July 2020

Disinfection & Sterilisation: UV for air and the targeting of surface biofilms stand out as leading areas of recent innovation

The global outbreak of novel coronavirus (COVID-19) has trigged a spotlight on disinfection and sterilisation solutions, attracting interest and investment from companies looking to develop new technologies. Our analysis on patents published in the disinfection and sterilisation technology area reveals UV lights and formulations that target surface biofilms are the undisputed leading technologies for indoor air sterilisation and surfaces disinfection respectively. A closer look into sterilisation solutions specific to mobility applications (cars, buses, trains for example) highlights both UV and also ion technologies as key applications.

Spreading of a virus in closed spaces is more likely than in open environments, that is why sterilisation of air is a key factor that can limit viral spread. The surfaces we touch in our daily routine can also be a vector of transmission, making surfaces disinfection a second key factor. We don't know yet how long this coronavirus can survive on surfaces, research has confirmed the ability of bacteria to survive for several months on inanimate surfaces.

What do we mean by cleaning, sanitisation and disinfection? Cleaning a surface simply removes visible dirt. Sanitising a surface makes that surface sanitary or free from most microorganisms that could affect your health. While Sanitisation only reduces the occurrence and growth of bacteria, viruses and fungi, disinfection goes a step further: eliminating many or all pathogenic microorganisms, except for bacterial spores. Sterilization describes the process that destroys or eliminates all forms of microbial life including spores.

We have analysed published patents across three main areas related to disinfection and sterilisation. The scope of each is described here.

- **Indoor air sterilisation solutions:** advanced air purifying solutions for the elimination of airborne viruses/bacteria in indoor spaces like elevators or buildings
- **Disinfection of surfaces by biocides:** Disinfection of hard surfaces using active ingredients, single chemical compounds (biocides) with antibacterial/antiviral action and/or mixtures with other ingredients with different functionalities i.e. surfactants, enzymes, etc.
- **Sterilisation and disinfection solutions for mobility applications:** solutions to effectively disinfect the interior of vehicles or public transports

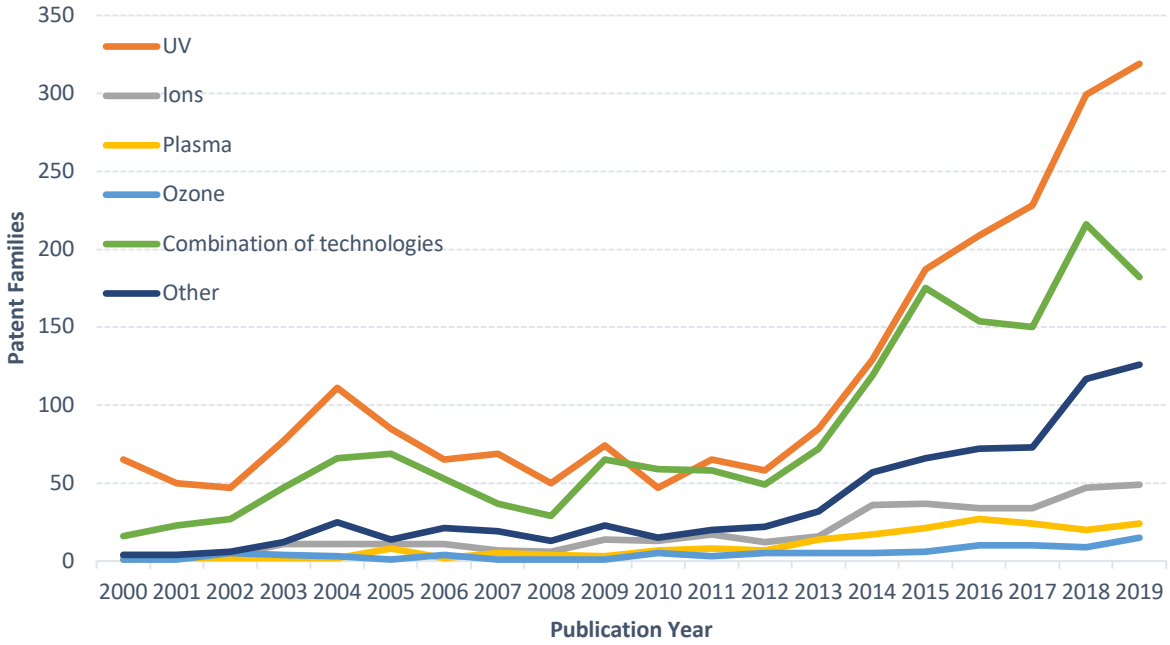
We recognize the role of patents in strategic business intelligence, in providing a view into who owns what technologies and where and in identifying new and fast-growing technologies. By harnessing the latest advances in machine learning combined with expert analysis, information can now be accessed with efficiency, accuracy and at a speed that is just not possible by traditional methods. Using Cipher, we have looked at innovation and invention trends across disinfection and sanitization solutions, identifying growing technologies and top players.

