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THE FUTURE OF TRANSPORT

EXPLORING INNOVATIONS FOR THE FUTURE OF TRANSPORT

AT A GLANCE

FROM THE TEAM LEAD

Entrepreneurs in the UK and around the world are re-imagining the future of transport. From passenger vehicles and batteries to aviation and shipping, new technologies, both hardware and software, will improve our quality of life, reduce carbon emissions and contribute to new job creation in our economy. Inventors persevere - despite obstacles - to pursue their visions. At Reddie & Grose we are proud to support the creativity of inventors with intellectual property protection. We protect innovation, design, and branding cross all sectors of industry and at all stages in the supply chain. If you are a multinational seeking a global IP portfolio, a start-up company launching a new product or brand, or an institution seeking protection for research results, we will advise on the best IP strategy for you and will protect and maintain your rights worldwide.

Our team of attorneys understands the unique requirements of our clients. We hold advanced degrees in aeronautical, chemical, mechanical and nuclear engineering, physics and materials chemistry. We have covered a number of industries, from aviation to energy to satellites and nuclear power generation. Some of us have worked as engineers and scientists before we entered the legal profession. As such, we can advise on emerging technologies as well as legacy technologies that are being adapted, perhaps with the addition of artificial intelligence or machine learning, for new applications. We are proud of what we have achieved together, and look forward to continuing success in meeting the needs of our clients.

Dr Paul Loustalan

MEET THE TEAM

Dr Paul Loustalan • Team Lead, Partner

Paul is a mechanical engineer whose PhD focused on fuel injectors for direct injection spark ignition engines, and was carried out under the sponsorship of two large automotive manufacturers.
Email paul.loustalan@reddie.co.uk, or click here for his full bio.

Andy Williams • Senior Associate

Andy is a Chartered Mechanical Engineer, and worked in-house at GE for many years before joining Reddie & Grose. Andy has handled technologies which have included aircraft propulsion systems and related sub-systems, aircraft landing gear and other aircraft systems.
Email andy.williams@reddie.co.uk, or click here for his full bio.

Pete Sadler • Partner

Pete specialises in drafting and obtaining patents for inventions in the software, electrical, electronic and physics fields. He works across a wide range of technologies, with recent work in the fields of electric vehicles, electric motors and soft starters, including associated control systems, and drones for military and civilian use.
Email pete.sadler@reddie.co.uk, or click here for his full bio.

Jon West • Senior Associate

Jon has extensive experience in drafting and prosecuting patent applications relating to the electrical, electronics and software fields, including computer-implemented inventions for connected transport ecosystems, audio and video sensors and related processing telecommunications, integrated circuits, machine learning and security systems.
Email jon.west@reddie.co.uk, or click here for his full bio.

Tom Sharman • Partner

Tom is an automotive engineer, with experience of working for a large OEM. He now works with clients to protect innovations and designs in the mechanical and automotive fields in key jurisdictions around the world. He also advises on the level of risk associated with launching new products in crowded technical fields.
Email tom.sharman@reddie.co.uk, or click here for his full bio.

James Spencer • Senior Associate

James has a background in Physics, and now works predominantly with multinational companies and SMEs across and wide range of engineering and technology sectors. He has significant experience managing global patent portfolios for his clients, and has spent time of secondment with a multinational client.
Email james.spencer@reddie.co.uk, or click here for his full bio.

MEET THE TEAM

Andy Attfield • Editor, Associate

Andy handles patent work in the software, electronics and electrical devices, and automotive fields. Andy has drafted patents across a broad range of technologies, including the fields of AI, electrical devices, software, and drones, for individual inventors and start-ups through to large multinational corporations.
Email andy.attfield@reddie.co.uk, or click here for his full bio.

Matthew Havron • Associate

Prior to entering the patent profession, Matt was a Nuclear Engineer at EDF energy where he gained considerable experience in the fields of power generation and distribution. He now advises SMEs and multinational companies on patent and registered design matters.
Email matt.havron@reddie.co.uk, or click here for his full bio.

Dr Dustin Bauer • Associate

Dustin is a native German speaker who handles patents in the engineering, materials and consumer products fields. His PhD focussed on hydrothermal synthesis of nanoparticles for use in a rage of energy storage devices, including lithium-ion batteries, sodium-ion batteries, and hybrid capacitors.
Email dustin.bauer@reddie.co.uk, or click here for his full bio.

Joshua Parsi • Associate

Josh has a Master's degree in Aeronautical Engineering working on projects involving fluid dynamics, structural analysis, turbomachinery, wind turbine design, MRI, robotics and automated drones. He has extensive experience in drafting and prosecuting patent applications in many different technical fields before the UK and European patent offices, as well as managing worldwide patent portfolios having a presence in other major IP jurisdictions.
Email josh.parsi@reddie.co.uk, or click here for his full bio.

Ally Orrin • Associate

Ally has significant experience in protecting inventions and designs, and advising clients on how to avoid patent infringement. She has worked with a range of innovators across different technical fields, and now regularly presents legal and technical arguments on behalf of clients.
Email ally.orrin@reddie.co.uk, or click here for her full bio.

Isabelle Tate • Associate

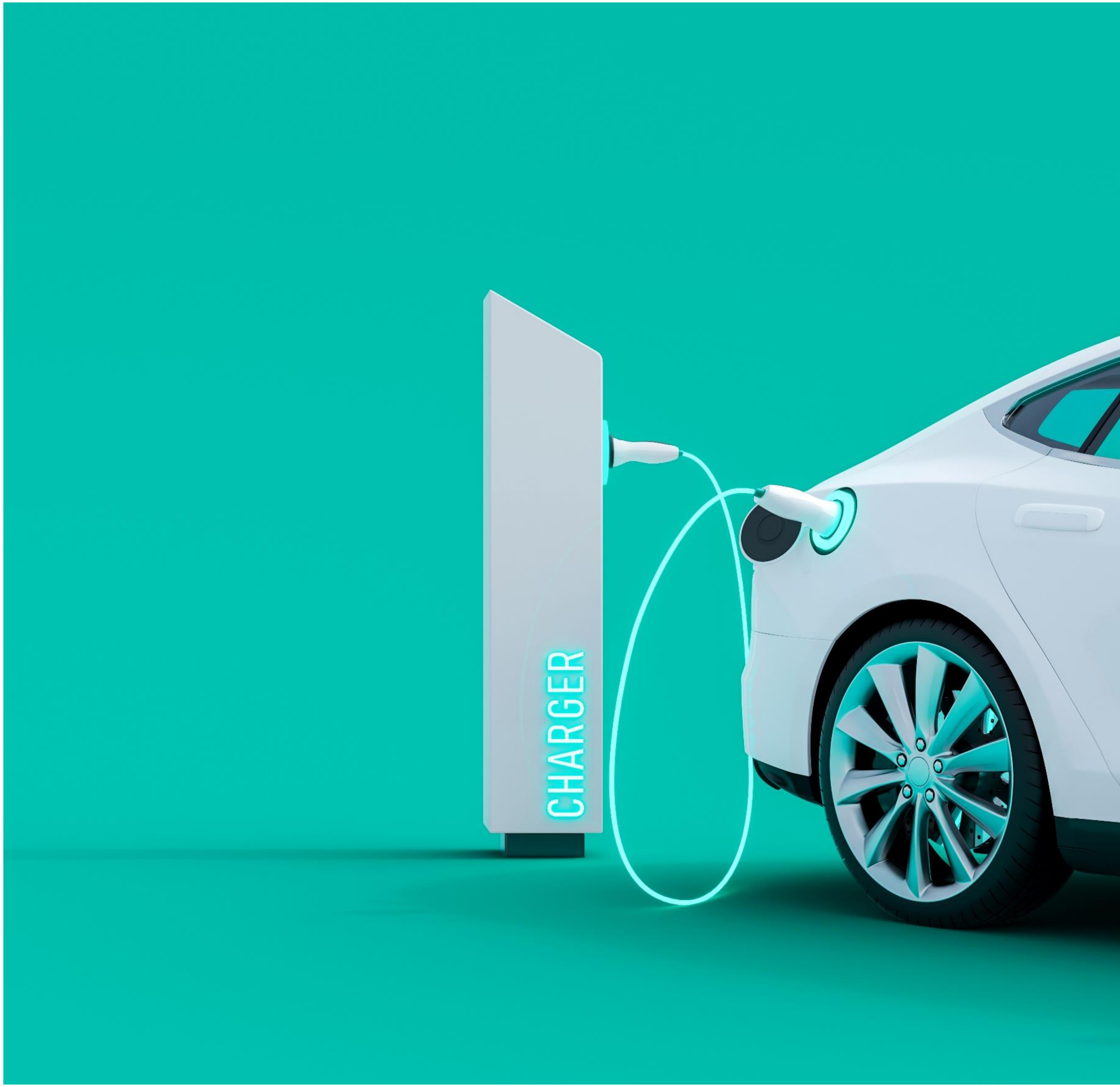
Isabelle is a Chartered Trade Mark Attorney. She assists clients with brand protection, focussing on contentious registry proceedings as well as other aspects of trade mark protection. Isabelle has particular experience in the automotive sector, having worked with a large automotive manufacturer for several years.
Email isabelle.tate@reddie.co.uk, or click here for her full bio.

