ANKARA YILDIRIM BEYAZIT UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

PATENT DATABASE ANALYSIS FOR CARBON REINFIRCED NANO-COMPOSITES USED AS CONDUCTIVITY SURFACES FOR AEROSPACE INDUSTRY

M.Sc Thesis by

AYŞEGÜL BEREKETLİOĞLU

Department of Materials Engineering

December, 2021

ANKARA

PATENT DATABASE ANALYSIS FOR CARBON REINFORCED NANO-COMPOSITES USED AS CONDUCTIVITY SURFACES FOR AEROSPACE INDUSTRY

A Thesis Submitted to
the Graduate School of Natural and Applied Sciences of Ankara Yıldırım Beyazıt University

by

Ayşegül BEREKETLİOĞLU

December, 2021

ANKARA

M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled "**PATENT DATABASE ANALYSIS FOR CARBON REINFORCED NANO-COMPOSITES USED AS CONDUCTIVITY SURFACES FOR AEROSPACE INDUSTRY**" completed by **AYŞEGÜL BEREKETLİOĞLU** under supervision of **PROF. DR. HASAN OKUYUCU** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

Prof. Dr. Hasan OKUYUCU

Supervisor

Prof. Dr. Ahmet PINARBAŞI

Jury Member

Prof. Dr. Rahmi ÜNAL

Jury Member

Prof. Dr. Sadettin ORHAN

Director

Graduate School of Natural and Applied Sciences

ETHICAL DECLERATION

I hereby declare that, in this thesis which has been prepared in accordance with the Thesis Writing Manual of Graduate School of Natural and Applied Sciences,

- All data, information and documents are obtained in the framework of academic and ethical rules,
- All information, documents and assessments are presented in accordance with scientific ethics and morals,
- All the materials that have been utilized are fully cited and referenced,
- No change has been made on the utilized materials,
- All the works presented are original,

and in any contrary case of above statements, I accept to renounce all my legal rights.

Date: 10.12.2021 **Signature:** ……..

Name & Surname: AYŞEGÜL BEREKETLİOĞLU

PATENT DATABASE ANALYSIS FOR CARBON REINFORCED NANO-COMPOSITES USED AS CONDUCTIVITY SURFACES FOR AEROSPACE INDUSTRY

ABSTRACT

Research and development studies has been developing especially on critical advanced technologies of aerospace industry along with aviation and space industry. Especially carbon reinforced nano composites can provide advanced technological support to meet such properties. One of this advanced technology is the nano composite technologies because nano composite materials have low weight and high electrical, optical, physical, chemical and mechanical properties. Nano composites are novel materials technology that has been improvingly used in aerospace industry. In the course of these improvements on novel materials, patent database analysis can support the studies and their route for improvements. Patent database search and analysis are important tool to identify technological roadmap. Researchers confirm their R&D policy by checking patent databases. In this study, patent database analysis has been carried out for carbon reinforced nano composites that are used for improving electrical and thermal conductivity of metal and composite surfaces used in aviation industry. It is also aimed to gather data to guide the evaluation of the relationship between patent database and technological development of carbon reinforced nano composites.

Keywords: aerospace, carbon, nano composites, patent

HAVACILIK ENDÜSTRİSİ İÇİN İLETKEN YÜZEYLERDE KULLANILAN KARBON BAZLI NANOKOMPOZİTLER ÜZERİNE PATENT VERİTABANI ANALİZİ

ÖZET

Havacılık ve uzay endüstrisinin gelişmesi ile beraber havacılıkla ilgili kritik ileri teknoloji çalışmaları ve araştırmaları da gelişmektedir. Bu kritik ileri teknolojilerden biri de düşük yoğunluklu, yüksek elektriksel, optik, fiziksel, kimyasal ve mekanik özellikleri nedeniyle nano kompozit teknolojileridir. Özellikle karbon takviyeli nano kompozitler bu özellikleri karşılayarak ileri teknolojik çözümler sağlamaktadır. Nano kompozitler de havacılıkta kullanımı yaygınlaşmaya başlayan yenilikçi malzeme teknolojilerindendir. Yenilikçi malzeme teknolojileri üzerine yapılan iyileştirmeler ve geliştirmeler sırasında, patent veri tabanı analizi, Ar Ge çalışmalarının yol haritası rotalarını destekleyebilir. Patent veri tabanı araştırması ve analizi, araştırmacılara teknolojinin nereye evrildiğini gösterir. Ayrıca patentler, araştırmacılara son teknolojik gelişmeleri gösterir ve yeni buluşlar hakkında ipuçları verir. Bu çalışmada, havacılıkta metal ve kompozit yüzeylerinin elektriksel ve ısıl iletkenliğinin iyileştirilmesi amacıyla kullanılan karbon takviyeli nano kompozitlerin patent veri tabanı analizi yapılmış ve sonuçlar analiz edilmiştir. Bu çalışmanın amacı, havacılık alanında kullanılan karbon takviyeli nano kompozit malzemelerin patent veri tabanı araştırması yapılarak patent veri tabanı ile teknolojik gelişmenin ilişkisini yorumlamaya yardımcı olacak veriler elde etmektir.

Anahtar Kelimeler : hava aracı, karbon, nano kompozit, patent

ACKNOWLEDGMENTS

I would like to take this opportunity to thank my tutor and supervisor Prof. Dr. Hasan OKUYUCU and for his support, guidance, encouragement and enthusiasm he showed from the initial stages to the end of the project. It has been an honor and a pleasure for me to work with him.

I would also like to express thank my jury members Prof. Dr. Rahmi ÜNAL and Prof. Dr. Ahmet PINARBAŞI for their guidance and my chef to Kasım PEKER for his support and guidance.

Finally, I would like to thank my family, Mom and Dad, for being with me all the way.

Without you, I wouldn't be here.

2021, 10 December **Ayşegül BEREKETLİOĞLU**

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

In recent years, the development of new technologies in aviation has accelerated. The use of lighter and stronger or more conductive materials are important in aviation industry. Several researchers are working on development of such materials. For making an appropriate decision, patent research and patent database analysis are important.

In this study, the importance of making patent database analysis especially in R&D studies is discussed. This study focuses on problems such as electromagnetic interference, lightning strikes, icing and radar visibility in aviation. It has been shown that the use of electrically conductive materials is needed to encounter for such requirements. It has been noted that these requirements, which were encountered by using conductive systems in old technologies, can be easily encountered by using lighter electrically conductive nano composites. In addition, the transition from complex system to advanced functional materials has been demonstrated by patent search and patent database analysis. In addition, the analysis shows which institutions, companies and universities are working on such development activities. In addition, with the patent database analysis, it has been shown which countries are studying on this subject. In this study, it is also discussed how should be done more effective patent research.

The analysis also showed an increase in the number of patents over the years. It is shown how research is done with patent database analysis. It is aimed to guide researchers and R&D workers. With this study, it is also aimed to assist production institutions in determining a technological roadmap. Keywords and classifications are used in patent search and patent database analysis. Using keywords alone during research may result in poorer results. Classifications can also be used to prevent that kind of situations. In this way, more effective results can be received.

