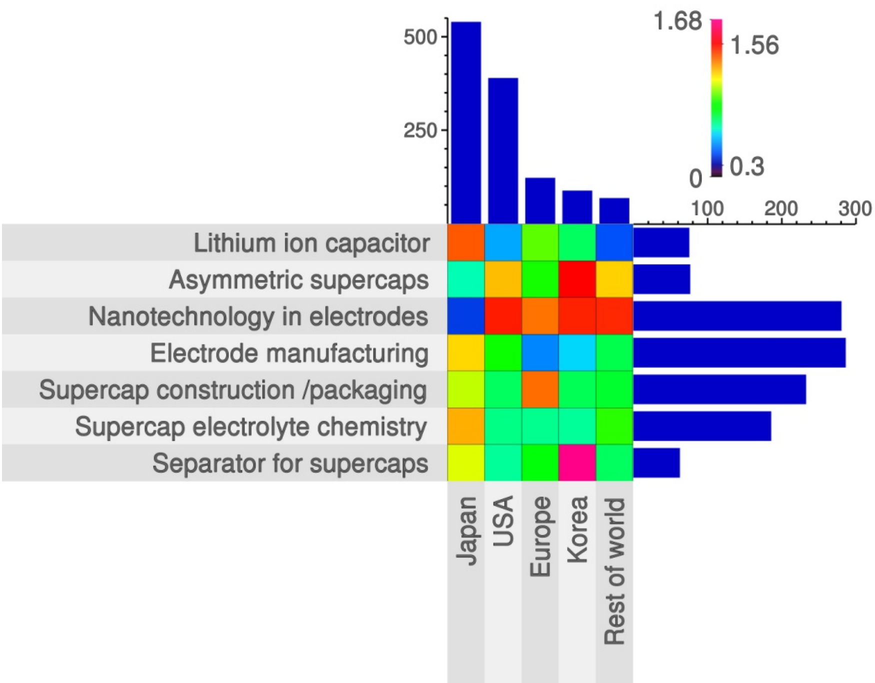


Fig 7.5b. Normalised Data



Source PatAnalyse

7.6. Technical categories vs National Patent Office Country

Fig 7.6. Technical categories vs National Patent Office Country

- Lithium ion capacitors remains as a predominantly Asian activity; Japanese patents are taken equally to Korea, China, Europe and US
- National patent filings for nanotechnology, asymmetric supercapacitors, mechanical construction and packaging are more biased towards US and Europe reflecting the origin of man patents in these areas

Fig. 7.6 **Technical categories vs National Patent Office Country**

Fig 7.6a. Absolute Data

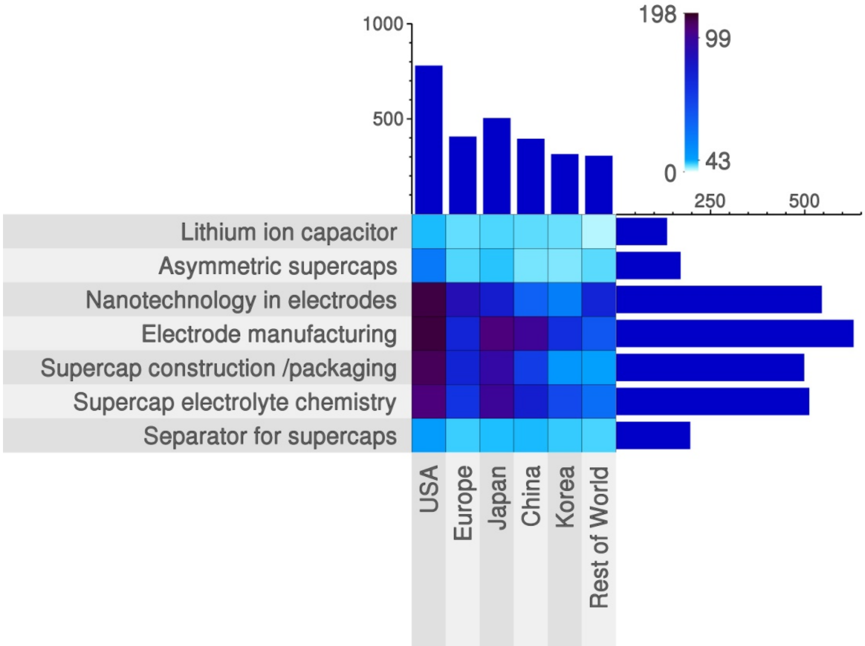
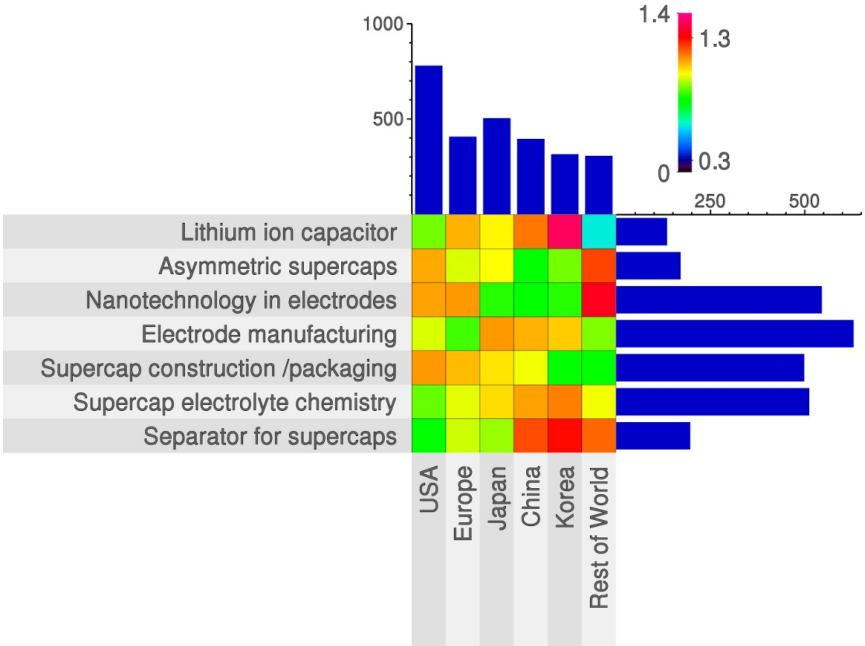


Fig7.6b. Normalised Data



Source PatAnalyse

8. On-board Electric Vehicle Battery Management System and external charging equipment

The Battery Management System on-board of an EV is used to decouple the battery from the electric motor through electronic control with built-in intelligence. Typically such systems are employing supercapacitors to buffer large but short power demands and regenerative braking energy. The development of new Traction Batteries combined with intelligent electronic cell management improves safety and practicality of development of the plug-in EV. The battery management involves not only monitoring the health of the battery cells but also a redundant cell configuration (one more cell than needed). With sophisticated switched wiring it is possible to condition one cell while the rest are on duty.

A Battery Management System is any electronic device that manages a rechargeable battery pack, typically monitoring its state, calculating secondary data, reporting that data, protecting the battery, controlling its environment, and / or balancing it. A battery management may monitor the state of the battery as represented by various items, such as:

- Voltage: total voltage and voltages of individual cells
- Current: current in or out of the battery or individual cells
- Temperature: average temperature, air intake temperature, air output temperature, or temperatures of individual cells
- State Of Charge (SOC) or Depth Of Discharge (DOD): to indicate the charge level of the battery
- State Of Health (SOH), a variously-defined measurement of the overall condition of the battery

A battery management may protect its battery by preventing it from operating outside its safe operating area, such as:

- Over-current
- Over-voltage (during charging)
- Under-voltage (during discharging), especially important for Li-Ion cells
- Over-temperature
- Under-temperature

The battery management system may actively prevent operation outside the battery's safe operating area.