Introduction to EVs

In 2020, electric vehicles hit a significant milestone: 1% of cars on the road globally were some form of EV. In terms of actual numbers, this equates to 10 million cars, almost half of which are in China and almost two thirds of which are battery electric vehicles (BEVs). In 2021, the global market size for EVs was estimated at $170 billion, while by 2030 it's expected to reach over $1.1 trillion. One could say that the EV market is being supercharged.

However, it has been a long time coming. The first electric vehicles were developed during the 1830s, and indeed were used commercially as taxis on the London streets by the end of the Victorian era. That early electric vehicles enjoyed success perhaps should not be that surprising, after all, at their most basis electric motors are incredibly simple contraptions. Unfortunately, whilst making an electric motor may be straightforward, powering a mobile electric motor is not.

Thankfully, in the last 20 years or so modern technology has been bought to bear on this problem, and the result is a plethora of new, commercially available EVs. Whilst vast improvements have no doubt been made, this same challenge of powering EVs still underlies many of the hurdles faced to day with brining EVs into the fast lane. However, with challenge comes opportunity, and there are many companies fighting to make the most of it.



Sustainability in the automotive industry

Sustainability in the automotive industry is an area which is likely to see ever greater focus as the world looks for ways of reducing reliance on traditional fossil fuels. This article looks at the role to be played by the adoption of electric vehicles (including related emission factors which are sometimes forgotten about), as well as alternative fuels such as hydrogen and biofuels, in the future of sustainable transport.

Electric vehicles, a great solution with some underappreciated downsides

In 2021 Polestar, the electric vehicle (EV) arm of Volvo, published a complete life cycle emissions analysis of one of its models.

However, while publication of such life cycle emission analyses is to be applauded, the devil is in the detail. Embedded emissions in EVs, that is the emissions created by manufacturing an EV, are significantly higher than for traditional internal combustion engine (ICE) vehicles. The major contributor to the higher embedded emissions is the battery cells. Life cycle emissions analysis often also does not consider the environmental and social effects of mining the materials required for the battery cells.

Returning to the cumulative lifetime emissions of a battery electric vehicle (BEV), if the BEV is charged entirely with renewable electricity, then the lifetime emissions of the BEV are made up entirely of the embedded emissions. However, more realistically, depending on which country an BEV is used in, at least some part of the electricity used for charging will be generated by fossil fuels, thereby increasing lifetime emissions during use of the BEV.

For an ICE vehicle, embedded emissions are significantly lower, and lifetime emissions mainly depend on the additional emissions used for driving – if running on conventional fuels, lifetime emissions will be higher, but if running on renewable fuels, lifetime emissions will be lower. Depending on various factors, an ICE vehicle running on renewable fuel or bio gasoline may have lower lifetime emissions than a BEV until it has run for 100,000 miles or more.

Although current conversation is mostly about emissions from running a vehicle, the public conversation may well expand to consider lifetime emissions and how to reduce embedded emissions in EVs as much as possible.

There is also scope for the battery manufacturing sector to enhance sustainability. To date, much of the focus has been on physical attributes of the battery, such as its energy density, charging time, and the like. However, as demonstrated by Northvolt, a Swedish battery developer and manufacturer attempting to reduce the emission footprint of its batteries, there is significant potential for innovation in improved sustainability of battery manufacturing.

Recycling of batteries from BEVs is also becoming an issue of growing concern (see here) – with some believing that electronic waste as a whole, and not just batteries, should be the issue to focus on. Research in the UK suggests that extracting lithium from batteries is currently very energy (and time) intensive, and that it requires less energy to produce a new battery than to extract lithium from an old one.

Second-life battery applications may be part of the solution, but the business models for second-life batteries have not yet been shown to work. It is possible that there may simply be too many batteries for such applications, and while automotive manufacturers are generally very good at recycling their (ICE) vehicles, a lot of users may prefer “good” (new) batteries over “cheap” (second-life) batteries.

There may need to be some incentives for OEMs to take batteries back and update them – although this may be costly and a technological challenge. A lot of work is needed to make batteries more easily recyclable.

Will IP get in the way between OEMs recycling, or updating, batteries and battery manufacturers? Although exhaustion of rights means that repairing a genuine product bought from the patent holder or a licensee is possible, it can be difficult to know if the boundary from (permissible) repair to (infringing) making is being crossed if extensive repairs are required. However, the updating of batteries may become a valuable new revenue stream for OEMs, and may lead to further innovation in this field.

Besides all this, EVs are not only considered “cleaner” because they do not emit emissions when being driven, but also as a solution to pollution given broader social trends such as urbanisation. The "simple" banning of IC engines by as soon as 2035 is by itself unlikely to achieve the desired result, the problem being far more complex.

Regulatory inconsistency and changing policy may also be having a negative impact on the adoption of, for example, hybrid EVs, as consumers may be uncertain as to whether and for how long they may be allowed on the roads. While most large car manufacturers have clearly decided to focus on BEVs, there is still a lot of innovation in ICEs (see here), albeit innovation in battery EV related technologies is obviously increasing fast (see here).

The future of ICEs and the role alternative fuels may play

However, the move away from ICEs will likely leave users of ICEs who cannot easily switch to electric engines, such as heavy duty applications, to suffer from a lack of investment.

Given the embedded emissions of a BEV caused by manufacturing, replacing ICE vehicles with EVs may actually lead to a short-term increase in emissions. The growing divide between national and local governments on emissions and pollution could lead to tighter regulation in cities than elsewhere. This can already be seen in London and many other cities around the UK and elsewhere, which allow only certain cars to drive within the city.

The rollout of E10 in the UK has been much covered by the media. The difference between E5, which was previously sold at UK petrol stations, and E10, is that the *maximum* percentage of bio-ethanol in the fuel has increased from 5% to 10%. While bio-ethanol has significant emission savings compared to fossil fuel, 10% may be the upper limit for a fuel mix which can ensure backwards compatibility, i.e. which may be used as a drop-in fuel with current ICEs. RDE2 standards are also a concern when it comes to bio-diesel as ICEs using bio-diesel are known to produce higher emissions of nitrogen oxides (NOx).

Biofuels are nevertheless seen as important for transport segments which are particularly difficult to electrify, such as shipping and heavy duty. Work on biofuels started over two decades ago. However, there currently does not seem to be sufficient incentive to develop and use bio-fuels: the consumer does not get any benefit from using 100% biofuel, OEMs have no incentive as they cannot control what users put in their ICEs, and biofuels are more expensive to manufacture for oil companies.

Hydrogen may currently receive more funding then biofuels, but how is hydrogen technology progressing? Electrolysis (as discussed here) is still struggling with efficiency concerns – although this problem goes away if there is a surplus of (renewable) electricity.

However, electrolysis for hydrogen may need to compete for the surplus of electricity with industrial demand as the electrification of industry progresses, and with second-life battery application. As such, the efficiency problem is central to green hydrogen production

and the research currently going on to make it more efficient may be central to its future success.

Although currently it looks unlikely that small hydrogen vehicles will make up a significant share of the market in future, for heavy duty applications, the future of hydrogen may look more promising.

However, currently, life cycle analysis for hydrogen does not look promising, as about 95% is produced by steam reforming from fossil fuels, which may result in whole-of-life emissions for a hydrogen vehicle being higher than for an equivalent ICE vehicle running on conventional fuels.

There are some projects which look to address some of these issues, such as Siemens' and Porsche's investments in a hydrogen-to-biofuel plant in Chile, where strong winds in Patagonia can be used to generate large amounts of excess wind power. Turning hydrogen into a liquid hydrocarbon makes it easier to transport around the world, largely using existing networks. However, the further step of producing a liquid hydrocarbon may add to, rather than solve, the efficiency problems.

Conclusions?

Technology and innovation have a large role to play in addressing the climate emergency.

We in the Future Transport Group are very much looking forward to working with our clients to protect their IP in that technology and innovations to help them achieve their commercial goals, which will no doubt help achieve societies goal of addressing the climate emergency.

Author: Andy Williams

Solid-state batteries: ready for the mainstream?

Indeed, the massive rise in demand for electric vehicles has only served to further the future importance of solid-state batteries to automotive OEMs and battery manufacturers.
This is supported not only by the number of patent applications being filed in this area (more on those below), but also by the large number of news stories relating to solid-state batteries, and their recent rapid progress to commercialization. Only by way of example, Solid Power (a solid-state battery developer) is due to start delivering solid-state batteries for testing to BMW and Ford by the end of 2022, Volkswagen has invested heavily in Quantumscape (another solid-state battery company), and Toyota has announced that it wants to put solid-state batteries in commercial hybrid cars by 2025.