1.1. Literature Review

1.1.1. Composite Materials

A composite material is a material composed of two or more component materials. The component materials have quite different chemical or physical properties. Composite materials are formed by the synergy of these different materials. Composite materials have advanced properties because they combine the properties of component materials. Generally composite materials are consisted of two phase as matrix material and reinforcement material. Matrix material is a holder for reinforcement material. Reinforcement material is the material that provides strength to matrix material. Application areas of composite materials are construction industry, automotive industry, aviation, marine, biomedical. Since they are light and durable materials, they have been used extensively for years, especially in areas that require low weight and high strength. Fiber Reinforced Composites are the most commonly used type of composite materials. There are three types of composites respect to their matrix material: metal matrix composites, polymer matrix composites and ceramic matrix composites. Metal matrix materials contain metal matrix material. This type of composite materials is generally used for their high conductivity. Polymer matrix materials contain polymer matrix which generally used in Fiber Reinforcement Materials. Ceramic matrix composites consisted of ceramic matrix which generally used in high temperature applications. The reinforced materials such as particle reinforced composite materials classify composite materials, fiber reinforced composite materials and structural composite materials. [1]

1.1.1.1. Particle Reinforced Composite Materials

Small or large particles are used in this kind of composite materials. Particle-based composites containing particles larger than 1 millimeter are referred to as "large particle composites". The utility of these particles tends to limit matrix deformation as a reinforcement mechanism. Particle-based composites containing nanometer-size

particles are referred to as "small-dispersed particle composites". These materials, unlike large particulate composites, carry most of the load when the matrix is subjected to mechanical stress. In this case, the strengthening mechanism takes place at the atomic level and involves the inhibition of the propagation of dislocation lines across the matrix by the dispersed particles as seen in Figure 1.1. [1]

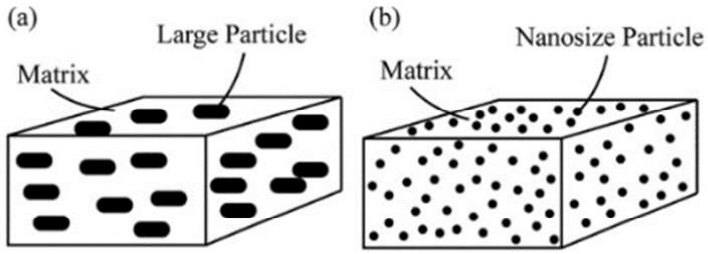

Figure 1.1 Types of particle reinforced composites (a) Large particle (b) Dispersion – strengthened. [1]

1.1.1.2.Fiber Reinforced Composite Materials

Fiber matrix composite materials are frequently used in applications requiring high strength such as aerospace. The material is obtained by surrounding fibrous materials with high mechanical properties, such as strength and modulus of elasticity, with metal, polymer or ceramic matrix. The properties of material are depend on matrix material and dimensionless quantity known as the length-to-diameter ratio of the fibrous phase as seen in Figure 1.2. [1]

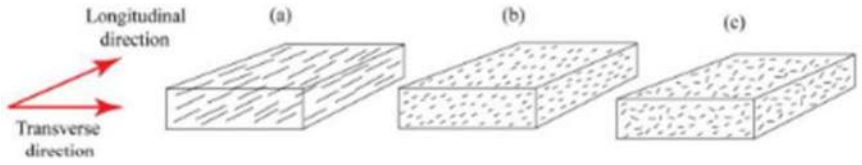

Figure 1.2 Schematic diagram of fiber reinforced composites (a) continuous and aligned (b) discontinuous and aligned (c) discontinuous and randomly oriented.[1]

1.1.1.3.Structural Composite Materials

Structural composites are obtained by combining or bonding more than one composite material. The mechanical properties, structural integrity and volume of the material vary according to the properties of the composite materials from which it is formed. Structural composites are examined in two classes as laminar composite and sandwich composite. Laminar composites are obtained by combining at least two sheet composite materials as seen in Figure 1.3. These sheets may consist of continuous and aligned fiber-reinforced composites. Sandwich composites consist of a high-strength outer structure and a relatively soft core material. [1]

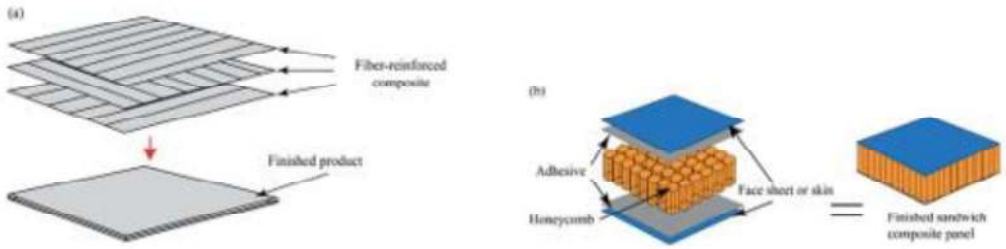

Figure 1.3 Schematic diagrams of the structural composites (a) laminar composite (b) sandwich panel.

The combination of 3 different materials is called advanced materials as seen in Figure 1.4.

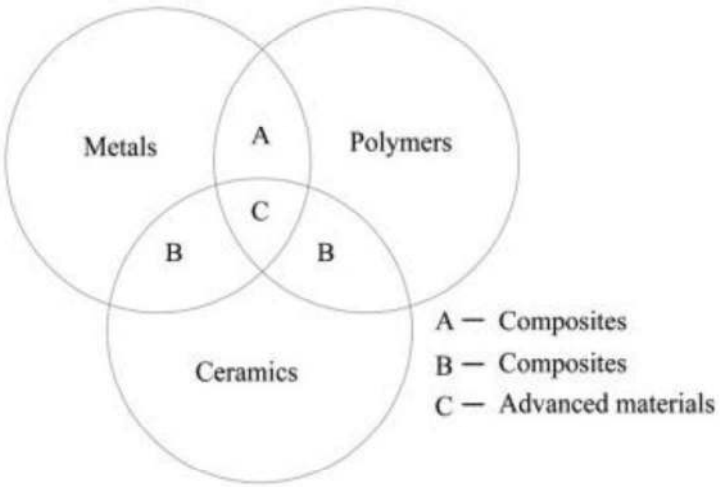

Figure 1.4 Classification of materials.

1.1.2. Nanocomposite Materials

Nano-sized materials are materials that have a size between 1 nm and 100 nm. When materials are nano-sized, the ratio of surface area to volume changes. Then, their strength increases. When materials are nano-sized, their surface area and interfacial interactions increase. Nano-composite materials are materials in which at least one component is nano-sized. In nanocomposite materials, the nano-sized reinforcement is generally dispersed in the matrix material. By adding nano-sized particles to the matrix material, the mechanical, electrical conductivity and thermal conductivity properties of the composite material can be improved. Various methods are used to produce nanocomposites with desired properties. These are hydrothermal process, sol-gel process, chemical vapor deposition, physical vapor deposition etc. [2]

1.1.3. Nanocomposite Materials in Aircraft Industry

In the aircraft industry, generally nanocomposites with polymer matrix and ceramic matrix are used. These materials are used in aircraft due to aviation applications as seen in Figure 1.5. Heat resistant ceramic matrix nanocomposites are used, especially since engine parts operate at high temperatures. Ceramic matrix nanocomposites are wear resistant.

In other regions, polymer matrix nanocomposites are used extensively.