It may also actively ensure that all the cells that compose the battery are kept at the same State Of Charge, through balancing. It may do so by:

- Wasting energy from the most charged cells, such as by connecting them to a load (such as through passive regulators)
- Shuffling energy from the most charged cells to the least charged ones (balancers)
- Reducing the charging current to a sufficiently low level that will not damage fully charged cells, while less charged cells may continue to charge

Another aspect of the current section is related to the charging stations for EV. Although most rechargeable electric vehicles and equipment can be recharged from a domestic wall socket, there is a growing need for widely distributed publicly accessible power points, some of which support faster charging at higher voltages and currents than are available from domestic supplies.

Patents related to the charging stations are mainly concerned with a safety – for instance interrupting the charging after discovering issues with the Traction Battery such as the increase in the battery temperature, overcharging, etc. The development of a range of heavy duty or special connectors is followed by the patents which aimed to break electrical connection in the emergency, especially if the driver has started moving EV without disengaging the connector. Surprisingly large number of patents is describing the charging without a physical connection using parking places equipped with inductive charging mats.

System level patents are describing intelligent charging stations capable to smooth the energy demand on the electric grid by coordinating charging of large number of EV. Business process patents are also dealing with the issues of identifying EV and collecting micropayments associated with a partial charging of the battery. Intelligent system can also take into account the amount of time available for charging using information regarding parking fees paid by the client.

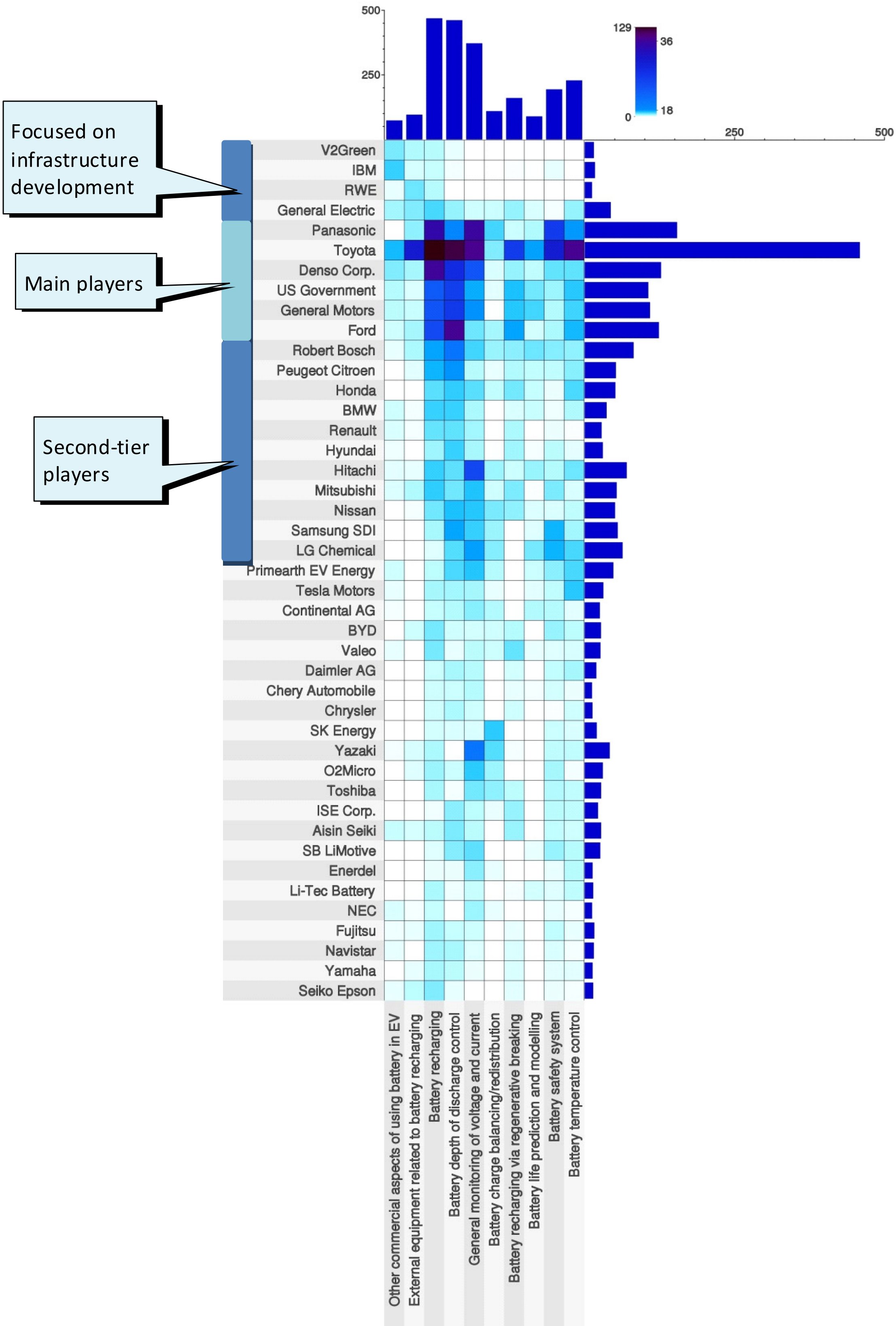
An alternative to recharging the battery in the vehicle is battery swapping: a battery switching facility that exchanges the vehicle's discharged battery for a charged battery. Regardless of the questionable practicality of such approach, patents are increasingly providing more and more detailed description of such process stations.

8.1. Top 50 Assignees vs Technical categories

Fig 8.1. Top 50 Assignees vs Technical categories

- Toyota is the only company at the list of the top players
  - Toyota is the most active player in the patenting technologies for charging stations
  - Toyota has stronger than average emphasis on the aspects of the battery recharging via regenerative breaking, battery safety, and battery temperature control
- The list of second-tier players includes Panasonic, Denso Corp., General Motors, Ford, and Robert Bosch
  - The common focus is in managing the process of battery recharging and in controlling the depth of discharge of the battery pack
- Companies like V2Green, IBM, RWE, and General Electric are developing IP position in recharging stations and business methods related to using batteries in plug-in EV