What are solid-state batteries?

Solid-state batteries are lithium-ion batteries in which the currently favoured liquid electrolyte is replaced with Li-ion conducting solids such as ceramics, glasses, or polymers. Some of the most-researched ceramics and glasses for Li-ion conductive solids include NASICONs, LISICONs, garnets, perovskites, and sulphides. Although many lithium polymer (LiPo) batteries are commercially available, they typically use highly conductive gel polymers as electrolytes, which are beset with the same safety issues as Li-ion batteries.
These solid-state batteries do not only promise safer batteries, by replacing the flammable and volatile liquid electrolyte, but also higher energy densities; this is achieved by using more energy dense electrode active materials, in particular anode materials such as lithium metal and silicon. Indeed, anode-free batteries have also been proposed, in which lithium deposits directly onto a bare current collector upon charging, potentially resulting in even higher energy densities.

Why aren't we all using solid-state batteries then?

So far, however, widespread commercialisation of solid-state batteries has been hampered by two main issues: a lower ionic conductivity compared to liquid electrolytes and a limited cycle life as a result of structural changes in the electrolyte material during successive charge and discharge cycles.
Another major problem of solid electrolytes has been found to be the lithium-ion migration and diffusion across the interface between the electrode(s) and the solid electrolyte.
While inorganic glass and ceramic electrolytes show promise, there remain questions regarding ion conductivity across the electrode/electrolyte interface, rigidity, and cycle life. Solid polymer electrolytes on the other hand suffer from narrower stability windows (which limits the energy density of the battery) and insufficient lithium conductivity.
However, these problems also offer ample opportunity for innovation.

What can the patent landscape tell us about the research and development of solid-state batteries?

Research and development of solid-state batteries is clearly accelerating. In 2009, the number of patent publications related to solid-state batteries worldwide (CPC classification code *H01M 10/0562*) was just 337, and had risen to over 1300 by 2016. Since then, the increase in the number of patent publications in this field has only accelerated, with about 4000 patent applications published in 2021 alone (see Figure 1). This equates to a 10-fold increase in the 12 years between 2009 and 2021, and about a 3-fold increase in the 5 years since 2016.

We note that although this CPC class includes any kind of secondary battery using an inorganic solid electrolyte, almost all of the patent applications published in 2021 mention lithium-ion.

So, has anything changed in the last few years?

Although one needs to be mindful when drawing conclusions about research and development activity from patent publications, in part because of the 18 month gap between first filing of a patent application and its publication, one trend has been unambiguous: the rise of battery manufacturers relative to automotive OEMs, which had for years dominated patent publications in the field of solid-state batteries.

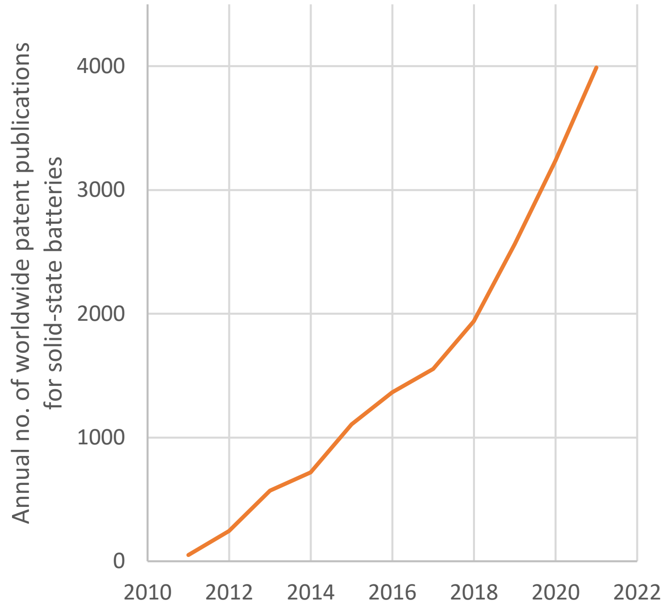


Figure 1: Worldwide increase in the number of patent applications published relating to secondary solid-state batteries over the past ten years (2012-2021) in CPC class H01M 10/0562.

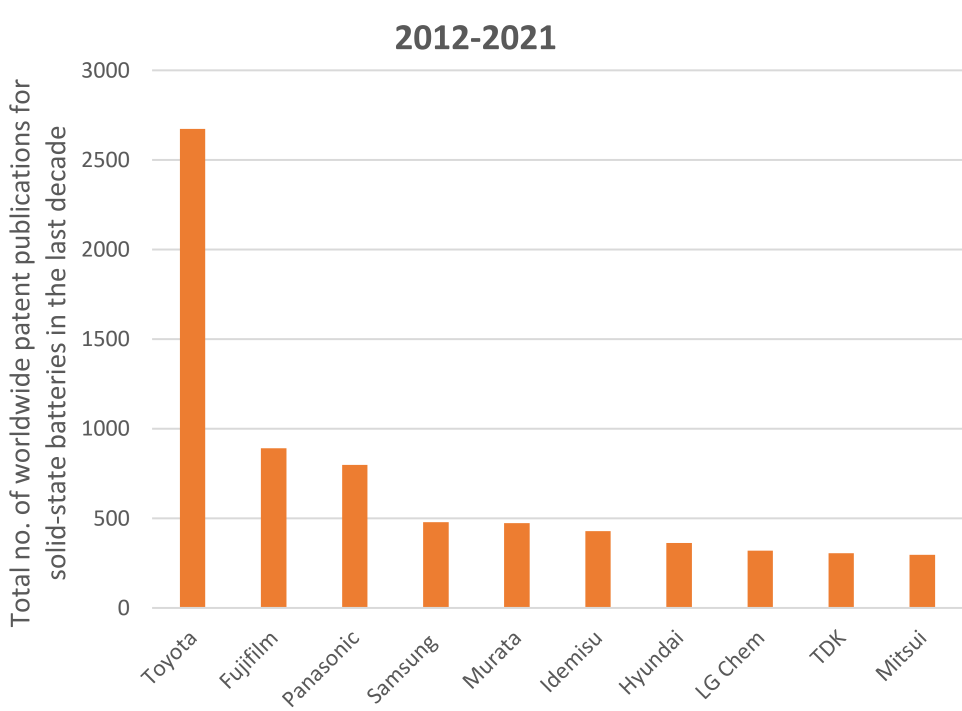


Figure 2: Ten largest filers for patents relating to secondary solid-state batteries over the past ten years, according to patent applications published in CPC class H01M 10/0562.

In particular, Toyota still has, by far, the greatest number of patent publications published relating to solid-state batteries when looking at the last decade (2012-2021, see Figure 2). However, in 2021, both Panasonic (130) and Samsung (77) had more patent applications published than Toyota (52), as shown in Figure 3. This appears to demonstrate an increasing investment of battery manufacturers into solid-state battery research – and is perhaps also a reflection of the fact that many automotive OEMs have been looking to diversify where they get the batteries for their EVs and hybrid vehicles from, and to perhaps even manufacture batteries themselves.

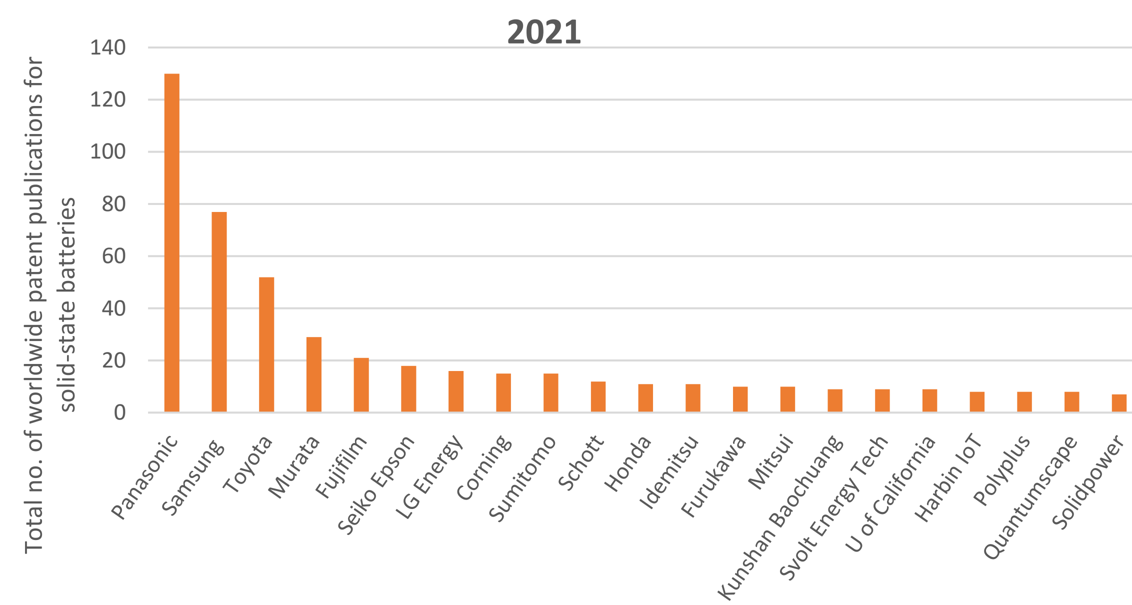


Figure 3: Top filers for patents relating to secondary solid-state batteries in 2021, according to patent applications published in CPC class H01M 10/0562.