Indoor Air Sterilisation Solutions

Air purifiers are generally used for cleaning indoor air by eliminating odours and pollutants. These systems use HEPA (high-efficiency particulate air) filters which can capture 0.3 microns particles or bigger. Thanks to Brownian motion and the continuous accumulation of pollutant particles on the filter holes, filtration effect may be improved resulting in capturing a portion of even smaller particles like flu viruses. In particular, Covid-19 particles are 0.125 microns but the droplets these particles travel in (when people cough, talk, or breathe) initially are larger, around 1 micron and that's a size easily captured by HEPA filters (Perry Santanachote, May 05, 2020). Another factor to consider is that Covid-19 particles can live up to several days on surfaces, hence a combination of filters and sterilisation techniques to inactivate the virus likely results in more effective solutions. Of course, using air purifiers does not guarantee a complete elimination of the virus, but this solution together with suggested hygienic and social distancing rules can help reduce transmission.

Analysis of patent families associated with indoor sterilisation solutions shows that different technologies have been used in combination with traditional air purifiers to inactivate or kill airborne viruses and bacteria: UV (ultraviolet) lights, ions, ozone, plasma and their combinations. Technologies that don't fall into the mentioned ones have been categorised as 'Other', which include technologies like spraying of disinfectants or solutions with multifilters.

Indoor Air Sterilisation: Patent Families by Publication Year and by Technology



Implementation of UV lights in air purifiers is the undisputed leading technology, whose filing trend has seen a massive increase since 2012. UV is a germicidal light, that means it can inactivate viruses and bacteria whenever it encounters them. In particular, UV light has massive energy compared to visible light and it is designed to convert molecules absorbed inside, destroying the DNA that the microorganisms require to survive. When the air penetrates in the purifier system it goes through the UV lamps which disinfects it directly through germicidal irradiation.

Of note is the increase in patenting activity in indoor sterilisation technologies and in particular in UV air purifiers, registered between 2004 and 2005, just after the SARS outbreak in 2003.

The second leading technology includes solutions that use a combination of two or more of the following technologies: UV, ions, plasma and/or ozone. Systems that use single ions, ozone and plasma technologies have not seen the same scale of growth in patent filing activity.

Technically speaking, ion air sterilisation solutions use purifiers with a built-in ioniser which helps trap air-bone particles and more effectively purify the air. The ioniser uses electrons to forms negative-ions by combining them with air molecules. Once the negative-ions are formed, they are expelled into the room where they attach to positively-charged dust, pollen and other contaminants to form larger particles. These are then more easily be trapped by air filters. On the negative side, ion purifiers emit ozone in varying degrees, which is an irritant substance for human's lungs.

Ozone air purifiers instead release ozone directly into the environment. Ozone is a highly unstable oxygen molecule (O_3). The third oxygen atom is loosely connected with the other two and easily attaches to pollution, viruses, bacteria and organic matter at the molecular level, resulting in oxidation and elimination of them, while reverting the ozone back to oxygen. Despite its strong sterilisation capability, ozone is not largely used in air purifier systems due to its negative effects on human health. In fact, when ozone is inhaled by humans, it remains just as reactive. This reactive nature is what makes ozone dangerous to humans and other forms of life because it can create a reaction in the lungs resulting in inflammation and damage of airways. Suitable therefore only to use in environments that have been evacuated for the air purification.