Metal matrix nano composites are less used cause of their limitations of process. Polymer matrix nanocomposites are used in areas where high mechanical strength, lightness and high conductivity are required in aviation. Nano fillers have extraordinary properties as they have a defect-free basic structure at the crystal level. There are different types of nano fillers such as nano tubes, nano wires, nano whiskers, nano particles, nano powders and etc. In the aircraft industry, nanocomposite materials solve problems that composite materials cannot solve. Composites with low electrical properties may be insufficient in solving problems such as electrical resistance, electromagnetic interference shielding, lightning strikes, icing. Nanocomposites containing highly conductive reinforcement materials are more effective in solving these problems. In recent years, nanocomposites have been used especially in some structural parts and coatings. Nanocomposite coatings are applied to aircraft in radar absorbing, lightning protection, ice protection and electromagnetic interference shielding applications. [3]

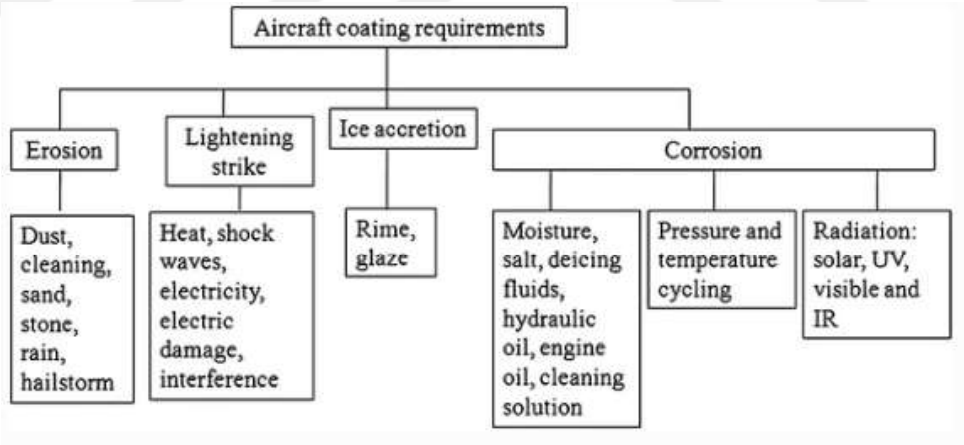

Figure 1.5 Aircraft problems that can be solved with nanocomposite technology.[3]

1.1.4. Electrical Conductivity Mechanism of Carbon Reinforced Nanocomposites

Electromagnetic interference can be caused by the creation of interference signals, and the effects of satellite signals. In some cases, electromagnetic interference can damage many of the aircraft's electronic systems and cause the avionics system to crash, resulting in even fatal accidents. Device enclosures for EMI shielding must be made of electrically conductive or magnetic materials. EMI shielding materials must have high electrical conductivity and high magnetic properties to provide EMI shielding. Generally, metal sheets made of steel, copper, nickel or aluminum alloys are used. However, metal shielding systems have significant disadvantages. Metal shields are heavy weight, costly processing, and low corrosion resistance. Because of this, conductive polymer matrix composite materials have been improved for usage as EMI shielding materials as seen in Figure 1.6. Thanks to the proper distribution of nanotubes in the polymer matrix, high conductivity is achieved. In that point, avoiding from agglomeration of CNT particles is important. Shielding mechanism of this material is absorption of the electromagnetic waves. Absorption also occurs as tunneling in CNT tunnels. In this way, shielding is provided, waves are not transmitted to the back side by staying in the material. [4]

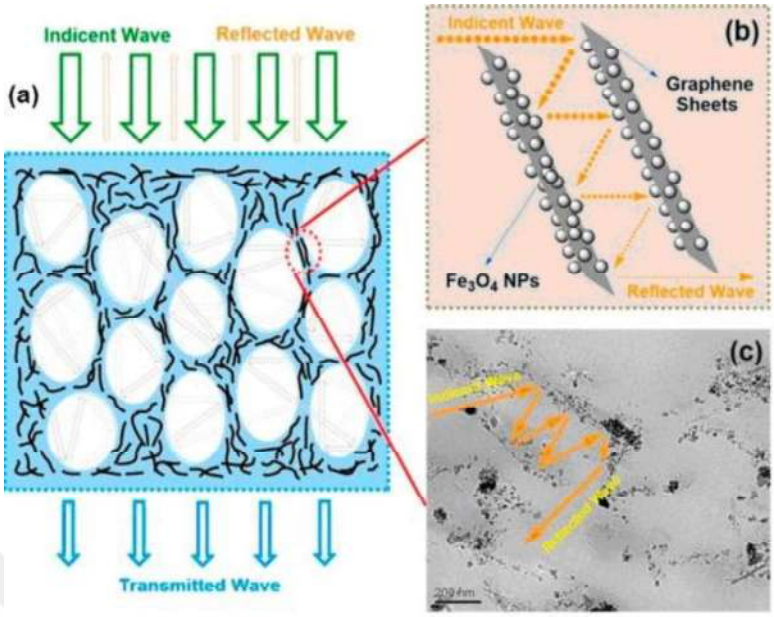

Figure 1.6 Schematic show of EMI Shielding Material [4].

Lightning strikes can cause great damage to aircraft, especially in stormy weather. Metal mesh structures are used in its structural parts to protect aircraft from lightning strikes. These structures balance the voltage load of the aircraft by transmitting the high voltage to the grounding device. However, metal structures are very heavy and not resistant to corrosion. Carbon-reinforced nanocomposites with high conductivity can serve as metal mesh structures. Carbon-reinforced nanocomposite laminate structures, coatings and thin films can be placed on the sharp-shaped areas of the aircraft, which can be affected by lightning, and can transmit the high voltage formed to the grounding center quickly. These materials, which have lightning protection function, can also have EMI interference shielding function as seen in Figure 1.7. [5]

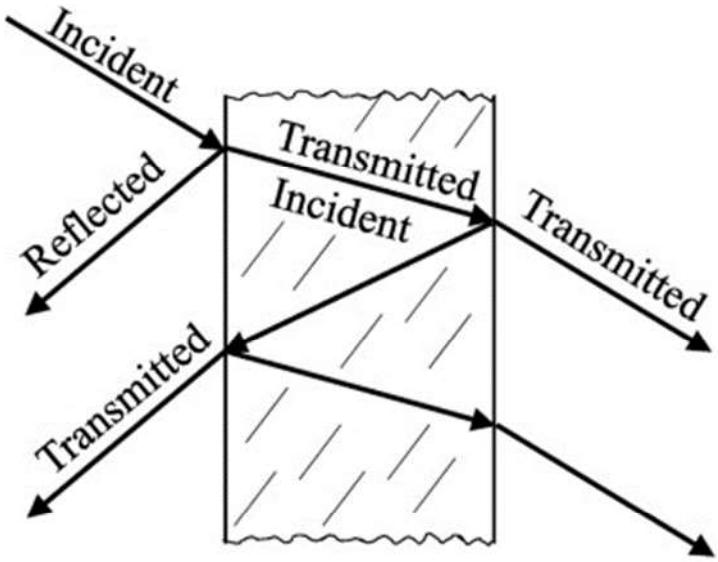

Figure 1.7 Schematic show of EMI Shielding mechanisms consisting of reflection, absorption, and multiple reflections [5].