Fig. 8.1 **Top 50 Assignees vs Technical categories**



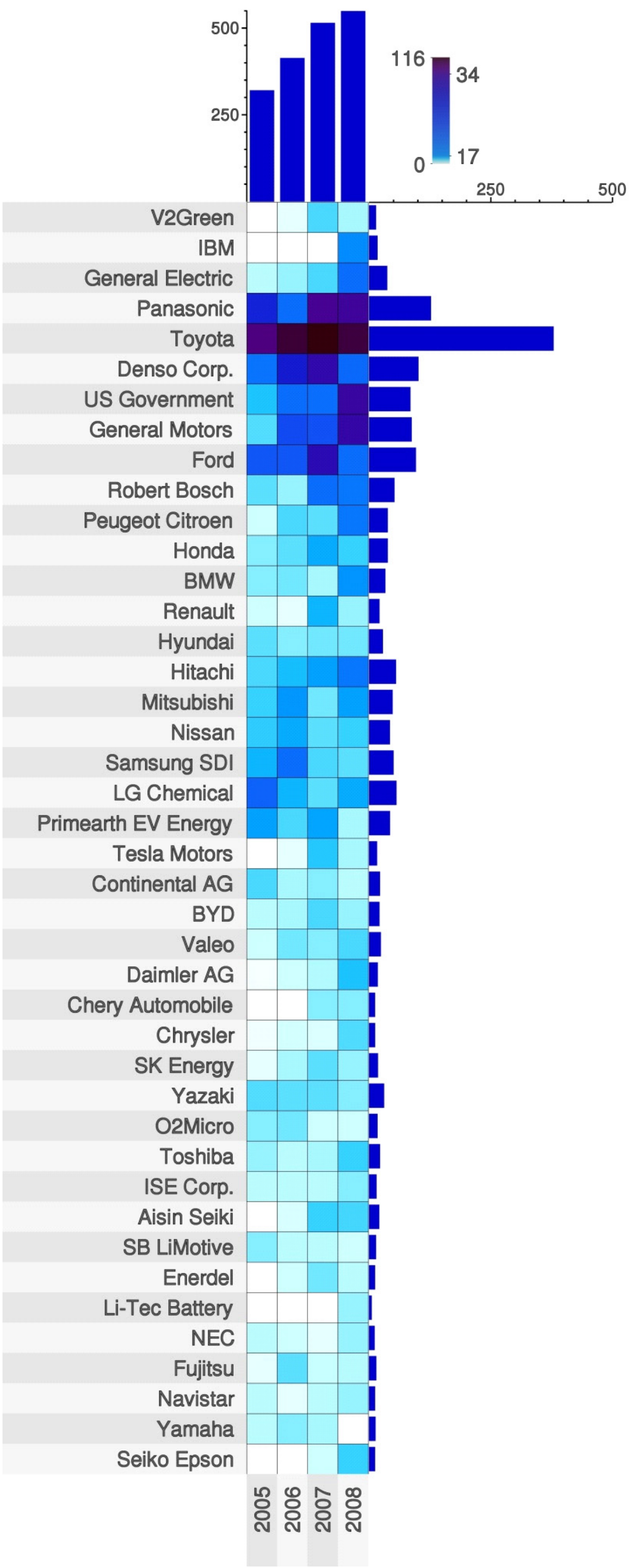
Source PatAnalyse

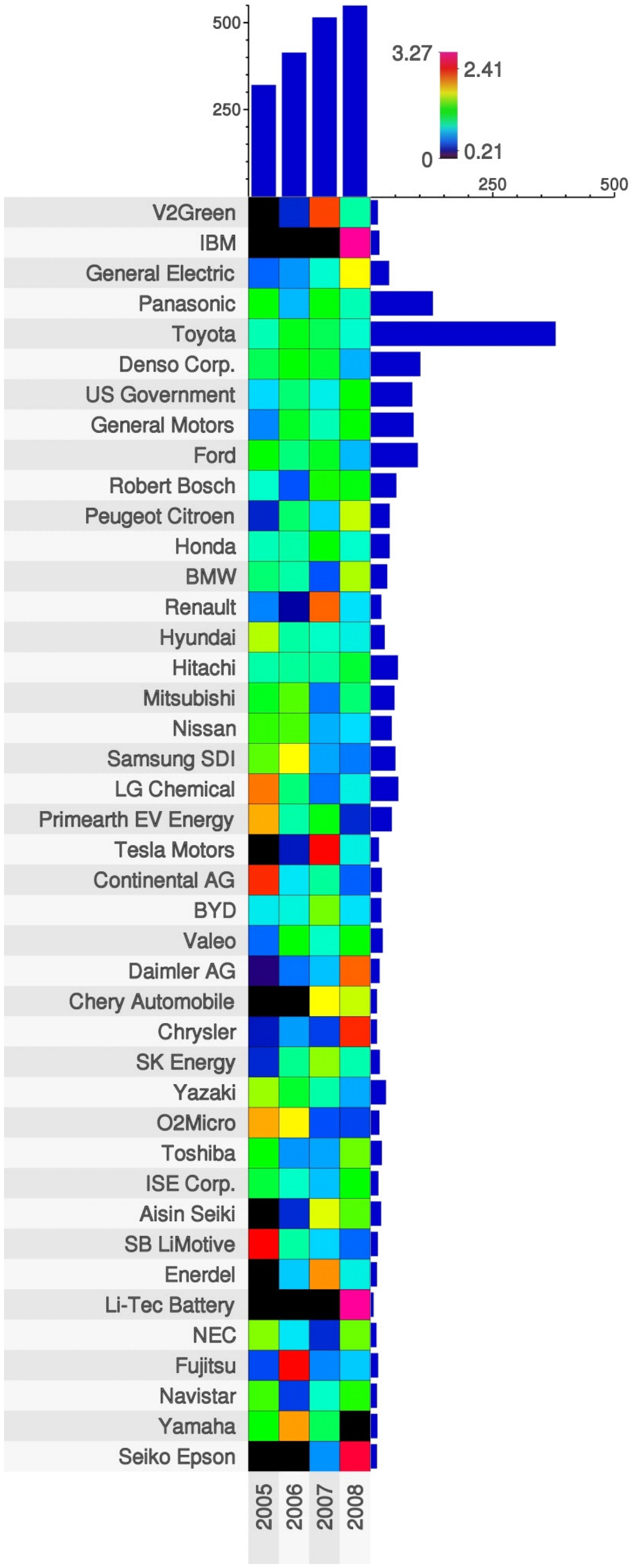
8.2. Top 50 Assignees vs Priority Years

Fig 8.2. Top 50 Assignees vs Priority Years

- The overall amount of patents on the Patent Map is growing fast, however not as strongly as the activities in the Lithium Traction Batteries
- Toyota's strategy in the Battery Management System portfolio is rather dissimilar to the one shown in Battery technologies. Toyota is a well established player in the Battery Management and its activities while growing in 2006 and 2007 are actually reducing in 2008. This behavior is likely consistent with a possible shift of R&D focus from developing systems supporting the usage of the Traction Batteries to the development of the Traction Batteries per se.
- Several companies are showing high level of growth of their patent portfolio. The list includes General Motors, Peugeot Citroen, BMW, Robert Bosch, Daimler AG, Chery Automobile, Chrysler, and Aisin Seiki
- Patent activities are down at Ford, Denso Corp., Hyundai, Nissan, Samsung SDI, LG chemical, Primearth EV Energy, Continental AG, and SB LiMotive

Fig. 8.2 **Top 50 Assignees vs Priority Years– absolute and normalised**





Source PatAnalyse

8.3. Comparison of Profiles for top companies in Battery Management

Fig 8.3 Comparison of Profiles for top companies in Battery Management:

- Toyota has substantially reduced its focus in temperature control and regenerative braking aspects of battery management
- Toyota has increased its focus in charging stations, battery recharging, and battery safety systems
- General Motors shows very strong jump in the patenting activities which might have some artificial component in it with possible political gains in mind. GM has special focus in the battery depth of discharge control.