It is also interesting to note that the largest patent filers in this field are rounded out by relatively small and/or more recent, research-intensive, companies such as Svolt (9), Polyplus (8), Quantumscape (8), and Solidpower (7), some of which have active cooperation agreements with multinational battery manufacturers or automotive OEMs.

Asia remains the dominant region in solid-state battery research

One fact that has not changed in the last few years, however, is the dominance of Asian, and in particular Japanese and Korean, companies in solid-state battery research. Eight of the ten companies with the most patent applications published in 2021 are from Asia.

Nevertheless, governments across Europe have been investing heavily in making their countries a battery powerhouse (excuse the pun), including in the area that is seen by many as the future of lithium-ion batteries:

solid-state batteries. For example, in the UK, the government has been investing heavily into battery research, including solid-state batteries, via the Faraday Institution (£246m research funding). And Germany is investing in a cluster to research materials for solid-state batteries. Indeed, none of this even considers that European (and American) automotive OEMs have been investing significantly into solid-state battery research, and start-ups with relevant knowhow and intellectual property, for years.

So what conclusions can we draw from all of this?

It seems clear that Asian companies such as Panasonic, Samsung, and Toyota are in the driving seat when it comes to solid-state batteries. However, European and American automotive OEMs as well as research-intensive European, American, and Chinese start-ups are catching up. And with solid-state batteries only just getting to the stage where large-scale commercialisation is realistic in, say, the next five years, it remains to be seen which companies will be able to protect the most important inventions.

However, given the extensive supply chain, and manufacturing technologies, required for the production of solid-state batteries, most inventions are likely worth protecting.

Considering the added complexity of solid-state battery manufacture, this is particularly true for manufacturing technologies and methods. For example, ensuring a good electrode-electrolyte interface is challenging. Protecting the core inventions required for successful manufacture of solid-state batteries will be critical in protecting a company's research – and future value.

If you would like any advice on how, and what, developments to protect in this area or any other related area such as battery technology or materials science, please get in touch.

Author: Dr Dustin Bauer

What role will fuel cells play in future electric vehicles?

In a concerted effort to tackle climate change, countries around the world have announced bans on new vehicles powered solely by internal combustion engines (ICEs), paving the way for an electric vehicle revolution. In this piece we look at the capabilities and shortcomings of batteries and how fuel cell technology may yet play a part in powering our transport networks.

The current picture

Petrol-based fuels used by our conventional ICE vehicles have a high energy density and can be stored easily and quickly. These attributes give us the benefits of being able to travel far with few and short stops for refuelling.

Electric vehicles available today largely employ batteries. Most of these batteries are Lithium-ion, which are incredibly efficient (90%), but have a considerably lower energy density than petrol-based fuels (approximately 30 times less). This means that battery-powered electric vehicles need a lot of batteries, and therefore a lot of weight, in order to provide performance comparable to conventional ICEs. For this reason, in applications where excess weight is undesirable, such as commercial aviation, battery powered vehicles effectively do not exist.

The other well-known drawbacks of battery-powered electric vehicles are a short range and a slow charge-time. However, these issues are becoming less prevalent as the technology improves. Taking Tesla as an example, each of the upcoming *Cybertruck* and *Semi* will boast 500 miles of range and the currently available V3 *Supercharger* can recharge 75 miles of charge in 5 minutes. Moreover, the Chinese car battery-maker CATL (Contemporary Amperex Technology Co. Ltd) announced a car battery capable of powering a vehicle for 1.2 million miles across a 16 year lifespan. CATL already supply Tesla, as well as other manufacturers such as Daimler, BMW, Toyota, Honda, Volkswagen and Volvo.

These figures would suggest that for day-to-day road-travel at least, current lithium technologies can meet the majority of demand requirements.

Fuel cell electric vehicles

A fuel cell is a device that generates electricity using hydrogen and oxygen. A typical fuel cell includes an anode, a cathode and an electrolyte membrane. Charged hydrogen ions are passed from the anode across the electrolyte membrane to generate current, which can be used to electrically power something. The hydrogen ions recombine with oxygen at the cathode to produce water, the only emission from the process along with hot air. Fuel cells are already used in a wide range of applications, and are particularly useful for providing emergency power in data-banks, airports and hospitals.

Fuel cell electric vehicles (FCEVs) are more similar to conventional vehicles in many ways than they are to battery-powered electric vehicles.

Fuel cells do not need recharging, and will instead continue to produce electricity as long as a fuel source (i.e. hydrogen) is provided. The range and refuelling time of a fuel cell is comparable to that for petrol-based vehicles. The fuel cell powered truck Nikola One, for example, has a range of up to 750 miles and a refuelling time as short as 10 minutes.

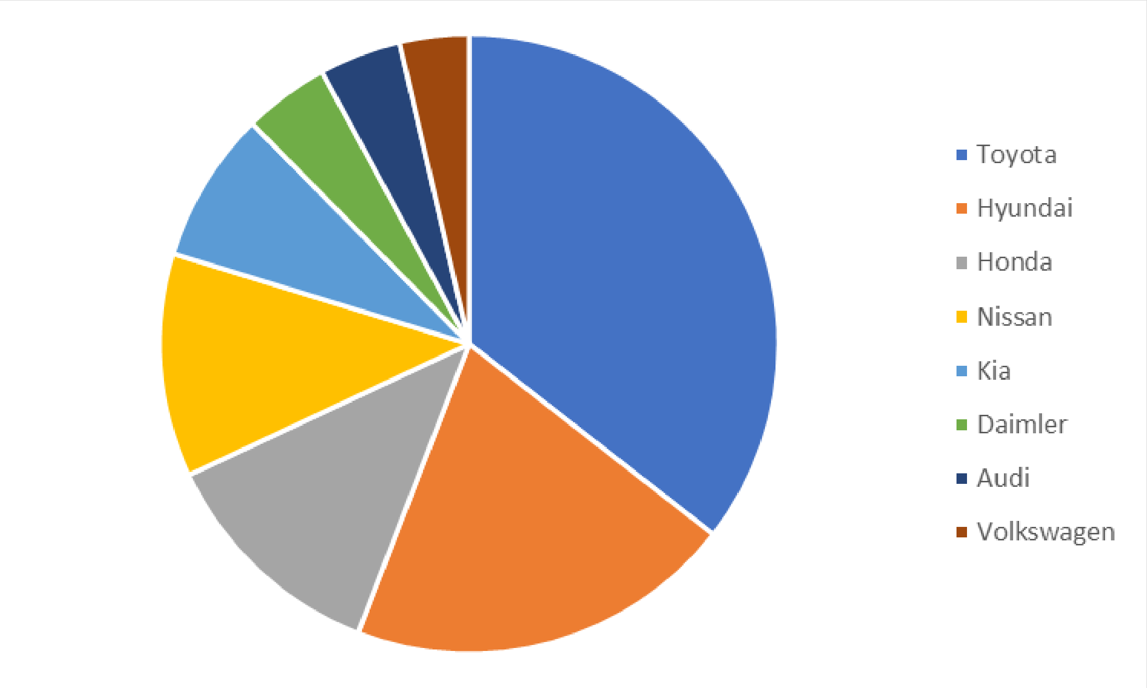
Furthermore, the energy density of fuel cells is much higher than that of batteries. This means that, in theory, fuel cells can store much more energy for the same weight when compared to batteries.
For this reason, in applications where the disadvantages of batteries are laid bare, such as longer distance road-travel, aviation and shipping, interest in fuel-cells remains prevalent.

In practice, fuel cells require associated tanks, pumps and a means of keeping the system cool. This parasitic weight has historically been somewhat of a barrier to fuel cells being used in certain applications such as aviation.