Icing often occurs during the flight of the aircraft. To prevent this, heating systems similar to thermo-heaters are used for structural parts. By using hydrophobic coatings on the surface, the formation of water puddles on the surface is prevented. However, since metallic structures are also disadvantageous, the use of carbon-reinforced nanocomposites has become widespread instead. For this aim, especially bulk nanomaterials containing dispersed electrically conductive nanoparticles have been used as seen in Figure 1.8. In this de-icing systems, Joule effect heating have been used. Electrical current applied to nano composite, than conductive nanocomposite heats. Heating via the Joule effect represents an effective strategy for rapidly comparing extreme cold and humidity conditions, reducing environmental pollution and controlling rheological properties during the process. The effectiveness of the Joule effect was evaluated for the same resin characterized by low viscosity values with incorporated carbon nanotubes and two different grades of expanded graphite. [6]

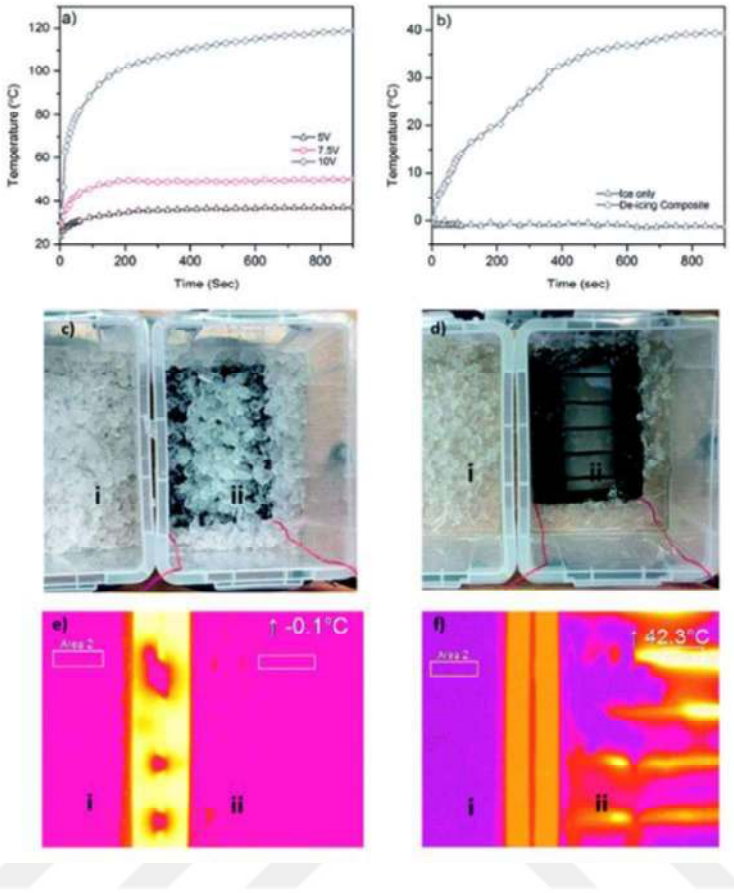

Figure 1.8 De-Icing system

1.1.5. Importance of Patent Analysis and Patenting on R&D Studies

Recent technological developments on aerospace and defense industries have guided researchers and producers to advanced materials. By research and development studies carried out as a result of the developments in industry and technology, many advanced materials are discovered and protected through patents. Industrial organizations and universities that examine these patents also strive to stand out by further developing this technological level. Advanced materials have low weight and high strength properties as well as advanced electrical, thermal and optical properties. [7]

Advanced materials have low weight and high strength properties, advanced electrical, thermal and optical properties. Due to these advanced features of these materials are good candidate for aviation industry. Researchers and producers make

efforts to increase technological maturity for use in target platforms by carrying out intensive R&D studies. These developments in technology have also been effective in the competition between companies. Especially for aviation and defense industry companies provide competitive advantage by closely following the advanced technologies of their competitors and by expanding their market shares by continuing their R&D studies in that direction. In this competition, patent numbers and patent quality are determinative indicators to choice of which companies or industries have demonstrate development and improvement in their technological level. Patent documents are better sources to evaluate the technical and commercial development of companies. So, patent reading is a new trend to get idea about technological level and the future projects of the players of the technology such as universities, companies, start-ups, and the other inventionships. [8]

Patents are legal documents that give inventors the right to produce and protect their inventions. The protection period of a patent is 20 years from the date of application. After the grant, a certain amount of dues must be paid each year. Patent protection requires some upfront investment. The patents are the documents that protect the intellectual property with legal way. Patents allow technical information to be disseminated. In addition, thanks to its public structure, it is accessible to everyone. In recent years, the number of patents and products has come to the fore in educational institutions such as universities and institutes, as well as academic studies. Patents provide some income to their inventor or assignee by licensing. In the academy, universities, institutes and R&D companies, there are studies on several technologies transferring their effort to the patent. During the studies, some innovative ideas that could be leading to some new technologies can be emerged. To protect these innovations, patent application is required. But the patent application process can take a long time to be granted. This process can delay the further technological improvements. [8]

Patent documents allow you to be the only party that can profit from the manufacture, use or sale of your invention. After the patent application, invention has been produced and turned into a commercial product. Third parties can solve the

invention with reverse engineering. Third parties cannot produce and commercialize this invention because of protection of inventions by patents. This indicates that only the people who have the invention can manage the sector. [8]

1.1.6. Pros and Cons of Patent Document Applications

Some inventors are not knowledgeable about the benefit of the patent document. Some other inventors do not receive support regarding preparing patent documents and applying for the grant. In this case, most inventions were not protected by patents. In addition, high patent costs have also caused many people to give up on patents. Patent documents are legal documents, to protect the right of the inventors. In the future, there may be cases of litigation if competitors do similar work. These firms or R&D centers may have to hire high-cost lawyers to make precise follow up procedures. In addition, the scope of protection of the specification should be kept wide and these details of patents should make the defense easier in court. The protection of a patent is only valid for the country in which it was obtained when it is processed as national. If the inventor is going to sell the product that is the subject of the invention in other countries, he should apply for those countries as well. Every patent is an idea for competitors. Based on patents, competitors can produce the same product using different production methods to prevent infringement. In addition, patent holders must enter the market within the 20-year protection period and take over the management of the market. Otherwise, patents whose protection period has expired can be easily used by competitors. [9,10]

Investors generally focus on patented products. Especially universities, institutes and R&D companies with a large number of patents are considered to be safer by investors. Patents also provide an advantage in terms of investment. The scope of protection of some patented invention may be very narrow. This, in a short time, is inspired by that patent and causes competitors to obtain much more patents. Also, some inventions may be covered by secret patents or trade secrets. Before an idea is patented, whether it is confidential, a trade secret or a patent application should be examined in detail. If the invention is not known by a large number of people in the

institution found, if there are not many documents belonging to the known state of the art, and conversely, it is not possible to understand it with engineering, it may be more advantageous to remain a trade secret. [9,10]

The patent or patent application document can be used for collecting information about technical nature and features of inventions about a technological field. [10] Patent documents can be said as an indicator for understanding the measure and count of the innovation on a special technological field. [11] Also patent analysis and reading is an important part of the technology management. Patent database analysis transforms the resulting data into useful and meaningful information. Thus, it enables us to have a lot of information about the technological area such as technology competition values, technological trend and the future of the technology. Patent analysis is interpreted according to technology competition according to the assignee, technical areas and development periods. Patent documents are used to evaluate technology trends. The analysis is concerned with the detailed classification of the technology that attracts users. During search the appropriate patents, the researcher use IPC (International Patent Classification) and the keywords that determine the topic. And the technical fields can be said as patent classifications of IPC or CPC. So, the usage of classification is a good idea during patent database search. [12]

1.1.7. Most Commonly Known Databases for Patent Analysis

The searchers have been mostly use the patent databases to obtain information about patents and to analyze the patents. The mostly used databases are Espacenet, Google Patents, Lens.org and Derwent Innovation Tool.