Fig. 8.3 **Comparison of Profiles for top companies in Battery Management**

Fig 8.3a. Toyota

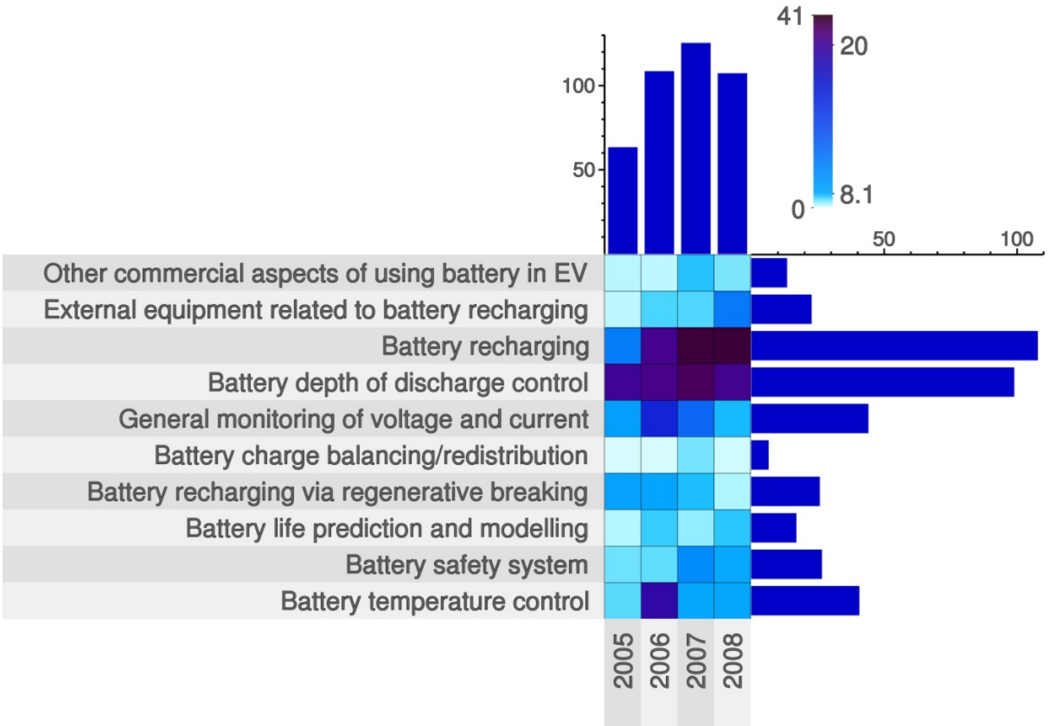
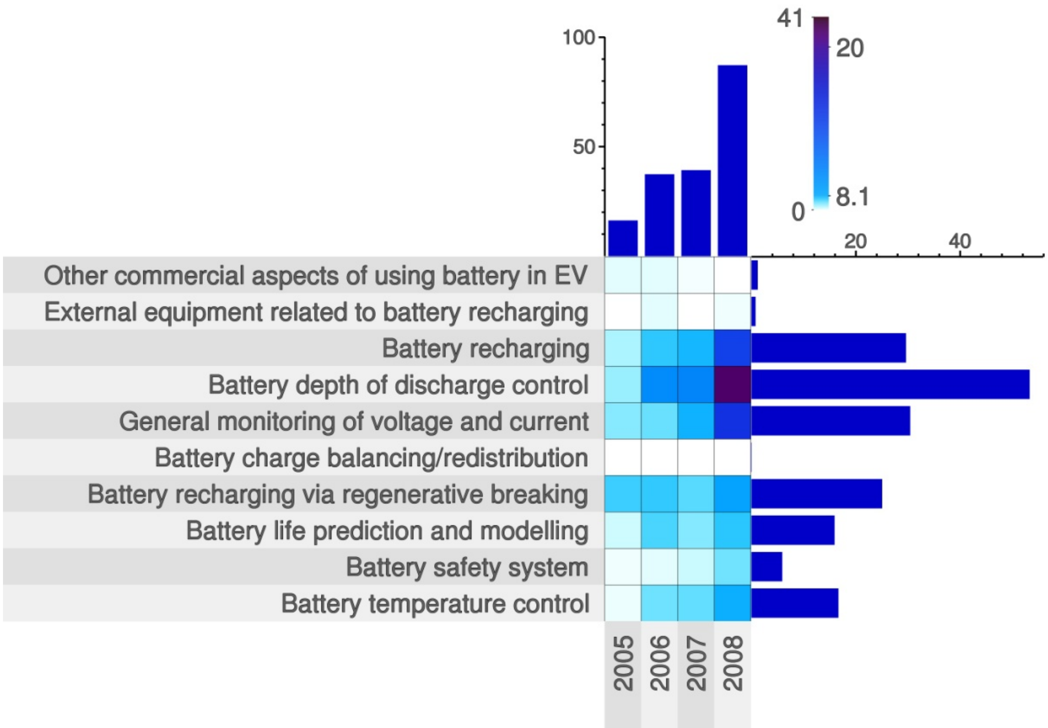


Fig 8.3b. General Motors



Source PatAnalyse

8.4. Technical categories vs Priority Years

Fig 8.4. Technical categories vs Priority Years

- Commercial aspects of using batteries in EV and development of IP for charging stations are the fastest growing areas of the patent portfolio. They are representing the least developed aspects of EV story and can be still classified as emerging stage technologies.
- The reduction in the patenting activities related to the regenerative braking technology is a recognition that it is already a quite mature technology with little potential for strong IP protection