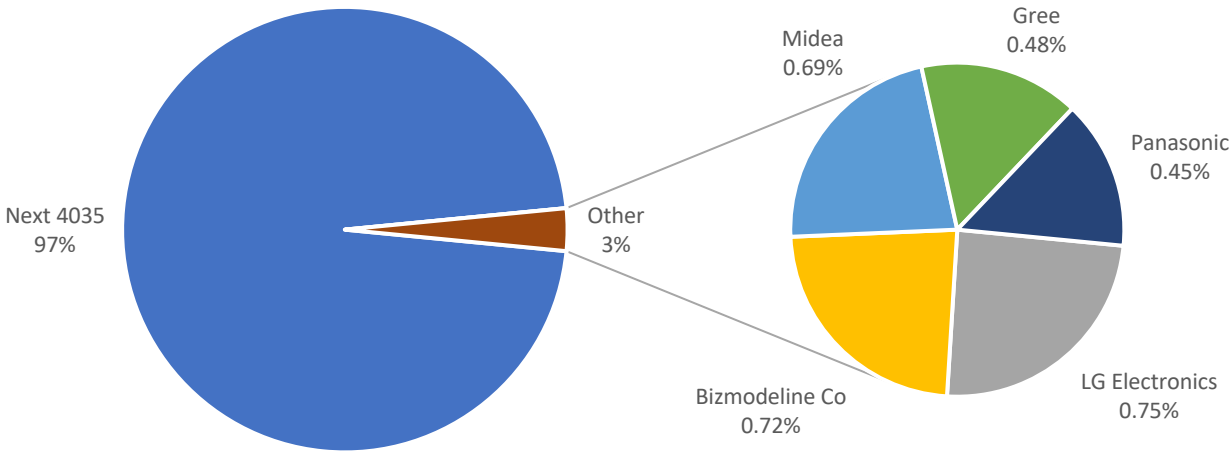
Another technology identified uses plasma in combination with traditional air purifiers: plasma air purifiers work by emitting both positive and negative ions which are able to separate and rejoin around harmful particles, trapping them. Once the airborne virus is trapped, it is easily removed by the air purifier filter.

Looking at the geographical distribution of all the 3,548 current active patent families in indoor sterilisation solutions, we see that China is the leading country with 78% of families, followed by Korea (10%), Japan (4%), US (3%), Europe (2%) and Rest of the Word (3%).

Indoor Air Sterilisation: Active Patent Families by Region

In terms of market share distribution, the top five organisations own only 3% of the total active patent families in indoor air sterilisation technology. The weighting to Asia is confirmed by the companies in the top positions: Korean LG electronics is the leader, followed by the Korean focused Bizmodeline, the Chinese Midea and Gree, and the Japanese Panasonic.

Indoor Air Sterilisation: Active Patent Families by Organisation



Surfaces Disinfection Solutions

Surface disinfection kills or irreversibly inactivates pathogens to avoid their spread and ultimately to prevent subsequent transmission. Disinfection may be required in the following situations:

- "high-touch" (i.e. frequently touched) surfaces
- surfaces where contamination is assumed
- surfaces with visible contamination