1.1.7.1.Espacenet

Because of easiness, effectiveness and efficiency of these tools by means of patent database analysis, these tools are widely used by patent experts. Especially Espacenet and Google Patents were used to search and find and read the patents from their sources. On the other hand, “the lens.org” and “Derwent Innovation Tool” are

used to analyze the patents. Google patents and Espacenet have better interface for searching and scanning. The lens.org and Derwent Innovation Tool have better interface to analyze the patents as charts and graphics. [9,12] An explanation pros and Cons of these four patents tools are given in the following titles. Espacenet or denoted as “esp@cenet” is an internet site released from European Patent Office (EPO). Espacenet site was launched in 1998. There is no registration required for searching. It is said that with the release of Espacenet, EPO made all patents applied internationally available to the public, the patent information was published in the easiest way not to remain in libraries, and the way patents were disseminated, organized, searched and obtained forever. Espacenet allows us to search for and read patents around the world. It offers free access to information on inventions and technical developments from 1782, when the EPO established, to the present, with advanced search features over time. Thanks to its easy-to-understand and accessible structure. Espacenet appeals to researchers from all over the world, including beginning researchers. This site is updated daily. It includes data on more than 120 million patent documents around the world. In addition, information can be obtained about the legal status of patent applications. Espacenet is frequently visited by patent experts. Experts use Espacenet to read patents, obtain translations, follow technology, provide technical solutions to technical problems, and study competitors. Espacenet is freely available for 7/24. In the Espacenet there are useful tools and resources. One of the resource is “Global Dossier”. The Global Dossier gives access the information of file wrapper of a patent application, wherever it is submitted by that particular patent authority. This information are about applicant/patent attorney, patent authorities' official actions, applicant statements, diagrams and drawings. Global Dossier also provides translation in many languages. The other tool is “Common Citation Document”. The Common Citation Document (CCD) tool provides access to citation data for the five largest IP offices (IP5) to access patent applications. This tool combines the previous technique referred to by all participating offices for family members of a patent application, displaying search results from different offices on a single page. In the Espacenet, there are smart search, advanced search and classification search. The smart search is a quick search

type that we can find a document with document number, title, inventor, assignee. The “OR” and “AND” words can be used during in the smart search. But this is not a detailed search. For a detailed search, advanced search must be used. In the advanced search, the users can use keywords, date interval, inventor, assignee, title, abstract, full text, claims, legal state, classifications, document number, patent office to find patents with a broad and detailed search result. In the patents obtained as a result of the research, the most relevant patents fitting with given data appear at the top. Thus, the most relevant patents can be accessed more quickly and easily. Later results have less relevance with given keywords. The order can be changed if older patents are desired to appear at the top. Likewise, the ranking of newer patents at the top can be achieved through a change in ranking. [13]

1.1.7.2. Google Patents

Google Patents is a patent database and patent search engine provided by Google. Google Patents is also an open digital library for indexed patents and there is no requirement to be registered for searching. Google Patents was launched in 2006. The beginner researchers and the experts intensely use this database because of its easiness and effectiveness. In the Google Patents, the users can read and search the full texts of the patents. Also there are a translation function on Google Patents. Google Patents includes more than 120 million patent publications from more than 100 patent offices. In addition, it includes many more technical documents and books indexed in Google Scholar and Google Books, and documents from the Prior Art Archive. Documents containing languages other than English are translated into English and displayed on the screen. Thus, the user is provided with convenience without the need for additional translation. In the Google Patents, the Non-Patent Literature can be displayed if it is chosen. The Non-Patent Literature covers the publication such as articles, journals, books, reviews, technical manuals or posters. Innovations are published in patents or literature documents. When prior arts are searched for a patent application, non-patent literature should be considered, because non patent literature can contain last technology for a patent application. Google Patent also gives information about recent technology in non-patent literature.

Google patents contains smart search and advanced search. In the smart search the users can find patents by writing keywords, classification, title, document number, assignee or inventor. This is a quick but not detailed search. If one user needs some more detail such as date, classification, inventor, assignee, he/she should go over advanced search. In the advanced search page, there are boxes for search terms as keywords or synonyms, date interval, inventor, assignee, patent office, language, legal status, document type and litigation. The keywords, synonyms or classifications are written for more accurate results on the search terms box. In addition, priority, publication or grant date interval can be written on search fields to restrict the search and to obtain better results. Also patents that are belong to inventors and assignees can be found by writing them in search fields. If patents belong to one or more patent offices can be specifically searched on Google Patents advanced search. Granted patents or patent applications can be also found in this search type. After the terms are written, the results page is displayed. The results and the search terms are seen on the screen at the same time, so the terms can be changed due to the results. By default, the more relevant results appear at the top. From top to bottom in page, the less relevant patents appear. If user wants to see newer and older patents to be shown above, "newer" and "older" options can be selected. In the Google Patents, usage of CPC classifications is good to narrow the scope of search. During search, if user clicks on a patent, the patent page opens. In the patent page there are full text, claims, drawings, legal state, bibliography and document number. The patent page of the Google Patents is easy to use and simple. The retrieved document can be downloaded or can be read on the page. [14]

1.1.7.3.Derwent Innovation

The other database tool is “Derwent Innovation Tool”. Derwent Innovation Tool is a complex program for investigators, patent experts, lecturers and business managers. This tool has a single, integrated solution structure that combines intellectual property documents, non-patent literature, business data with analytical, collaborative and alert tools for business decision support throughout the IP lifecycle. Patent abstracts developed and indexed by the editors enable full text patent data

searches from major patent authorities in English, Chinese, Japanese and Korean. Derwent Innovation Tool serves powerful analysis for patent experts and searchers. Derwent Innovation Tool was released by Clarivate Analytics. This tool requires registration and fee payment. Derwent Innovation is generally used for technological trend analysis. In addition, it is ensured that patents filed by competitors are monitored. The Derwent Innovation Tool is also extremely useful for FTO (Freedom to Operate) research before a patent application. Derwent Innovation is a proprietary patent research application that provides reliable patent data and tools to monetize and license intellectual property and support litigation activities. It also includes the Derwent Patent Citation Index (DPCI), which indexes patent and literature citations backwards and forwards. Derwent Innovation is using "Smart Search" and artificial intelligence technology for patent database searches. In this tool "Optimized Assignee" technology is used with Ultimate Parent to reveal current patents and final ownership and legal status estimates. In the Derwent Innovation Tool, the alerts can be used for legal status changings. The competitor assignees can be tracked in Derwent Innovation. Derwent Innovation Tool contains smart search and advanced search. In the smart search, the users can find patents by writing keywords, classification, title, document number, assignee or inventor. This is a quick but not detailed search. If detailed results are required, advanced search should be used. In the advanced search page, there are boxes for search terms as keywords or synonyms, date interval, inventor, assignee, patent office, language, legal status, document type and litigation. The keywords, synonyms or classifications are written for better results on the search terms box. In addition, priority, publication or grant date interval can be written on search fields to restrict the search and to obtain better results. Also patents that are belong to inventors and assignees can be found by writing them in search fields. After the search terms are entered, the patent results are seen. The bibliographic data of the patents can be read on this page. Also there are analysis page is positioned under the results page. In the analysis page there are analysis of assignee, document type, priority country, priority date, classifications, citations, text field keywords and themescape mapping. Themescape mapping is type of mapping the used keywords in the patent about the topic search. In the assignee