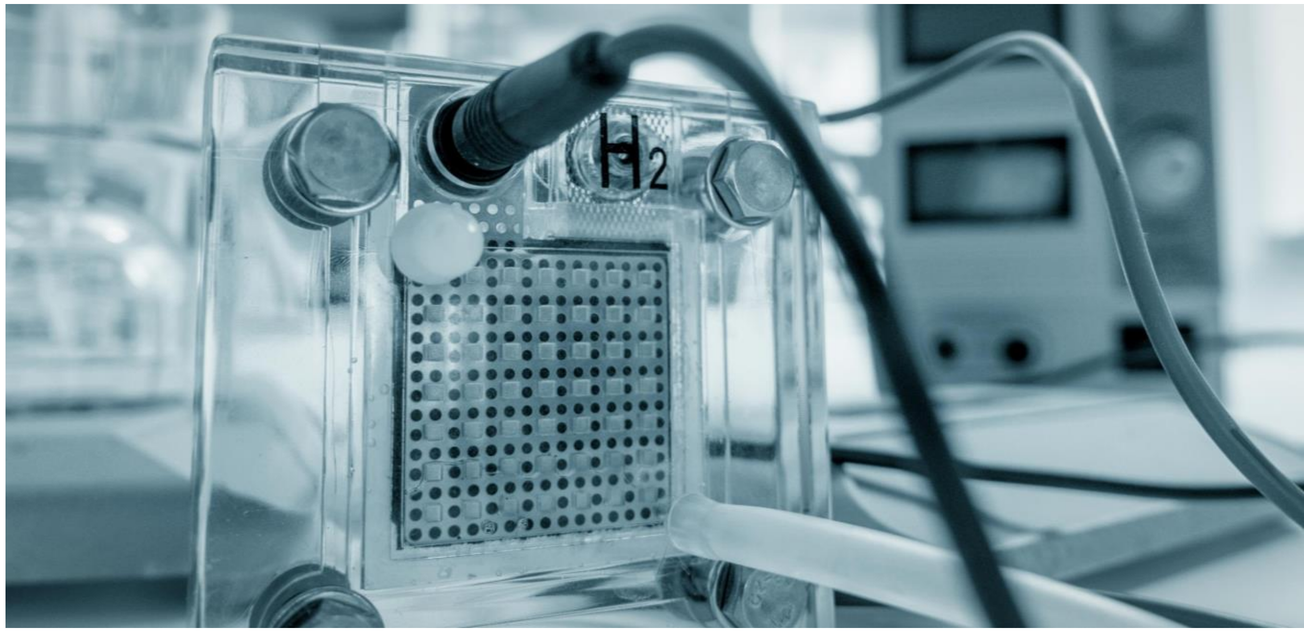
However, advancements are being made in this area. HyPoint, a California-based company, has demonstrated an air-cooled hydrogen fuel cell powertrain that produces 2000 W/kg of specific power with an energy density of 1500 Wh/kg. It is hoped that devices such as these could be used to power eVTOLs and small aircraft. These figures far exceed the energy density attainable by lithium-ion batteries with a comparable power output.

Patent Perspective

Patent filing and publication statistics are often a good indicator of the technologies particular industries and companies are focusing on. Although filing numbers relating to fuel cells are dwarfed by those for batteries the general trend is upwards. In terms of the companies that have been innovating in fuel cells in recent years, it is interesting to note that the companies with the biggest fuel-cell related portfolios are all car manufactures, as shown below in Figure 1.



Regardless of the progress of batteries, cars are still the biggest market for fuel cell technology. Of the top eight companies shown above, there is a notable focus on the Far-East. Three are Japanese (Toyota, Nissan, Honda), and the biggest fuel cell advocate, at least in patent terms, is Toyota, with almost 36% of the total number of filings of the top eight companies. South Korea has two applicants in the top eight (Hyundai and



Kia).

The governments of Japan and South Korea are both actively encouraging growth and production of FCEVs. Japan wants to have 800,000 FCVs on the road by 2030 and South Korea wants 850,000. The ministry of Economy, Trade and Industry (METI) of Japan set out a strategy back in September 2019 for reducing Japan's reliance on imported energy, reducing Japan's environmental footprint, and positioning Japan as a fuel cell technology exporter.

Future outlook

It would appear that, thanks in large part to companies in Japan and South Korea, FCEVs still have some part to play in the future of road transport. It will be interesting to see exactly how big and wide-spread this part is. Whilst Japan and South Korea may yet achieve their targets relating to FCEVs, the roll-out of these vehicles may only be local. If other parts of the world do not share the ambition of the Far East, and opt to stick with batteries, it will be difficult to attract the large investments needed for the necessary FCEV related infrastructure (refuelling stations, mass hydrogen production) to make FCEVs feasible. That being said, it seems there will be niches, in long distance travel, or aviation, where FCEVs may gain some better footing due to the advantages fuel cells have over heavy batteries.

Author: Matthew Havron

Electric Vehicle Charging is Moving Forwards

One of the major problems that faces the emerging electric vehicle (EV) market is the range of electric vehicles. While, due to improvements in battery technology and car design and efficiency, some electric cars now have ranges well over 300 miles, a more comparable level with the range of their internal combustion (IC) cousins, they often come at the cost of, well, a much higher cost than petrol or diesel cars.

Another related problem is that while a driver can refill the petrol tank in their IC car in a matter of minutes and then carry on with their journey, electric vehicles typically take substantially longer to charge. Fast chargers for electric vehicles go some way to overcoming this problem, but they only work with cool batteries which in the real world usually limits the use of fast chargers to once per journey. So, despite dramatic improvements, the range of electric vehicles is still putting the brakes on this growing market.

However, advances recently published in the journal *Nature* are mapping the route towards a potential solution. In 2017, a paper by Shanhui Fan and Sid Assaworrarit demonstrated how wireless charging technologies could be applied to objects in motion. A second paper published earlier this year has now shown that this concept could be developed to power electric vehicles. In this second paper, Fan and Assaworrarit demonstrated that relatively high power could be transmitted over a large range of distances of up to 65cm while maintaining over 90% power transmittance efficiency.

While the 10 watts that Fan and Assaworrarit were able to transmit over this distance is far from the power required by an electric vehicle (10W is around the power used to charge mobile phones wirelessly), the authors state that it should be possible for their method to be scaled up to the kilowatt or even hundreds of kilowatt level. Coupled with the fact that the wireless power transmission only takes a few milliseconds, a charging system built to these specifications could be more than ample to power the electric vehicles of today, and, given that electric vehicles will only get more efficient as further developments are made, it could also provide a long term solution to our transport needs.

But powering electric cars and lorries on-the-go isn't the only application for this technology. In the near term, one of the most promising applications of wireless charging on-the-go would be to power the many thousands of robots that operate in warehouses all over the world. For example, in a previous blog we discussed how supermarket delivery company Ocado have successfully leveraged technology and their IP in their high-tech, robo-staffed warehouses. Wireless on-the-go charging could enable Ocado to make their warehouses even more efficient by reducing the need for robots to temporarily stop work to recharge. Wireless on-the-go charging could reduce the number of robots necessary to complete orders, free up warehouse space currently taken up by charging points, and eliminate wasted time travelling between the warehouse floor and the charging locations.

It is clear that this new invention has many applications, and could prove to be a driving technology in the continued electrification of our world. Should the inventors be looking to commercialise their invention, obtaining patent protection for it would likely prove crucial. Such protection would allow them to be behind the wheel when it comes to who uses their invention – they could implement it themselves, license it to others, or sell the rights to use it completely. In this case, given the potential broad range of applications in many different industries, a comprehensive licensing regime could prove to be a lucrative route. However, given that patent applications take 18 months to publish, we will have to wait and see whether the inventors have decided to capitalise on their ideas in this manner.

Author: Andy Attfield

Introduction to AVs

Autonomous vehicles have come a long way since the days of the DARPA Urban challenge, the US Department of Defence’s $2 million challenge to build an autonomous vehicle back in 2007. The challenge involved building an autonomous vehicle that could complete an urban track, while following traffic regulations and avoiding other cars. Out of 11 finalists, only 6 teams finished, with the winner averaging a speed of only 14 miles per hour.

Fast forward ten years to 2017 and Waymo, a subsidiary of Alphabet Inc, Google’s parent company, launched their early rider program, providing commercial rides in an autonomous vehicle to 400 people around the city of Phoenix. By mid-2018, Waymo’s fleet of driverless cars was driving more than 24,000 miles a day – the equivalent to a round-the-world trip. But Waymo are by no means the only company gearing up to make driverless cars a part of our every-day lives, and the sector has only been expanding in the last few years.

Just about every motor company out there is joining in the race to develop autonomous car technology. This is no surprise. In 2020, the global autonomous vehicle market was estimated at $1.5 billion, and by 2028 it is expected to grow to over $11 billion. But traditional automotive OEMs are not alone, and are being joined in the autonomous vehicle space by many companies not usually associated with the motoring world, such as Apple, Intel and Huawei. The inclusion of tech companies, alongside traditional motor companies such as Ford, BMW and Volkswagen, goes to show the vast range of technology that is being brought to bear on the problem, as well as the breadth of the challenges faced. Clearly, the sector is ripe for innovation.