Fig. 8.4 **Technical categories vs Priority Years**

Fig 8.4a. Absolute Data

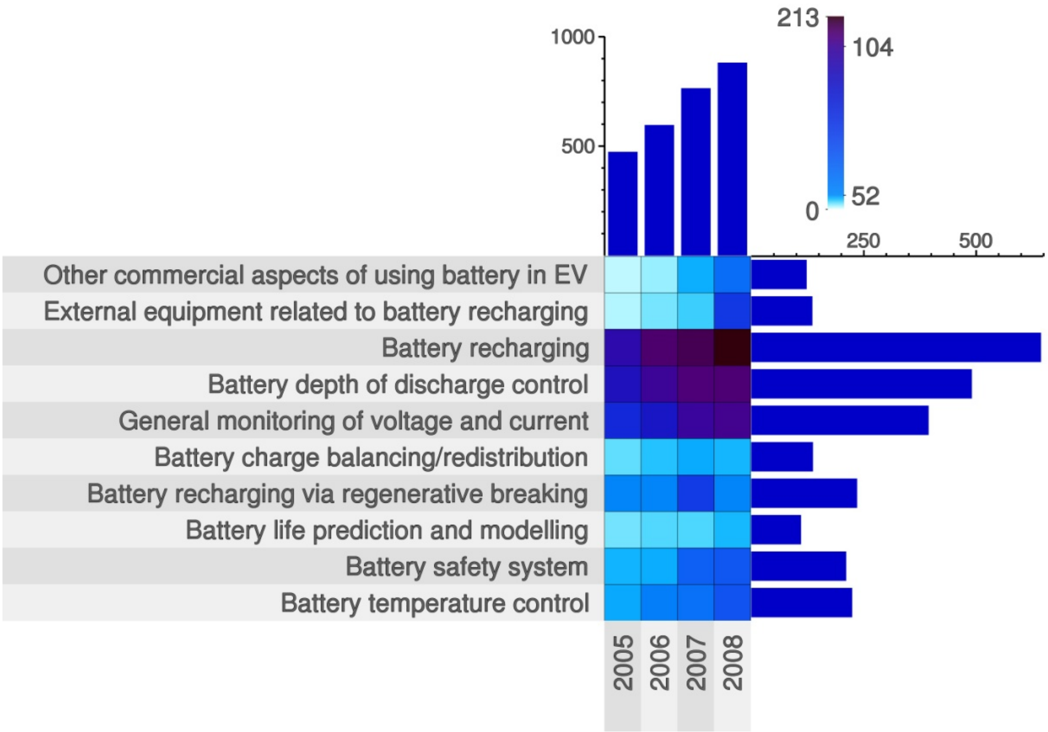
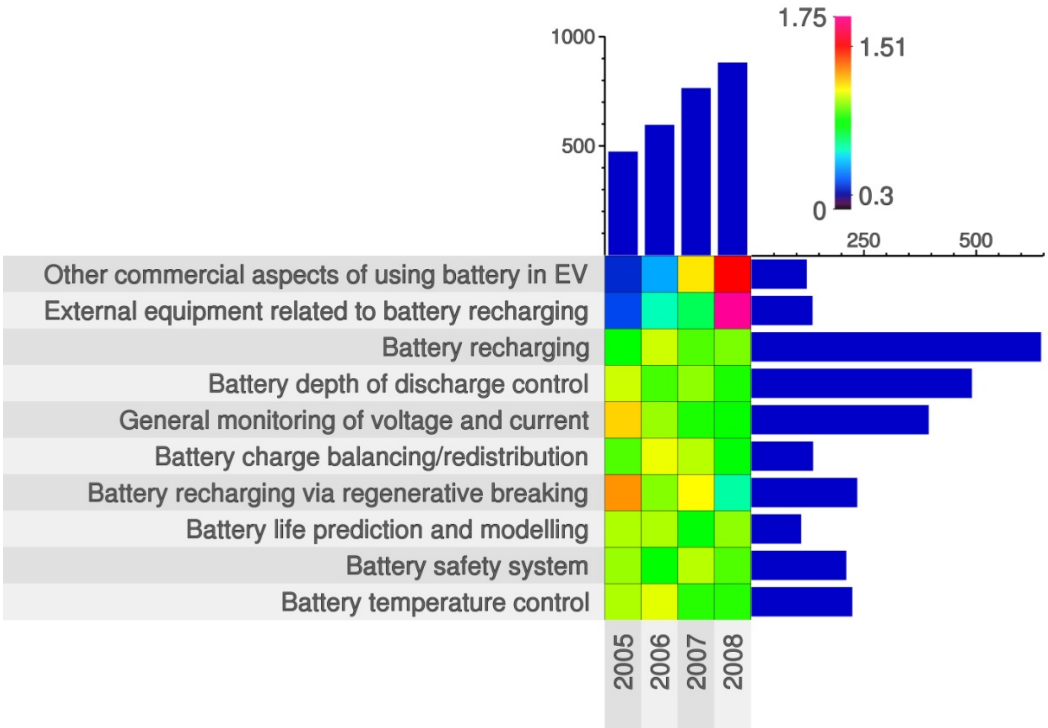


Fig 8.4b. Normalised Data



Source PatAnalyse

8.5. Countries of origin vs. Priority Years

Fig 8.5. Countries of origin vs. Priority Years

- US is on a par with Japan. If not for Toyota, US will be shown as a much stronger player compared to Japan
- Europe positions are relatively strong. – much stronger if compared to the Battery technologies
- US and Europe are growing much faster if compared to average
- Koreans activities are on a down (due to LG Chemical and Samsung SDI policies)

Fig. 8.5 **Countries of origin vs Priority Years**

Fig 8.5a. Absolute Data

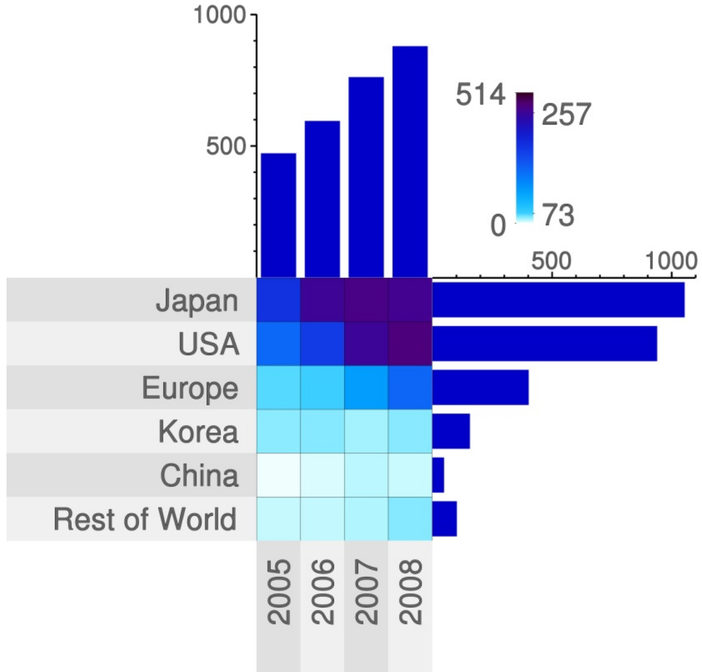
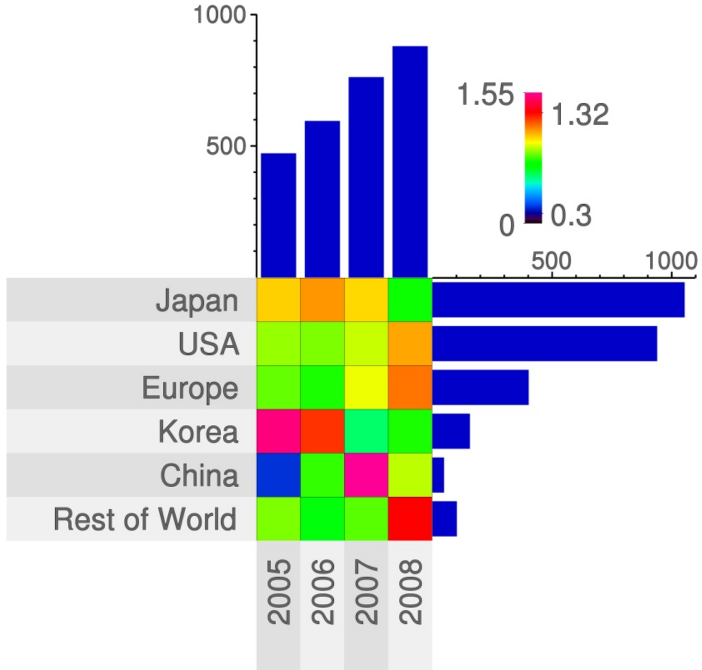


Fig 8.5b. Normalised Data



Source PatAnalyse

8.6. Technical categories vs. Countries of origin

Fig 8.6. Technical categories vs. Countries of origin

- Patenting activities related to the regenerative braking technologies are strong mainly in US
- Business method patents related to commercial aspects of using batteries in EV are patented mainly by US companies
- Patents related to the recharging stations are patented by companies from US, Europe, and Japan. European activities in this category are on a par with the Japanese one.
- Battery safety and temperature control of the battery pack are relatively more important for Japanese and Korean companies