analysis, a bar chart is shown the top 10 assignees by record count in patent search results. In the document type analysis, a bar chart is shown the document type as patent applications, granted patents, or utility models. In the year analysis, a line graph is demonstrated trends in patent publications, based on the top several publication years. This can be chosen due to priority year, publication year or grant year. In the priority country analysis, a world map is shown of the top 10 patent offices in which patents were filed, based on country code. In the classification analysis, a bar chart is shown with the top 10 IPC or CPCs according to search results, based on Classification current. In the citation analysis, a list is shown with the forward or backward citation counts for each of the top 100 assignee/applicants according to patent search results. In the keyword analysis, a list is shown to categorize records through linguistic analysis and review of the patent search results. In the themescape, a topographical map is shown to analyze patent search results on the relationship between records. [15]

1.1.7.4.Lens.org

Lens.org is a patent database and analysis site. Lens.org is an informational tool for business executives, faculty, students, experts and investors for effective, efficient and fair problem solving. This tool covers common knowledge and patents. It provides analysis on intellectual property rights together with academic information flow. Lens.org is frequently used to bring optimized technical solutions to technical problems due to its easy-to-use structure. Lens.org is driven by the Cambia company. Lens.org aims to source, consolidate and link various open knowledge sets, including scientific studies and patents, to provide information to a human-centric user experience built on discovery, analysis, decision-making, and collaboration. Lens.org's development process took 20 years. The Lens.org includes more than 225 million scientific studies, more than 127 million global patent records, and more than 370 million patent series. According to the search input, it optimizes the results and tests the users. The lens architecture was created by Lens Meta Record. Len.org is used to find, analyze, manage and share information. Lens.org does not require registration for simple analysis and patent database search. However, some detailed

analysis tools are paid and require registration. In the search mode, the keywords, date interval, classifications, inventors and assignees can be written. During patent search, the search fields can be selected for a better result and analysis. According to keywords of the search, the keyword number can be selected and applied. Keywords and synonyms can be entered with usage of “OR” and “AND” to distinguish the words. Then the results come out. In this database, there are not smart search. Only advanced search can be run out. But the analysis function is more practical than search mode. In the Lens.org, the scholar information and patent information can be searched individually. In the lens.org, results of the search more relevant results appear at the top. From top to bottom in page, the relevancy gets less. If user wants to see newer and older patents to be shown above, "newer" and "older" options can be selected. If the “group family” is selected, only one family of INPADOC patents can be seen. This is a useful function for search and the analysis. In the search screen, the patents can be selected and opened in a new page to examine the patents. In the patent page, there are information about patent such as title, patent number, drawings, assignee, publication and/or grant date, family information, priority information, legal state, bibliography, full text, claims, cited works and classification data. The user can read full document in this page. If the analysis is required, in the bottom of results, there are analysis of results. In the analysis page, there are analysis about publication year, applicants or assignees, classification analysis, inventor, country and technological area. The publication year analysis shows the patent family count due to publication year, so the patent counts can be analyzed by year. Not only publication year but also grant year or priority year can be chosen. The applicant and assignee analysis shows the patent family count due to assignee or applicant name. The assignee or applicant can be chosen. The classification analysis shows the classification numbers due to patent family count. The IPC and CPC can be chosen. The inventor analysis shows the inventors due to patent count. The country analysis shows the country names due to patent counts. The technological area analysis shows the top keywords that gathered from patents and cited works due to patent count. [16]

1.1.8. Pros and Cons of Patent Databases and Specific Usage of Databases

The Espacenet and Google Patents are better tools for database search and reading the patents. In the Espacenet search engine of patents is advanced and has developed properties. The search history is stored for further searching. The search and results pages are individually side by side and are shown at the same time. If a patent is clicked on results page, the patent page opens side of the result pages, so the search page, result page and patent page are shown on the screen at the same time. Because of these reasons, Espacenet is advantageous way for patent search. But in Espacenet, there are not any analysis in the site, so Espacenet cannot be used for analysis.

The Google patents is an improved search engine for patent search. The search page and results page are shown at the same time. The search terms can be refined due to results in Google Patents. Because of these reasons, Google Patents is advantageous way for patent search. But in Google Patents, the analysis is weak for an advanced analysis, so a better tool is required for analysis.

The Derwent Innovation Tool has a good patent search engine however Derwent is mostly preferred for its improved and advanced analysis of patent search. The analysis is shown a different page from the search page and very detailed, so Derwent Innovation Tool is more effective for analysis.

Lens.org has a great patent search engine, but its analysis tool is advanced and has improved visuality. Because of this reason, Lens.org has advantageous way for patent database analysis. [13-16]

1.1.9. Sample Patent Analysis of Two Different High Technological Materials

1.1.9.1.Study of Liu et al

There are similar studies about patent database analysis on materials science. In one of the study, there are two cases of patent database analysis as Light Emitting Diode (LED) material technology and Thin Film Transistor (TFT). In the first case a strategic plan was mentioned in the development of technology. And in the other

case the technological roadmap was shaped by using patents. Patent database analysis transforms the resulting data into useful and meaningful information. Thus, it enables us to have a lot of information about the technological area such as technology competition values, technological trend and the future of the technology. For the search of LED patents, the “H01L” and “H01S” IPC classes were used since these cases contain patents most about LED technologies. And the keywords of this search were ‘electro_opti*’, ‘led’, ‘leds’, or ‘light emit*’ which are mostly relevant words of the LED technology and 478 patents were found between 1980 and 1994. According to patent database analysis, the assignee and patent numbers have been increased year by year. During the patent search, the firms that dominate the LED technology were seen and analyzed. Especially AlGaAs and InGaAlP materials examined that mostly used as LED application materials. In above mentioned study, by using patent database analysis, companies that contribute to the development of LEDs and the upstream, midstream and downstream firms have been revealed. The assignees of LED materials can be classified into three main groups due to their products according to the patent database analysis. The upstream firms and industries have produced the semiconductor products which are advanced and costly technologies, and the midstream firms have produced photodetectors and then the downstream firms have produced lamps and the other illumination applications. Analysis, that classify the firms by means of product portfolio, shows us the performance of firms, industries and assignees and their competition ability. That analysis explains the product portfolio and technical-production details of the product. While the development of this LED technology, different colors of the LED lights was also discovered. This development could be seen along patent database analysis. After discover of the LED lights, the usage area of LED was expanded with LED technology development. Also this patent database analysis contains that the countries and companies competing on LED technologies such as HP and AT&T from the USA, Siemens from Germany and Toshiba, Matushita, Shin-Etsu, Sharp, Hitachi and Mitsubishi from Japan. This patent database analysis is a guide in formulating a strategic plan for the production and use of LED material technology. In the second case of this study, TFT material technologies were examined with

patent database analysis and this analysis could be used in technological map planning. In this case 479 patents were examined between 1969 and 1993. According to this patent database analysis, in the year of 1982, the patents about TFT scree technologies were decreased and a new technology of “TFT-LCD Screens” patents were increased. That shows us the TFT technology evaluated to LCD technology.