Legislative update:
are the roads ready for autonomous vehicles?

Despite the predictions of politicians in years gone by, driverless cars are not yet roaming UK roads. However, the road blocks to seeing this come to reality are not only technological – here we will take a brief look at some of the steps the government is taking to remove the legislative barriers to operating autonomous vehicles on our public roads.

For many years, highly trained drivers have been guiding cars kitted out with specialist sensors to gather data to inform and refine the Artificial Intelligence (AI) destined to provide the brain of autonomous vehicles (AVs). By analysing this sensor data, information can be gleaned about the road environment, the traffic flow and the behaviour of other road users in such urban environments. Through this data, the AI brains can be trained in order to take over the driving responsibilities in a fully autonomous vehicle.

However, the AI is not the only thing that needs to be trained – drivers also need to be trained to understand the limits of these systems, certification standards need to be set so that AV models can be reliably mapped to the capability a driver can expect, and the legal framework needs to be adapted to accommodate the transfer of responsibility (and liability) away from the driver. For example, Rule 150 of The Highway Code currently states that the driver "MUST exercise proper control of [their] vehicle at all times", which would not be the case when an AV is operating in a truly autonomous mode. Government consultations have identified such rules and explored how these could be adapted in a clear manner so that all users understand what is expected of them in an autonomous vehicle, and it is reassuring to see that the UK Government is playing its part in paving the way for AVs to begin operating on UK streets.

An initial step on the road of automation will be the introduction of Automated Lane Keeping Systems (ALKS), which is set to be the first commercially available system that is designed to take over dynamic driving tasks from the driver to truly control the vehicle within the relevant operating conditions. The UK aims to be a global leader in the development and adoption of such automated vehicle technology and has pursued this in government consultations on which national updates are required for the adoption of ALKS.

Current iterations of these systems are directed to motorway usage, but in a single lane and with speeds limited to 37 mph, rather than full motorway speeds. This use case is particularly directed to queueing and stop-start traffic on motorways, which can be some of the most energy inefficient parts of a journey. Accordingly, this speed limited technology is set to reduce vehicle emissions, prevent human error accidents, and improve the easing of congestion.

The initial consultation concluded that driver awareness and education is going to be key in the safe adoption of ALKS technology, with suggestions for the responsibility for this training being divided between the government and the vehicle manufacturers themselves. This will not only help some drivers to overcome their caution around the technology, but also help others to know the limits of these systems and prevent over-reliance through assumed competence. A key issue to be overcome appears to be the balance between the capabilities of the system through over-engineering, and the response timeframe within which the 'driver' can reasonably be expected to regain control of the vehicle, with the requisite situational awareness, following a transition demand (for example when the automated systems operational conditions have been exceeded).

The ALKS technology is designed to keep the vehicle in a given lane, with the driver being required to regain control for any lane change manoeuvres etc., and thus many will disagree with the government's labelling of this technology as autonomous. While drivers are intended to be able to perform non-driving activities during ALKS usage, they should be in a position to regain control of the vehicle (within 10 seconds according to current proposals) when requested through a transition demand. As such, ALKS technology can at least be considered to be an enhanced driver assistance system that, with the appropriate driver understanding of capability, is a step in the right direction for autonomous driving.

The UK Government estimates that AVs will be approved an on UK roads within the next year, and it will be exciting to see if 2023 is truly going to be the year that it happens.

Author: Jon West

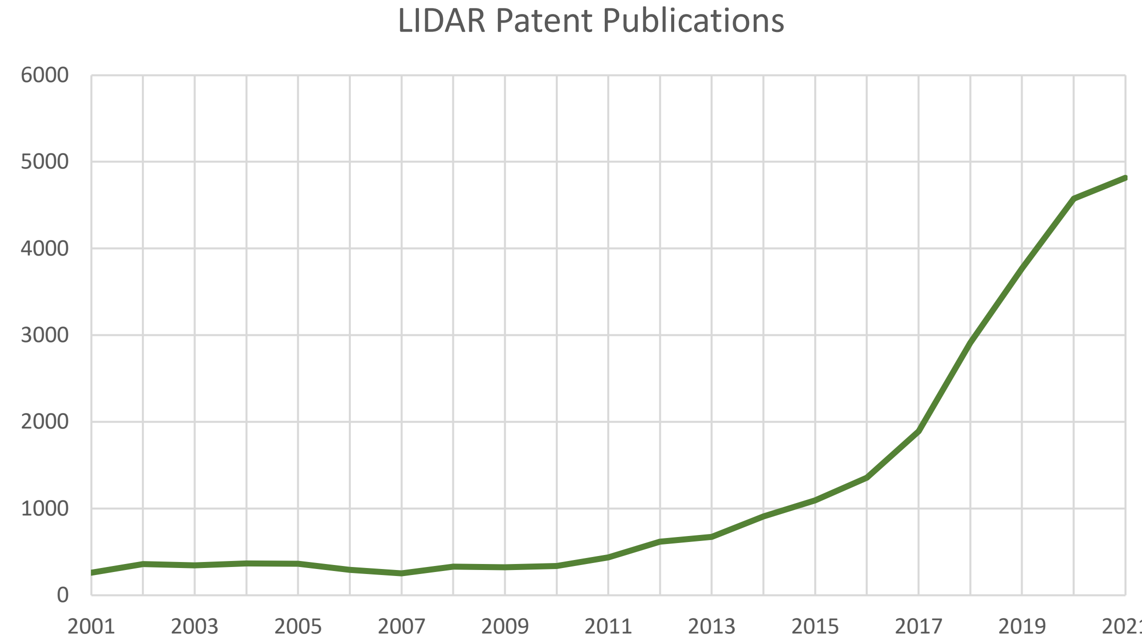
LIDAR – Mapping out the road ahead

A key technology behind many attempts at self-driving vehicles that people may have heard of is LIDAR, but what actually is this technology? If your first though is, "LIDAR sounds a bit like RADAR…" then that's good – LIDAR essentially means "Light RADAR". The technologies function in a very similar way – where RADAR uses radio waves that are reflected back from an object in order to detect that object, LIDAR uses lasers.

One of the major advantages of LIDAR is that LIDAR systems can have centimetre resolution over large distances, up to 100 meters, and Waymo's system can even detect the direction that a pedestrian is facing to help predict their likely movements. Most companies developing autonomous vehicle capabilities, with the notable exception being Tesla, have been employing LIDAR as the basis for a network of sensors that allow the car to "see". However, one of the major problems that will need to be overcome to enable successful commercialisation of driverless cars is the cost of LIDAR systems.

Ten years ago, LIDAR systems could cost us much as $75,000 – far too expensive to be used on a commercial scale for consumer driverless vehicles. However, recently, the cost has dramatically shrunk, with units being available for only a few thousand dollars. This is the result of many companies, both start-ups and established tech and motor companies, that have been, and still are, working to bring down the price. While economies of scale have helped, and will continue to do so, the biggest savings are a result of technological advancements.

And LIDAR advancements can mean big money. In 2018, Waymo received $245 million from Uber in compensation for stealing trade secrets relating to Waymo's LIDAR technology. While this sounds like a lot, it isn't even a sixth of the $1.8 billion that Waymo initially sought. Nevertheless, while Waymo didn't try to protect all of their LIDAR developments with patents, they still do have a number of patents relating to LIDAR, and the value that they and others place in the technology can be seen in recent patent filing trends.



This graph shows the number of patent applications that have been published each year for the last 20 years, and have been classified under the International Patent Classification heading of "Systems using the reflection or reradiation of electromagnetic waves other than radio waves, e.g. lidar systems" (G01S 17) in either "Lidar systems, specially adapted for specific applications: for mapping or imaging" (G01S 17/89) or "for anti-collision purposes of land vehicles" (G01S 17/931).

As can be seen, in the last five years, the number of yearly patent publications has increased by around a factor of five as companies attempt to protect their investments by obtaining patent protection for their inventions. These patents will be crucial for both the established players looking to fend of rivals and for new start-ups hoping to obtain investment and maintain their edge in a competitive market.

Some of the key LIDAR technology areas that many of these patents will be trying to cover are types of beam steering technology and distance measurement mechanisms, as well as the software for interpreting the measurements and ways to combine different types of LIDAR (and other) sensors to provide more information to a vehicle's driving system.

Beam steering technology relates to how a LIDAR module "looks around". The most common mechanisms include spinning LIDAR, mechanical scanning LIDAR, optical phased array LIDAR, and flash LIDAR.