Fig. 8.6 **Technical categories vs Countries of origin**

Fig 8.6a. Absolute Data

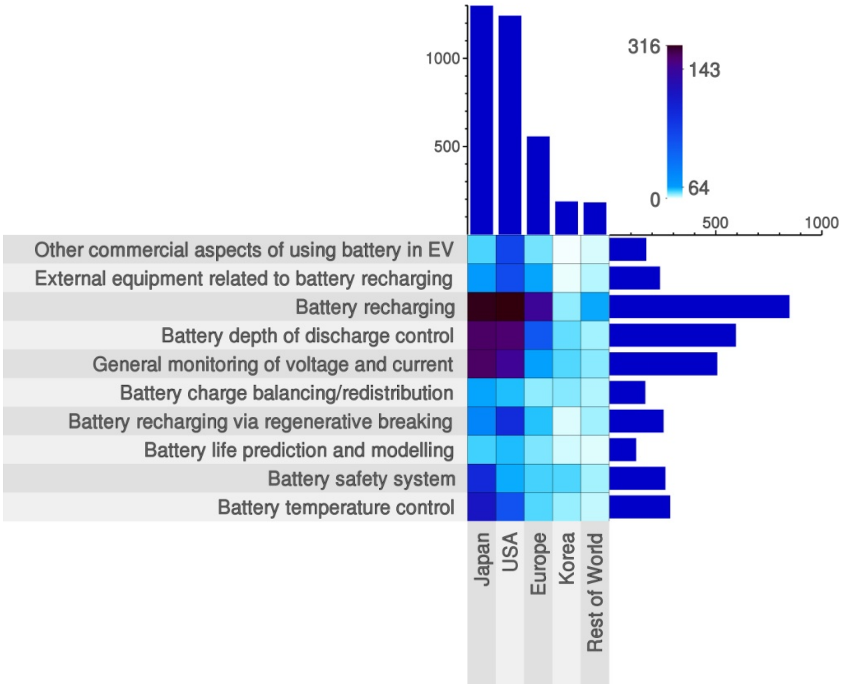
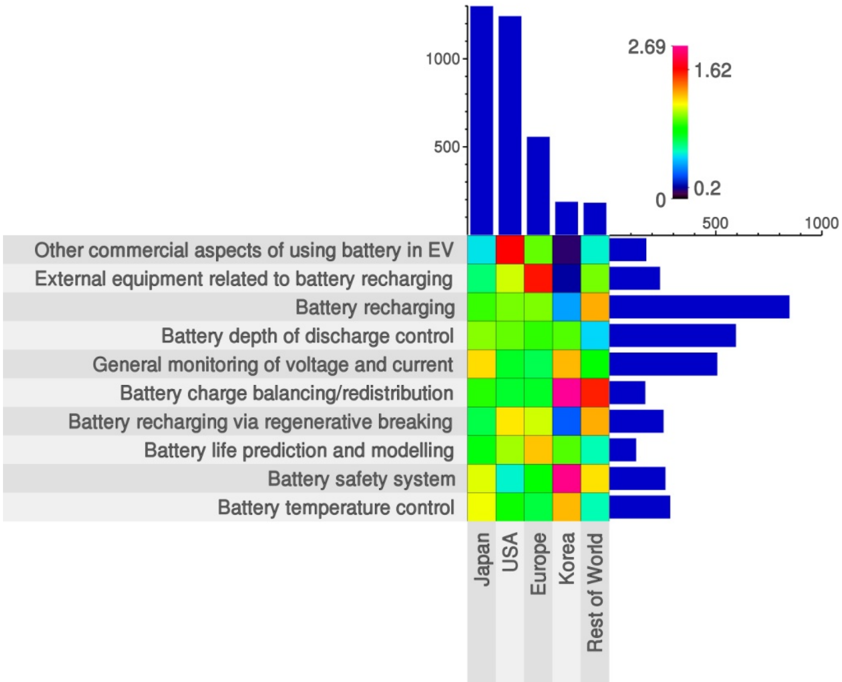


Fig 8.6b. Normalised Data



Source PatAnalyse

8.7. Technical categories vs National Patent Office Country

Fig 8.7. Technical categories vs National Patent Office Country

- Battery safety and temperature control of the battery pack remains an Asian activity due to the origin of substantial number of patents from Japan and Korea
- Korea is substantially underrepresented on this Patent Map. It seems that Japanese companies are taking their patents to US, China, and Europe mainly ignoring the opportunity to file Korean patents. Due to the lack of patent activities originated from Korea itself, the overall number of Korean patents in this particular sub-portfolio is quite small

Fig. 8.7 **Technical categories vs National Patent Office Country**

Fig 8.7a. Absolute Data

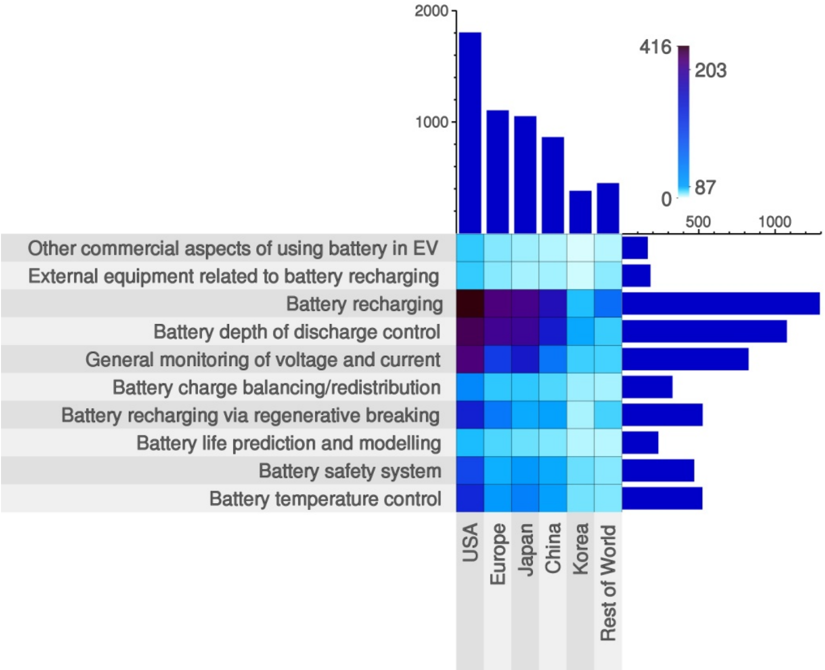
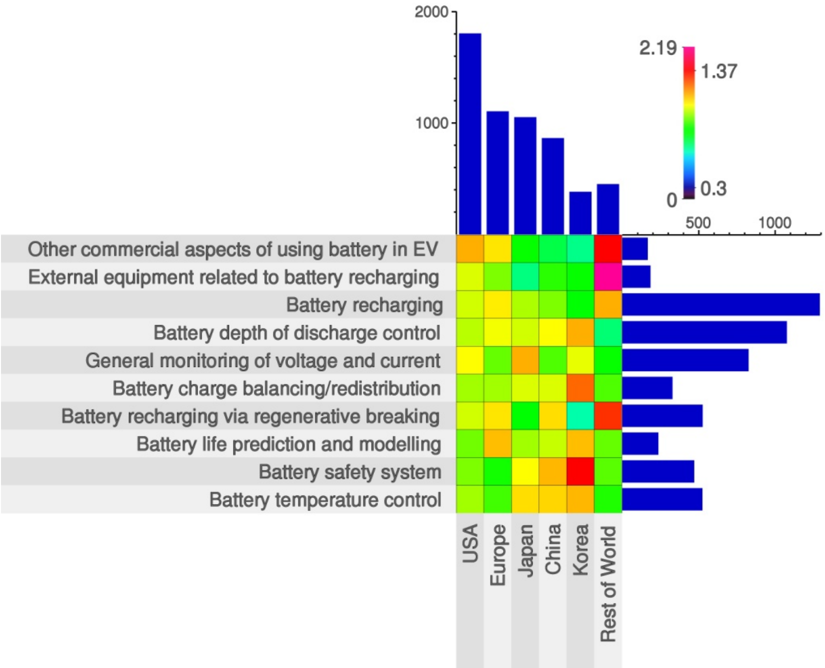


Fig 8.7b. Normalised Data



Source PatAnalyse

9. Most offensive granted patents with priorities from 1993 to 2000

The nearly exponential growth of the patent applications related to the lithium battery technologies has started since 2000 and is still continues right now however at a much slow pace. Most patents filed these days are incremental one and it is more difficult to access their offensive power due to the significant overlap between patents from various companies. The rather low quality of the prior art search performed at National Patent offices is leading to the situation when a lot of granted patents will not stand out a more thorough invalidity search request. Thus it is more straightforward to analyse the offensive power of much older granted patents as there is much less prior art which can be used to invalidate their claims in the case of the litigation scenario. Specific research has been carried out by PatAnalyse to evaluate the offensive strength of granted patents with priority predating the patenting boom started since 2001.