In addition, in this study, a formula for technological trend analysis and measuring the amount of innovation is revealed. Innovation size was measured using this formula.

This study offers future plan for technological performance of industry competitors in related technologies such as TFT and LED material technologies. In addition, this study provided an example for technology development on Taiwan industry. This result supports the use of patent analysis to accurately measure technological and production performance.

Technological road map is about technology management and development. In this study, the problems on LED and TFT material production and usage were determined and noted. It is aimed to be more instructive by integrating patent researches in R&D studies. By determining the technological trend by means of patent research, it was ensured that the researches proceed due to new technological improvements. Due to patent research studies, technical solutions were identified for LED and TFT material problems that occurring in service and production. Then the development of patented and unique products or methods will be guided clearly. In the first stage of a technology that was newly developed, very few patents were granted and a limited number of firms and assignees were interested in this technology. After that, same technology was started to grow and so, many patents were filed. Then a steady course was followed in this technology. Then the number of firms and patents starts to decrease. At this point, technology must be changed or improved. Consequently, an advanced R&D study would be introduced effectively for this changing [17].

1.1.9.2. Study of Huang et.al

The other study, Huang et.al. examined the special patent database analysis in U.S. Patent and Trademark Office about Nanoscale science and engineering (NSE). This study found out the indicators of the technological structure such as number of patents, cites per patents, current impact index, technology independence, technology cycle time, science linkage. Patent analysis of this study is to evaluate technology development performance based on the number of published patents and various citations.

There are lots of works on new technologies especially technologies related to nanotechnology. It is important to make them accessible from all over the world. Because these type new technologies are open for further developments. While starting to a new technological investment, it requires a smart search of databases in order to have broad information about these developments. In this study, the patent data were assessed and mapped in order to support these technological developments. Patents were obtained from USPTO, published between 1976-2002 have been examined in this study. During analysing of patent data, “content and keyword map”, “basic search analysis” and “cited sources” were taken into consideration. The basic search analysis, the cited sources and their network information provided a basic information for countries, assignees and the technological fields. In the other hand, the content mapping could provide information about mostly featured technical concepts and the best strategy for patent searching based on keyword search. In this study, the closest patents on the nanotechnology were revealed by making a full-text search. Patents were found by keyword-based research. The words are filtered to reach more accurate results. For this purpose, the closest patents on the subject were examined and the words in these patents were used. Especially in this study, the B82 class is emphasized. Because this class includes patents specific to "nanotechnology" within the IPC classification. In the research, three special criteria have been examined as patentability factors in nanotechnology. First of all, the novelty and unique properties and functions in the nano-sized materials. Another important point is novel functions and properties at the

nanoscale should be clearly defined and contain sufficient technical knowledge. And the last point is these new inventions must be industrially applicable and producible. In this study 7 main keywords were used with their synonyms and variations and they reported the patent count due to these keywords. For this analysis, five key indicators were used which were taken from Narin's study [10]. These indicators are namely the patent count, the patent citation count, impact index, technology evaluation time and science linkages. The technology independence measure derived from common industrial applications were considered in this analysis too. These indicators are explained as the patent count indicates the numbers of the activity on a technology of companies and countries, cites of patents indicate actual impact of the patents on a technological field, current impact index indicates the quality of patent document that are cited recent 5 years, the technology independence shows that the technological improvements independence, the technological cycle time shows the changing time of the one technology to another advanced technology, the science linkage shows the links between industrial improvements and academic studies and articles.

In the analysis of this study showed that the 60% patents were filed from the top 20 patent owner countries between 1976-2003. The top four countries were U.S.A, Japan, Germany and France. Number of patents shows us these countries are most studied on nano technology in 1976-2003. The top average four assignees were IBM, Xerox, 3M and Kodak. With the technological cycle in time, the topic of the patents has been changed from production methods to different products. Especially after 2000s, the computer and transistor technology patents raised but before 1990s, mostly the production technics were raised. According to citations of the patens, the most patents cited by USA, that shows the USA dominated nanoscience and engineering between years of 1976-2003. And the other two most patent cited countries were Germany and Japan. These two countries also dominated the nanoscience same years as USA as. In this study, other country citations were mapped and showed as visual graphs and tables. The top four assignees are also to four most cited patent holders. In this study, another analysis was about the map of

the contents of the patents. This map was a topographic map of the contents and the mostly used keywords in these patents. This map was useful for further patent database search because the searcher could see the most relevant keywords on this technology. This map also gave the information about important contents of the patents. In this study, the content map contained semiconductors, dielectric layers, thin film, transistors, metal oxides and the other mostly relevant words.[18]

1.1.10. Patents and Guiding to Investments

Nowadays, advanced materials such as nanocomposites are widely used in aircraft electronics systems, structural parts, inner parts, lightning protection, electromagnetic interference shielding systems. Because of light weight, high strength, good electrical and thermal properties they are good choice for material selection during design and production planning of aerial platforms. Especially electrical and thermal properties of composite and metal surfaces and structural parts are critically. These parts are protecting and sustaining the aerial platforms. Carbon reinforced nanocomposites have excellent electrical and thermal properties because of nano-sized carbon particles. Nano-sized carbon particles such as CNT (carbon nanotube), fullerene, graphene and carbon black have better properties than bulk size. Because smaller size materials such as nano materials have lower imperfections and grain boundaries than bigger size of materials [8]. According to this technological trend analysis, our study offers the possible applications on Patent Database Analysis for Carbon Reinforced Nano-Composites That Used for Improving Electrical and Thermal Conductivity of Metal and Composite Surfaces of Aerospace.

Patent analysis is one of the most virtual tool for investors. The investments on the aircraft sector have been guided effectively by the patents. If patents count on a technological field would increasing, that means this technological field will rise. These improvements in any technology attract attentions of investors. Especially start-up companies take many investments to encourage to production. In addition, investors can apply for a patent database analysis to see the technological trend. They

can employ some patent experts for this purpose. This is an indication that investments can be directed according to technological orientation. This situation has led to an increase in patent applications both in the public and private sectors in the aviation industry. The higher the number of patent application is the higher of number of investments in any field of technology. In the start-up years, there were too much usage of the patent analysis for the investments. This also helps competition of the companies. They are concrete documents that can be seen. Patents may get venue not just for investors but also for patent owners. Licensing and breach revenues are used for this purpose. When a company strategically uses IP, it will be more likely to release products that appeal to their customers. Patent analyzes are guiding to meet the needs of customers and to invest in this area of technology. [19,20]

1.1.11. Strategies That Are Followed by Major Technological Companies

The Boeing company is one of the most leading companies in global aircraft sector. Boeing is ahead of many companies, especially in terms of innovation. It dominates technology in aviation and space. Boeing Company protects its rights of innovations with patent certificates. So, competitors try to develop their technologies by getting inspiration from Boeing's innovations. Boeing especially gives a considerable effort to protect its rights by means of reverse engineering. In this way, the innovations in the products it sells are protected even if they are disclosed by other producer. Boeing also earns financial earning by licensing its patents. When a company obtains a patent on an important technological innovation that has not been done before, it can sell it to other companies. Thus, it ensures the development of technological innovation and can earn license income. Boeing invests billions of dollars in R&D to maintain and further improve its market position. As a result of these investments, new innovations emerge and these innovations are patented. In addition, the inventors who made new inventions are also awarded. This awarding procedure people more enthusiastic to do more effort on new technologies.