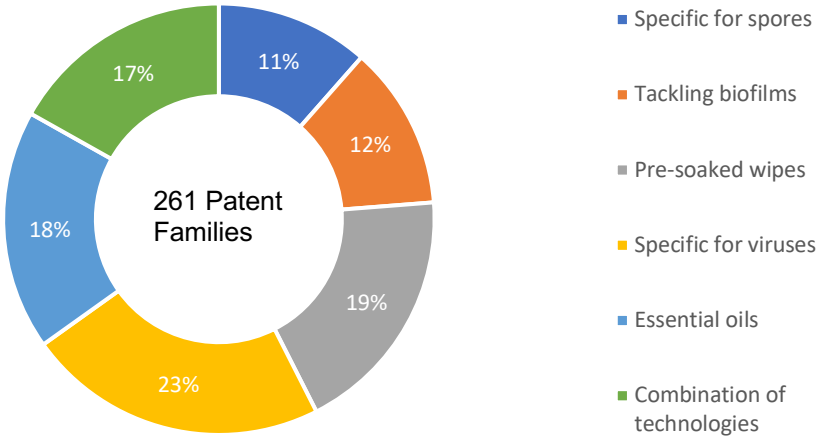
The effectiveness of a disinfectant depends on a number of factors: those characteristic to the product, those characteristic to the application, and those characteristic to the microorganism. Product factors include concentration, formulation, water solubility and pH. For example, the concentration exponent, describing the relationship between dilution and activity of a biocide, must be considered, as well as the bioavailability of the substance and its stability. Application factors include the type of surface, the temperature and contact time as well as humidity and the mode of application (with or without mechanical action).

The primary mechanism of action for a biocide is by contact: the disinfectant is distributed on the surface according to specific procedures, comes in contact with bacteria or viruses present on the surface and kills them. Recent patents in this area refer to some new and emerging aspects of surfaces disinfection formulations, which were grouped in the following categories:

- Specific action against biofilms
- Pre-soaked wipes with disinfectant
- Specific efficacy against viruses
- Specific high efficacy against spores
- Formulations including essential/natural oils

Our analysis on patents published in surface disinfection solutions technology shows that there are 1,108 active patent families in this area. Taking a closer look at them we have extracted and categoried families belonging to the new and emerging technologies mentioned above: Spore, Biofilms, Wipes, Viruses, Essential Oils and families that combine two or more of these technologies together.

Surfaces Disinfection: Active Patent Families by Technology



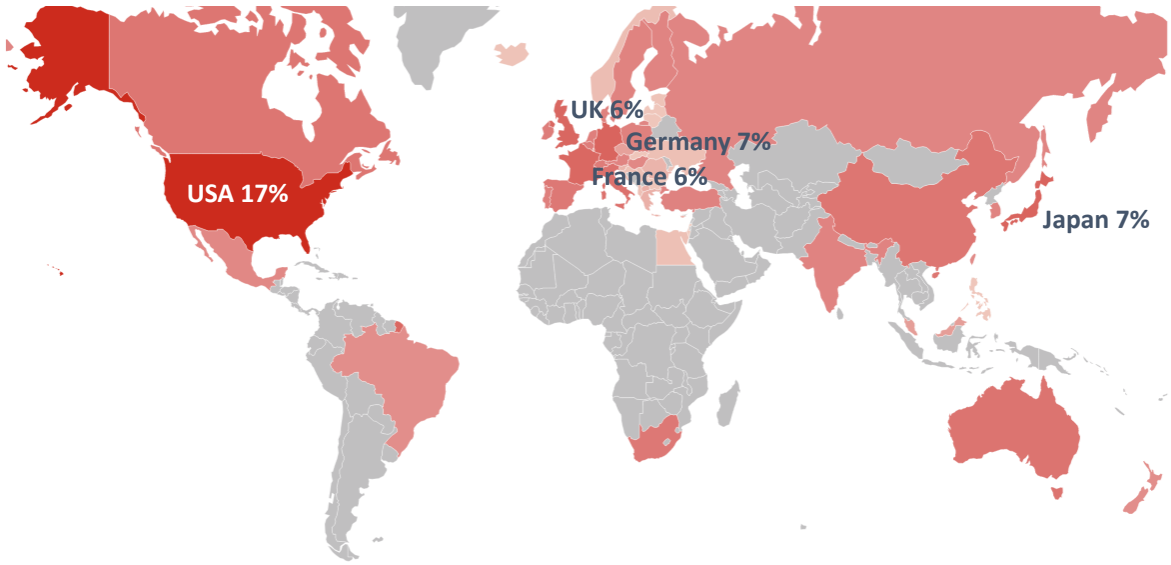
An interesting and complex challenge in surface disinfection is represented by biofilm, which is generally defined as a layer of microorganisms adhering to the surface of a structure, which may be biological or inanimate. Organised in this layer, the community of microorganisms secretes a protective coating made by extracellular polymeric substances (EPS). Biofilms are a large problem for public health because it represents a protective environment, which allows the bacteria (or viruses or fungi) to survive for long period also in a desiccated state. In addition, biofilms periodically can 'slough off' and release planktonic bacteria (i.e. microorganisms free to move) that may act as a source of infection.