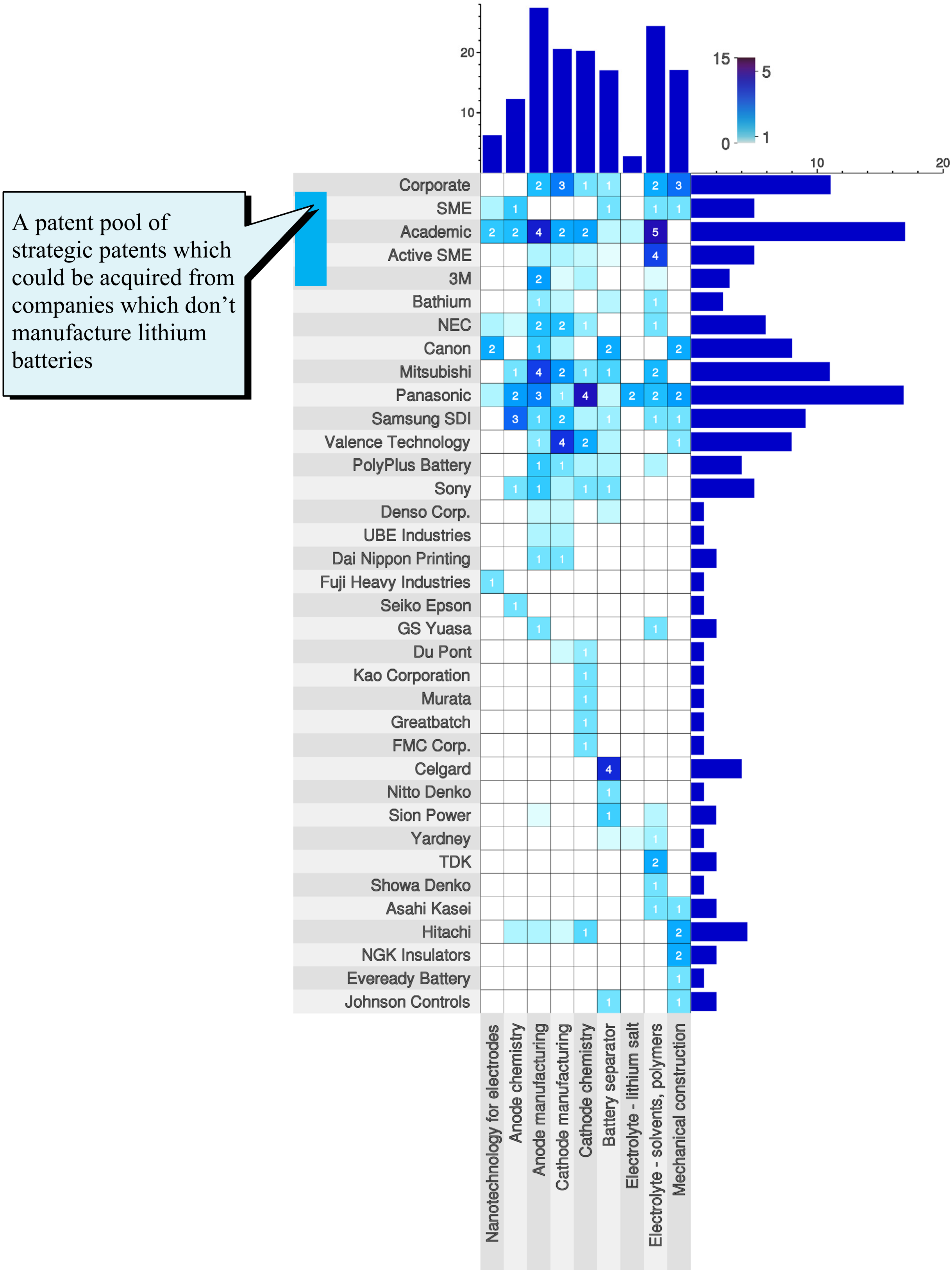
Companies with a few offensive granted patents with priorities before 2001 are more vulnerable in the case of patent litigation regardless of how many incremental patents they are hold in their portfolios. Our results presented below suggest that major players don't put enough attention to the possible litigations leaving themselves vulnerable to the exposure of the sudden attacks of the patent aggregators and other non-practicing entities.

9.1. Lithium Battery Technologies

Fig 9.1. Top Assignees vs Technical categories

The list of major players is changed. LG Chem, Toyota and Nissan have disappeared from the patent map. They are replaced by Canon, Mitsubishi, Bathium. Valence Technology and PolyPlus Battery