Spinning LIDAR is as it sounds: an array of lasers that is spun around at high frequency. This method has the advantage of 360 degree coverage, but comes with the drawback of involving a large number of moving parts. Mechanical scanning LIDAR, meanwhile, uses a moving mirror to scan an area with a fixed array of lasers. This has fewer moving parts than a spinning LIDAR, but also comes with reduced angular coverage. Optical phased array LIDAR uses a row of emitters and controls the direction of the laser. This solid state technology is relatively new, and provides for the prospect of LIDAR systems with no moving parts which could lead to long lifetimes and high reliability. Finally, flash LIDARS use a single laser flash to illuminate a large area at once, either from one wide angle laser or from multiple laser pointing in different directions. While such a system with a single laser will struggle to reach long ranges due to the power of the laser being spread over a large area, a multi-laser system could quickly become expensive due to the large numbers of lasers required.

Distance measurement methods are the different ways in which the laser light can be used to obtain a distance measurement. The basic approach is time-of-flight LIDAR which simply measures the time it takes for a laser pulse to leave the laser, travel to an object, reflect and travel back from the object, and be received by the LIDAR system. Other systems make use of a continuous wave, modulating its frequency or amplitude. While frequency and amplitude modulation require more complex electronics and processing, frequency modulation allows the velocity of objects to be measured, as well as their distance, while amplitude modulation is more resistant to interference.

It will be interesting to watch the development of these different approaches to LIDAR as the technology matures and is deployed on a commercial scale with the rise of consumer autonomous vehicles. Will it be the case that one LIDAR system accelerates ahead of the crowd to become dominant, or will different manufacturers utilise different types of LIDAR? Perhaps different types of LIDAR will be used together on the same vehicle to obtain the benefits of each. While it is impossible to say for sure which systems will succeed and which will be left behind on the curb, what is clear is that properly protecting the intellectual property developed in relation to LIDAR will be key to determining who the winners will be in this emerging market.

Author: Andy Attfield

Autonomous vehicle tech: computer vision

If a human can do it with two eyes then can computers do it too? Many of the big players in the automotive space are betting on an amalgamation of different, but complementary, types of sensors (including lidar and radar) to develop self-driving cars. Tesla, however, have famously long believed that just cameras and computer vision software are enough. But is this actually true behind the scenes?

The idea sounds simple enough. Computer vision software is fed live video images captured by cameras around the vehicle (Tesla use eight of them). The software implements a neural network, that has been trained using lots of pre-prepared image data, to detect roads, cars, objects and people in the video feed. Of course things are not so simple in real life, but if the neural network can be made complex enough and the training data set big enough, some researchers hope they will end up with a system capable of replicating a human driver and dealing with the large (possibly infinite) tail of edge cases that vehicles can face on the roads in the real world.

To explore what Tesla are doing in this field let's take a look at some of their US patents and applications. In particular, let's explore the recently introduced International Patent Classification (IPC) G06V, which relates to "image or video recognition or understanding". This IPC class was only introduced in January 2022 and so reflects mostly recent patents and patent applications published since then.

Tesla's US patent application US 2022/0108130 relates to autonomous vehicle computer vision and particularly how to train machine learning models by taking into account the properties of the cameras used to capture the training images. This fits in with the public face of Tesla's approach to autonomous driving.

However, Tesla still seem to acknowledge that lidar, or similar technologies, will be required in autonomous vehicles, at least initially.

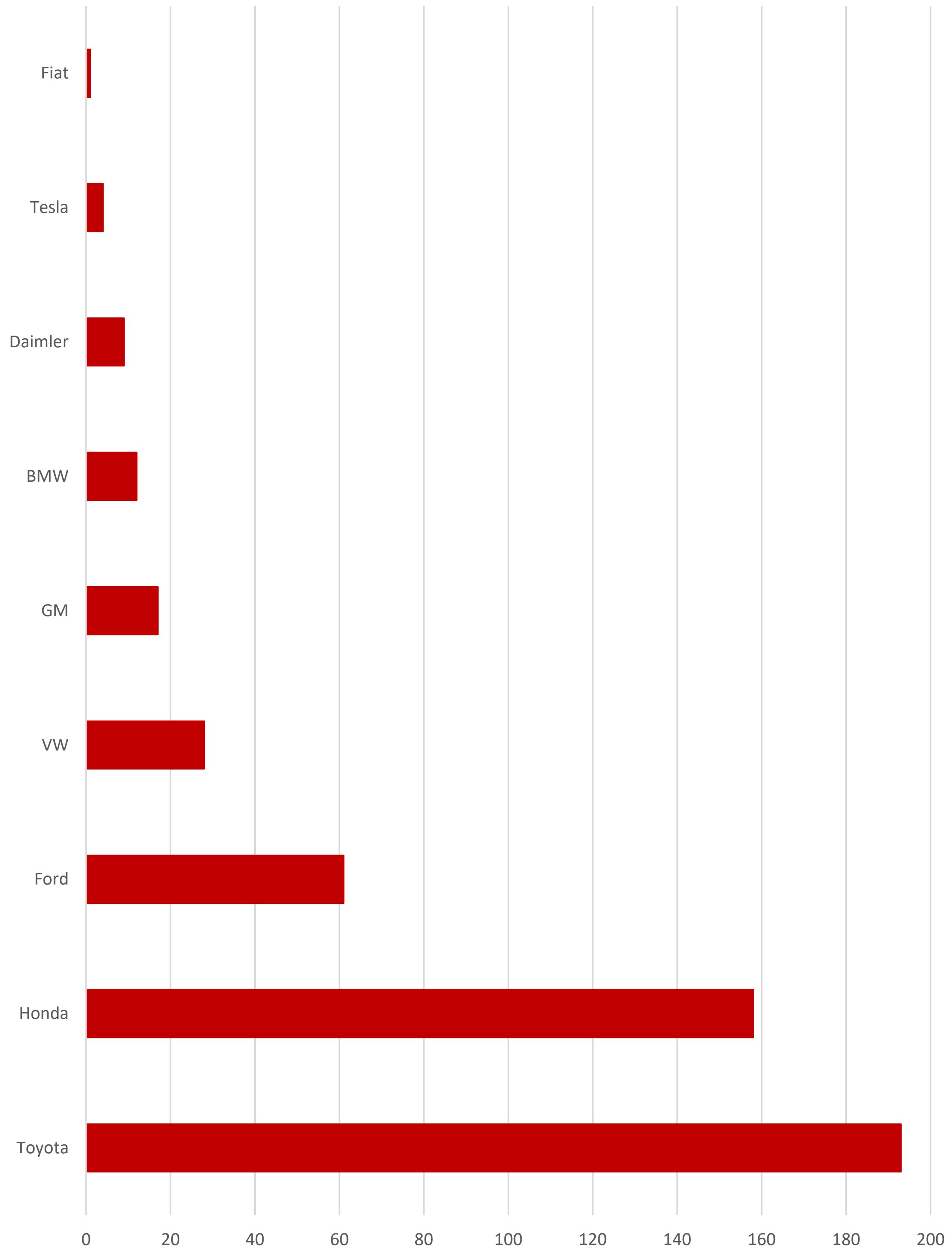
In 2019 Tesla acquired computer vision start-up DeepScale. With that purchase came US patent US 11361457, which relates to training computer models for autonomous control systems. The problem it addresses is labelling of training data for training AI systems. Typically a data set would be labelled with human assistance and this labelled data would be used to train the AI. This is easy for a human to do when the training data is in a familiar format, such as images or videos captured by an optical camera. It becomes much harder when the data to be labelled is in an unfamiliar format such as lidar sensor data. To solve this problem, the patent suggests using a computer program to take a first set of annotations, generated by a human, of the output of a first sensor (e.g. a camera), to automatically identify a second set of annotations to apply to the output of a second sensor (e.g. lidar or radar). This makes use of alternative sensors at the training stage, whilst still relying on cameras in the end vehicle.

Along similar lines, Tesla's application US 2022/0284712 seeks to improve training data by fusing camera data with auxiliary sensor data, such as lidar. The lidar data is associated with objects identified from the vision data. The superior object distance information provided by lidar is correlated with the vision data to allow accurate determination of distance to the object within the training data set. The hope would be that a vision based system trained on such data would be more accurate at determining object distances.

So it can be seen that although Tesla are patenting technology related to vision only autonomous systems, they still expect other sensor input such as lidar or radar to be important in the future, at least in the model training stage.

What about other players in this field? The major OEMs are all involved in developing autonomous driving systems and, unsurprisingly, are filing patent applications for their inventions. Whilst they may be using sensor

US Patent Families for Image Recognition or Understanding (IPC G06V)



technologies such as lidar and radar, this does not mean that they are ignoring computer vision solutions. In fact, as can be seen from the graph below, they are actively investing in IP in this area.