Biofilms represent a crucial aspect in developing biocides formulations because they reduce susceptibility of the microorganisms to the biocides. Causes of reduced susceptibility to antimicrobial agents in biofilms are multi-factorial, including reduced penetration (particularly due to changes in cell density and the production of EPS), slow growth (and subsequent reduced metabolism of antimicrobial agents), modulation of the stress response and other metabolic processes.

One of the key strategies in tackling biofilms, identified in many recent innovations, is a combination of active ingredients: some adjuvants can destroy the biofilm matrix, thus exposing the microbes, and biocides can explicate a full action against the 'unprotected' microorganisms. Using enzymes able to dissolve the biofilm matrix is an approach described in some patents, where formulations include DNase or dispersinB. Creating a hostile environment to prevent the formation of biofilms is another strategy disclosed in some patents, and it is at the basis of the implementation of antimicrobial surfaces. Options include metals such as copper and silver, or chemicals such as organosilanes with quaternary ammonium groups and light-activated antimicrobials.

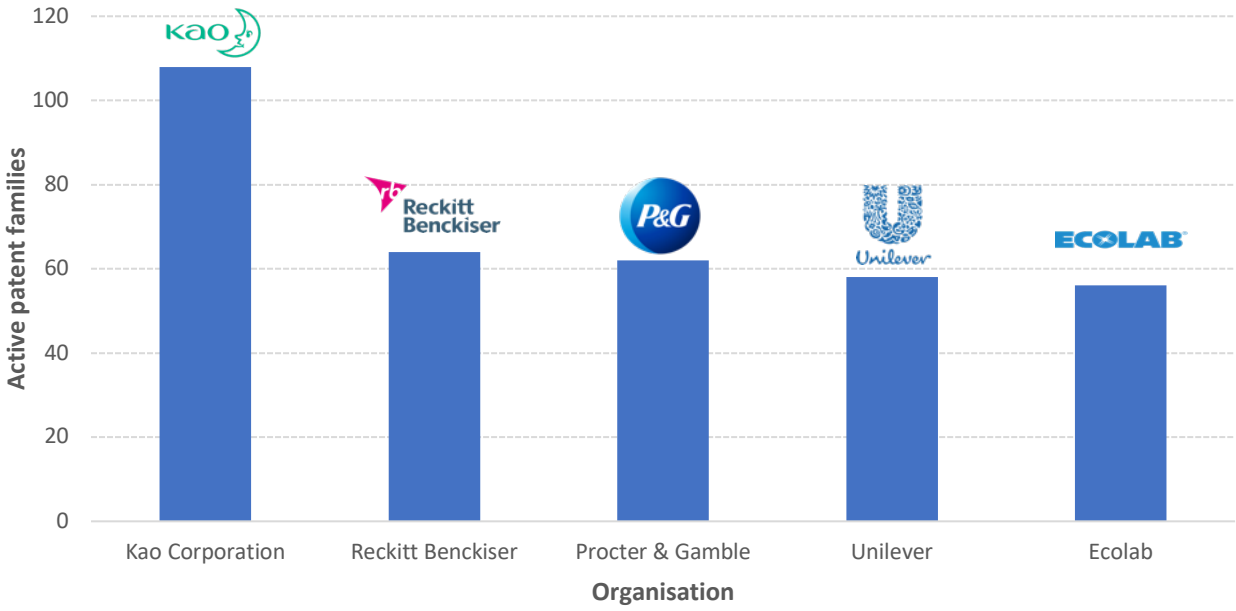
If we want to discover the geographical hubs linked to surfaces disinfection innovation, the distribution of active patents is a good indicator and shows US, Europe and Japan have a comparable relevance. If we look at granted patents, we can also have an understanding of which are the leading countries in Europe. While globally the leader is US with 518 granted patents, the other countries in the top 5 list are Japan, Germany, UK and France.