Fig. 9.1 **Top Assignees vs Technical categories**



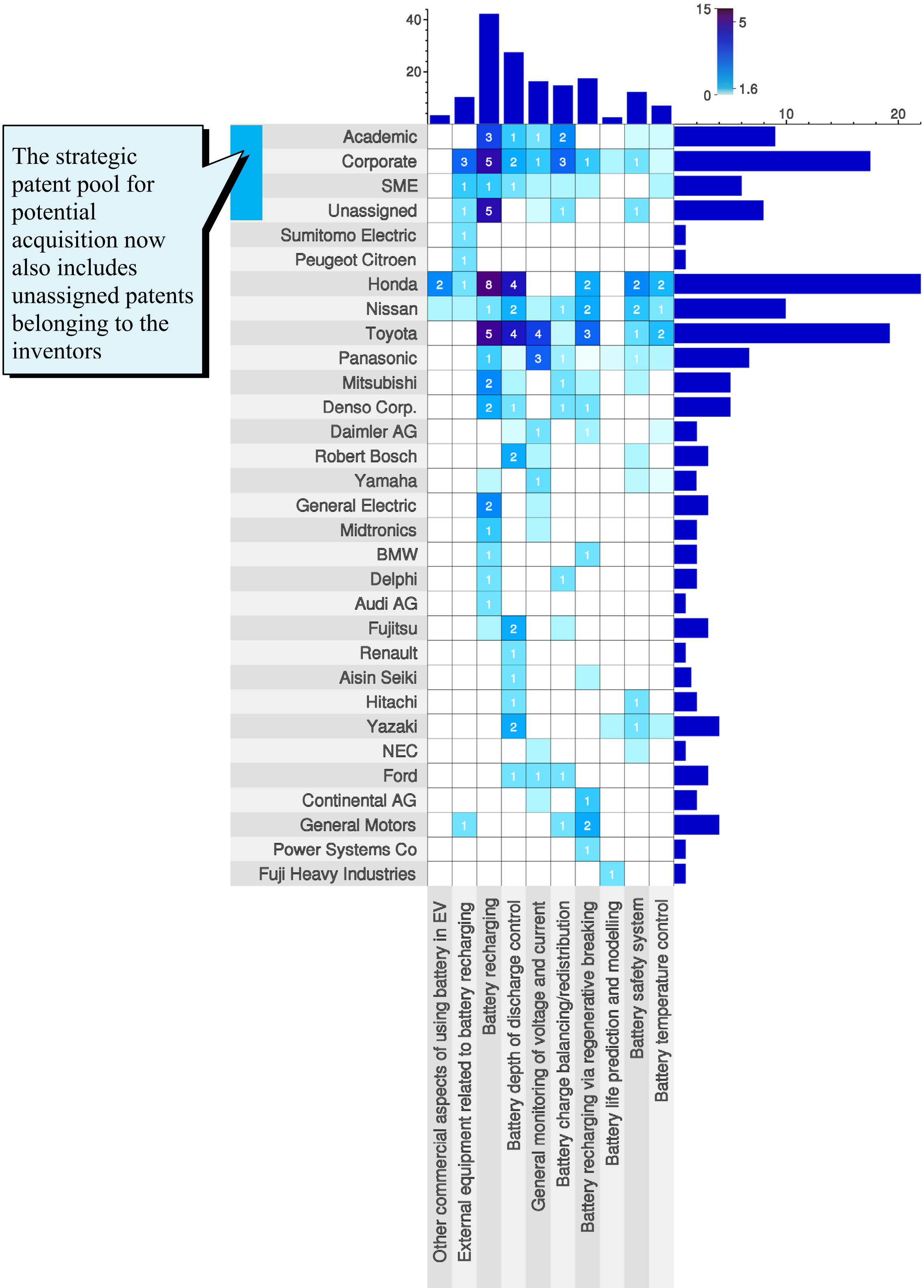
Source PatAnalyse

9.2. On-board Electric Vehicle Battery Management System and external charging equipment

Fig 9.2. Top Assignees vs Technical categories

Ford and General Motors have disappeared from the top list. They are replaced by Nissan and Honda. Toyota remains at the top. Patent trolls are not yet players on this patent map, however this will surely change in a very near future.

Fig. 9.2 **Top Assignees vs Technical categories**



Source PatAnalyse

Appendix 1:
About PatAnalyse

Access to the Report Patent Database and to on-line interactive Patent Maps can be made available via an on-line service to the subscribers. Interested party should contact PatAnalyse for pricing as well as for further details of the on-line patent knowledge management system provided for receiving updates of the current study. The "software-as-a-service" Web 2.0 user environment to the Report Patent Database is fully supporting a multi-user collaboration for the users from the same client company and provides the client company a true confidentiality regarding their activities in the patent database system.

Current analysis of the patent portfolio for the report "Advanced Energy Storage Technologies: Patent Trends and Company Positioning" is provided at the top level. Further detailed patent studies referencing individual patents can be provided under the request. Such projects can address specific questions of importance to our clients. If necessary, the patent projects can be provided under attorney-client privilege. Our clients can receive an unrestricted access to the on-line patent portfolio developed for the specific projects.

For further details please contact PatAnalyse at info@patanalyse.com and visit web-site at www.patanalyse.com

"Completeness of search results and thorough generation of Patent Landscapes is followed with insightful interpretation; the workflow is supported with the best in class on-line portal patent knowledge management system"

PatAnalyse is an integrated technology consultancy specialising in high quality exhaustive patent searching and comprehensive analysis of the trends presented in the patent portfolio.

The PatAnalyse's core team of software developers, technology and business consultants is based in Cambridge, UK. The main members of the team have been working together for over a decade on a wide variety of patent landscape assignments.

We have developed innovative on-line tools for organising the workflow of patent projects to support dispersed collaborative teams and to provide close integration between the artificial intelligence and the real judgement of subject area experts. The software is focused on improving the efficiency and quality of patent searching, and in assisting our clients with mining patent data in the post-project phase.

Using our advanced tools, and breadth of technical expertise, the PatAnalyse team works together with clients on patent studies which map the competitive IP landscape to deliver unique insights into competitive intelligence. Patent Mapping tools provided by PatAnalyse ensure the accuracy and completeness of the results, but it's our business consultants who make the real difference. Our experience in technology consultancy allows us not just to map the Patent Landscape, but also to provide an interpretation closely aligned to the client's business strategy.

A typical projects aims to:

- inform the strategic decision makers in the client organisation;
- align research budgets according to the gained intelligence;
- help to focus patent filing efforts in areas more likely to produce broad patents;
- benchmark the clients' existing patent portfolio against competitors;
- clearly understand the strengths and weaknesses of the patent portfolio of major competitors;
- improve efficiency of internal portfolio management;
- facilitate smart decisions by including a relatively accurate risk assessment in FTO analysis;
- help to avoid wilful infringement and treble damages;
- assist with technology scouting;
- identify and evaluate the most appropriate acquisition targets;
- determine if any potential blocking patents will affect the right for the in-licensing technology;
- support required defensive activities with key evidence.

By identifying the strongest and most appropriate patent set from the client's patent portfolio, such projects can also assist in cost reduction and revenue generation through the abandonment or sale of non-core IP.

To cope with the increased volume of patent data PatAnalyse Ltd has developed revolutionary techniques for patent searching. Our tools allow the search to evolve into a *self-learning iteration process*, improving the completeness of the final results. In the past our techniques have routinely demonstrated the ability to find several times more relevant patents than even the most experienced information specialists in client organisations.

PatAnalyse delivers investigative consultancy projects to answer specific IP related questions which address the strategic business needs of our clients. PatAnalyse is mainly focused on providing premium services which are critically dependent on the completeness of the patent searching results:

- high profile Validity searches to provide key evidence for preparing opposition cases or obtaining an opinion of counsel as to the invalidity of a patent;
- comprehensive Freedom to Operate (FTO) analysis for achieving relatively accurate risk assessments; a special focus is provided to help avoid wilful infringement claims and subsequent treble damages;
- due-diligence studies before in-licensing or acquisition;
- tailored 'Patent Landscape' studies for detailed reviews of international R&D trends, technology scouting, or for achieving strategic portfolio alignment.

In order to deliver comprehensive Patent Landscape studies PatAnalyse has developed innovative methods using modern 'Software as a Service' technologies. Within our tools the power of artificial intelligence algorithms is closely integrated with the judgement of subject area experts. Special emphasis is also given to the efficiency of task distribution, organising collaboration between the experts, and in assisting our clients with mining patent data in the post-project phase.

The involvement of the client team in the study will vary between different assignments according to client requirements. But it is important for PatAnalyse to establish close working relationships with the client team at the project start-up meeting in order to understand the set of questions which should be addressed in the study. At the end of the project, clients receive a report including strategic recommendations based on the analysis of Patent Maps and individual patents; the patent portfolio with classified documents is provided via an interactive on-line portal and also as a backup-file.

On the current market, the consultancy offering from PatAnalyse delivers the highest accuracy of result with the most efficiency. In any case PatAnalyse is able to deliver Patent Mapping studies at levels of complexity way beyond the capabilities of most patent consultancy firms.

Dr Victor Zhitomirsky

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For over ten years PatAnalyse has delivered IP intelligence to its clients. We provide custom consultancy, research and advisory services delivering: patent landscaping - competitor intelligence studies, due-diligence studies before in-licensing or acquisition, strategic portfolio alignment, freedom to operate (FTO) analysis, litigation support for nullifying claims of asserted patents.

For more details visit www.PatAnalyse.com