It is surprising that Tesla's patent filings in this area are behind other manufacturers by some margin, especially given that they are pinning their efforts on camera based technology. Perhaps this can be explained, to an extent, by a difference in approach to IP. Toyota and Honda historically file lots of patent applications. This is one way to ensure value is captured and helps to mitigate the risks associated with infringing third party patents. Tesla, on the other hand, have adopted an "open source" strategy for several years making its patented technology available to other parties (provided they reciprocate of course). Admittedly Toyota operate a similar model, but only for a limited set of technologies (which does not yet include their computer vision patents).

Another reason could be that Tesla are relying on alternative forms of protection for their computer vision innovations. Trade secrets protect valuable commercial information and don't require the publication of any details around the innovation, unlike patents. Tesla may have made the decision to protect some of their software innovations in this manner, especially if it would be difficult to determine if their competitors are using their techniques to train an autonomous driving model. Trade secrets can be powerful, but rely on robust and swift enforcement to prevent secrets leaking out (see, for example, Tesla's ongoing 2020 suit against Rivian, who recruited former Tesla employees). Normally a balance is needed between trade secrets, patents and other forms of protection.

However you look at it, a complimentary sensor system involving computer vision and lidar, perhaps with radar and ultrasonic sensors as well, seems to be the direction of travel for most players in the autonomous driving field. In the long run, will Tesla's alternative vision be proven right? We shall see.

Author: Pete Sadler

RADAR: Autonomous Vehicle Technologies

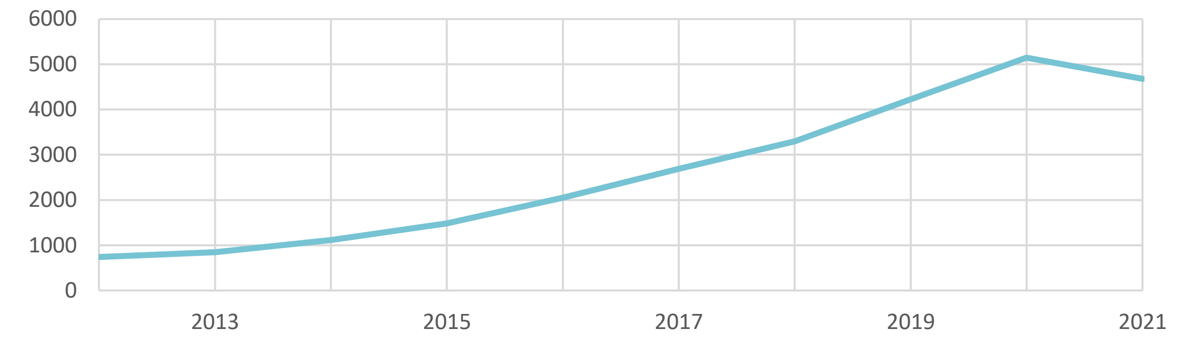
Radar was one of the first systems for detecting remote objects, famously deployed along the British coast in the Second World War to provide early warning of incoming German fighters. While the implementation of the technology has advanced greatly since then, the physical principles behind it remain fundamentally the same in modern radar systems.

The term radar came about as an acronym for “radio detection and ranging”. Detecting objects and determining the distance to them are two key challenges for making driverless cars, and so it is perhaps not surprising that radar systems are being incorporated into autonomous vehicles. Depending on the type of radar, in particular the wavelength, radar systems can be used in a number of different ways in an autonomous vehicle, including blind-spot monitoring, parking assistance, and obstacle detection. Furthermore, compared to other forms of sensor, radar has the advantage of working well in poor conditions, such as fog and rain.

However, radar is far from a perfect solution covering all the sensing needs of an autonomous vehicle. For example, it is relatively low precision compared to LIDAR, and can’t determine colour like visual image recognition. In practice, autonomous vehicles will likely utilise some combination of sensors, including radar.

Technologies like image recognition, of which Tesla is a great proponent in the autonomous vehicle space, are often the most headline grabbing. This is no doubt in part due to their frequent link with machine learning and artificial intelligence – both buzzwords. However, whilst radar may have roots stretching back deep into the twentieth century, new applications for autonomous vehicles pose new challenges, and these challenges provide a ripe environment for new radar innovation.

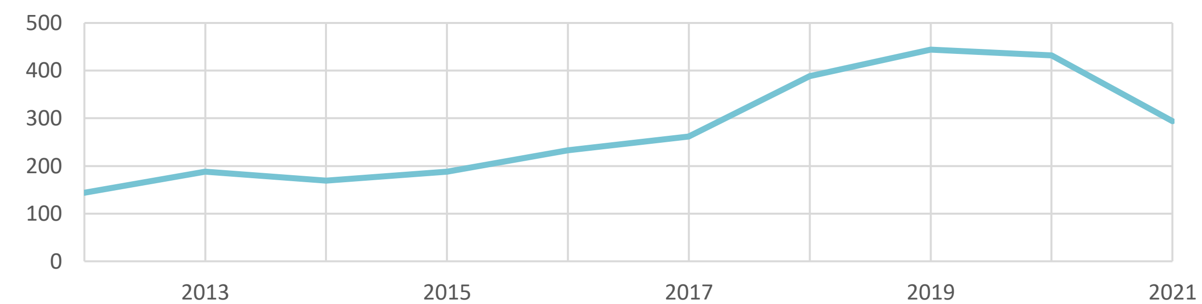
Anti-Collision Radar Patent Pubications



That innovation in this area is happening can be seen by the sharp increase in the number of related yearly patent publications in the last decade. The above graph illustrates the number of patent documents published in the category “G01S13/931" which is for radar or analogous systems specially adapted for anti-collision purposes of land vehicles (excluding “G01S2013/9328” for rail vehicles). This category includes a number of related sub-categories of radar that may well prove crucial to realising fully autonomous vehicles, including radar for parking operations, monitoring blind-spots, and controlling steering, breaking and acceleration. Since 2012, the number of yearly publications has increased by a factor of six.

Looking specifically at the categories of radar systems for controlling steering, breaking and acceleration (G01S2013/9318, G01S2013/93185, and G01S2013/9319 respectively), a similar trend can again be seen, with patent publications increasing by approximately a factor of three between 2012 and the peak in 2019.

Radar for Controlling Steering, Breaking and Acceleration Patent Publications



Looking at the top patent filers in these classes, unsurprisingly they are dominated by large vehicle manufacturers, such as Toyota and GM, or leading suppliers to the automotive industry such as Bosch and Denso. However, a number of other companies more recently entering the automotive space, and more specifically focused on autonomous vehicles, are also represented, such as Waymo.

Unfortunately, whilst capable of detecting things out of sight, radar won't give us a view of the future to see what autonomous vehicles will look like in five, ten or even thirty years, or what technologies they will be using. However, what is clear is that radar looks set to play an important role in making self-driving cars a reality, and those companies that can carve out as much of this technology space as possible, and protect this territory with patents, will enjoy a competitive advantage in the market at a crucial time.

Author: Andy Attfield

HERE TO HELP

At Reddie & Grose, our Future Transport team are dedicated to innovation in all of its aspects. Our patent and design attorneys have extensive experience of advising research and development departments and a deep understanding of the key issues in an often complex legal and business environment.

We help businesses in their due diligence and analysis of whether they are free to launch their products. We then protect their innovations by preparing and prosecuting patent applications – building portfolios of rights to protect their commercial interests. We are also skilled in assisting clients to enforce their patents and designs, filing oppositions and cancellation/ revocation proceedings against third party rights, helping to defend our clients' position in infringement proceedings and defending clients' rights in oppositions and cancellation proceedings brought by third parties. Our trade mark attorneys are experts in protecting brands and have considerable experience in building trade mark portfolios covering the UK and the wider world. Their knowledge of technology, combined with unusually extensive experience of overseas trade mark filing, prosecution, opposition and enforcement, means they are particularly adept at helping companies to build relevant portfolios protecting their current and future business.

We pride ourselves on listening to our clients and offering expert and pragmatic advice that is tailored to our clients' needs. Avoiding a 'one size fits all' approach has allowed us to build up many valued long-lasting client relationships.

The contact details for the Future Transport team leads are as follows:

Dr Paul Loustalan
paul.loustalan@reddie.co.uk

Pete Sadler
pete.sadler@reddie.co.uk

Tom Sharman
tom.sharman@reddie.co.uk

At the start, it can be difficult to decide whose expertise is most appropriate for a project. Please start with the person you think is most appropriate. Our team leads can then build a team tailored for your project.

London
The White Chapel Building
10 Whitechapel High Street
London E1 8QS
T + 44 (0)20 7242 0901

Cambridge
Clarendon House
Clarendon Road
Cambridge CB2 8FH
T + 44 (0)1223 360 350

Munich
Hopfenstrasse 8
80335 München
Germany
T + 49 (0)89 206054 267

The Hague
Schenkkade 50
The Hague
Netherlands
2595 AR
T +(00)31 70 800 2162

General enquiries:
enquiries@reddie.co.uk

Reddie & Grose
www.reddie.co.uk