Surfaces Disinfection: Granted patents by country



Who are the key competitors and what is the nature of their core businesses? The top organisations are multinationals, either from the chemical industry or FMCG sectors. Looking at active patent families for the surface disinfection area, over 30% of patent families are owned by the top five organisations, although Kao Corporation has a stronger position compared to other companies.

Surfaces Disinfection: Active Patent Families by Top 5 Organisations



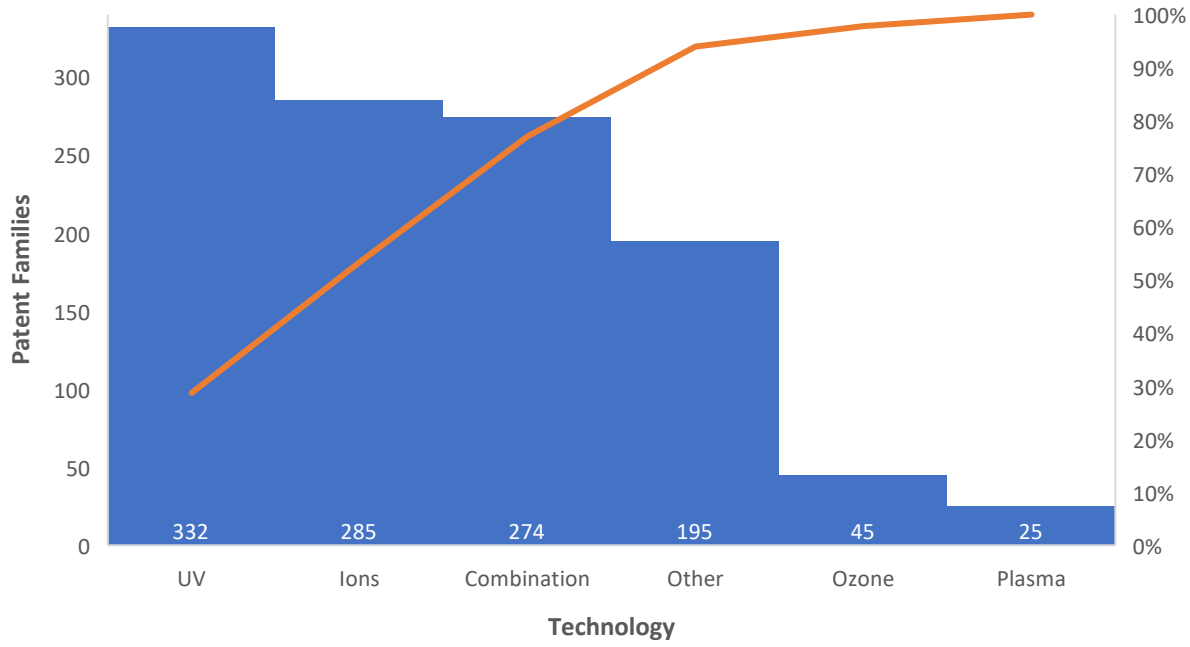
Sterilisation and Disinfection Solutions for Mobility Applications

COVID-19 has changed the reality of life in public indoor spaces. It doesn't stop there, taking a public transport or renting a car for a trip exposes us to the risk of catching viruses and bacteria. Risk that we probably prefer to avoid during a pandemic outbreak. But how can we reduce this risk? What extra measures can be taken on top of social distancing and hand washing? In March, the Shanghai public transport firm Yanggao introduced UV light to disinfect buses while in China a bus driver developed a system to autonomously spray disinfectant in bus cabins.

We have demonstrated that UV technology is the leading technology in the space of indoor air sterilisation. For surface disinfection, understanding biofilms and finding solutions to deal with them is a priority. Taking a look next at Mobility applications - what are the leading technologies, and who are the top players?

Taking a look at the inventions related to disinfecting and sterilising the inside of vehicles. The technologies include sterilisation of air as well as disinfecting surfaces, for example bus handles. Analysis of the 1,156 active patent families published in Sterilisation and Disinfection solutions for Mobility shows that UV is the leading technology, followed by Ions solutions and the 'combination' category which contains all the patent families related to two of multiple technologies within UV, Ions, Ozone and Plasma. The Pareto line highlights that 77% of active patent families belong to these top three technology categories. The remaining 23% is split between 3 categories: 'Other' which contains all the patent families that do not belong to any of the other categories shown in the chart, Ozone and Plasma.

Sterilisation and Disinfection Solutions for Mobility: Active Patent Families by Technology

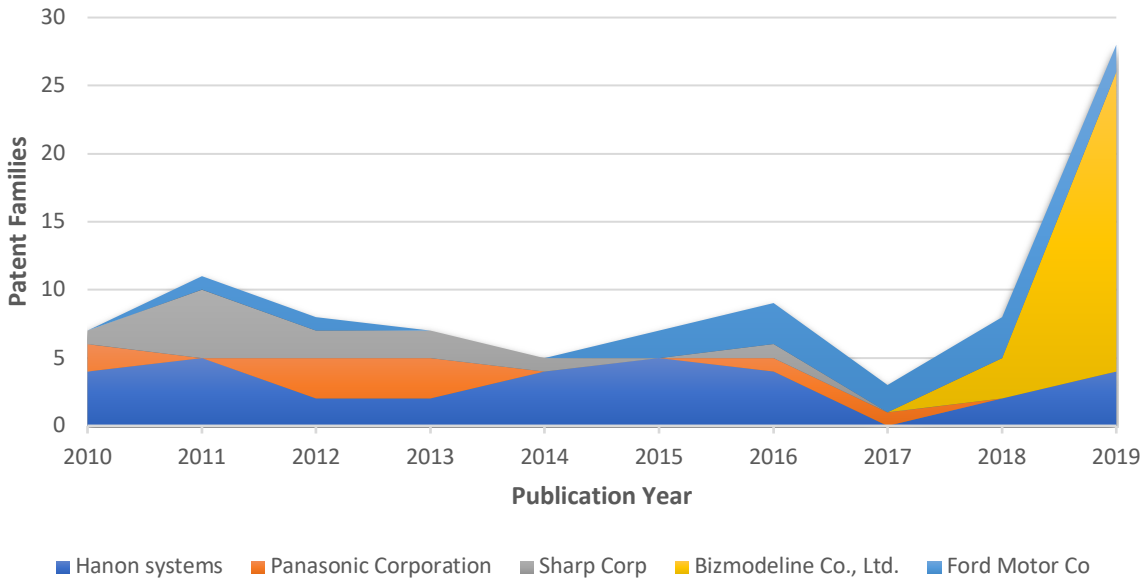


In a recent patent, Ford Motor describes a method to disinfect surfaces, and in particular car door handles, applying one of the strategies described above. The material used to manufacture the handles is composed of different layers and includes an antibacterial compound coating. The biocide coating is inert in normal conditions, but is activated by an LED light built into the handle system.

Geographic distribution of patent families in this technology shows a similar picture to the one seen for indoor air sterilisation technology: high predominance of Asian countries with 67% of the 1,156 active patent families published in China, 12% in Korea and 7% in Japan.

Looking at the publications from 2010, we have identified the top 5 organisations with the highest number of families published in this technology: Hanon systems, Panasonic, Sharp, Bizmodeline and Ford motors. In particular, it is interesting to notice the significant increase of Bizmodeline patent activity since 2018, an increase of more than 600% between 2018 and 2019.

Sterilisation and Disinfection Solutions for Mobility: Patent Families by Publication year and by top 5 Organisations



For more information on who owns what and where in the Disinfection and Sterilisation solutions space, access Cipher via your subscription or if you'd like to understand more about the data used in this article, contact us directly at www.cipher.ai.

Federica Sbaccanti, Automotive Consultant federica.sbaccanti@cipher.ai
Paolo Montone, Solutions Consultant paolo.montone@cipher.ai
Niall McMahon, Head of Research niall.mcmahon@cipher.ai