Also educations are provided to encourage scientists and engineers to produce

innovations. Boeing also invests in more advanced technologies to anticipate their future business needs for example additive manufacturing and artificial intelligence in the area of technology that the number of patents increases. [21]

CHAPTER 2

METHOD OF PATENT DATABASE ANALYSIS

In this study, the last 10-year and last 5-year patents and patent applications was analyzed which are about carbon reinforced nanocomposites that are used to improve functional properties of composite and metal structural materials of aircrafts. This study focuses on improvements on electrical and thermal properties of structural parts as well as strength. Number of patents about electrical and thermal properties of structural parts are much higher than that of other properties. The information that obtained from patent applications, a method has been developed to determine today's innovations on carbon reinforced nanocomposites and related technologies. During the study lens.org, Espacenet, Google Patents and Derwent Innovation Tool were used to obtain the information about patent databases and patent analyses.

There is smart search, advanced search and classification search that can be use in patent databases according to the type of research. Smart search is a fast search type, which is useful for known patent number, assignee, inventor or a title. The representative parameters can be written on smart search box of Espacenet and Google Patents and then the related patents can be found while “lens.org” and Derwent Innovation Tool do not contain this type of search. The other search type is advanced search that a useful tool when you want to obtain wide information about a technological topic when you know keywords, classifications, time interval. All the databases contain this type of search. Classification search is useful for patent classifications of a known technological topic. The keywords are written in classification box and the useful classifications can be found. After this, classifications are chosen for searching the patents.

For a broader patent search, first of all the most appropriate and near keywords and their synonyms should be found and used in text fields of research. The keywords must be diversified by keeping inside the topic. Keywords can be found in full texts

or the literature which are about the topic. For a detailed search, "AND" should be put between different keywords and "OR" should be placed between synonymous keywords. Using classification in advanced search is useful for reaching more practical results. Words and classifications should be written separately in parentheses. Classifications are also useful for search. By writing the classifications in advanced search, more accurate results can be obtained. If the study has a date constraint, It can be also written in advanced search.

In this study, for composite aerospace parts 73 INPADOC (The International Patent Documentation Centre) patent families, for metal aerospace parts 60 INPADOC, totally 139 INPADOC patents and patent application families found by using the relevant keywords were examined and analyzed for last 10-year and for composite aerospace parts 44 INPADOC Patent families, for metals 38 INPADOC Patent families, totally 85 INPADOC patent and patent application families have been studied for last 5-year.

2.1. Choosing Classifications

In this study, in the patent databases, advanced search was used to search and analyze. But we also used classification search to found classifications. The classification search was done with Espacenet as seen in Figure 2.1. The keywords in Table 2.2 were used. These keywords are assigned as the best keywords to find better results. And also we used B82Y, C09D, and B64C classifications to obtain better results. Also date restriction was used for last 5 years and last 10 years as 01.01.2021-01.01.2016 and 01.01..2021-01.01.2011.

The data obtained from databases, classified and analyzed due to prior date, prior country, assignees. The date of the patents is important since the technological improvements are provided by time. And the countries also important to see which countries have more technological studies and infrastructure to develop this technological and scientific infrastructure. Assignees are important to indicate the role players and the competitiveness of the specific technological area.

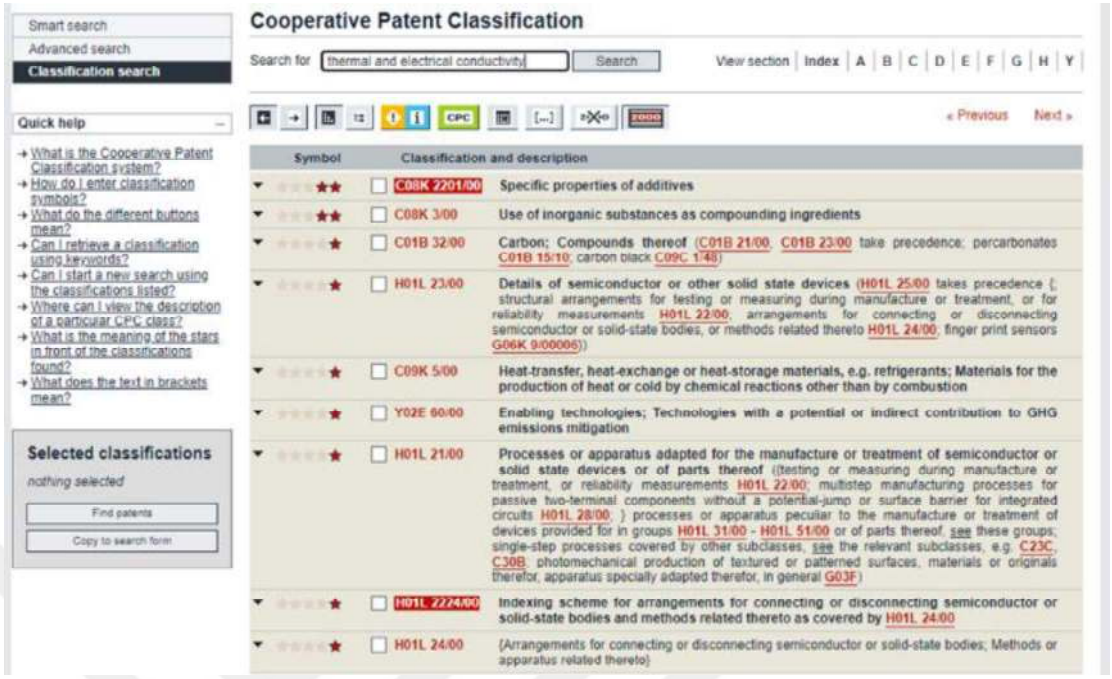

Figure 2.1. A classification search in Espacenet about topic

In the Table 2.1 the CPC (Cooperative Patent Classifications) are shown which is used in this study.

Table 2.1 Cooperative Patent Classifications of the Carbon Reinforced Nano-Composites That Used for Improving Electrical and Thermal Conductivity of Metal and Composite Surfaces of Aerospace

CPC	Description
B82Y30/00	Nanotechnology for materials or surface science, nanocomposites
C09D5/00	Anti-corrosive paints containing metal dust
C08J3/00	Process of treating or compounding macromolecular substances
B64C	Aircraft class
C01B32/00	Carbon compounds

2.2. Choosing Keywords

For more effective and accurate results, the search strategy can be divided in two parts as for composite structural materials and metal structural materials.

For polymer matrix composite materials:

ALL=((aircraft) OR (aerospace)) AND ALL=((carbon) OR (graphene) OR (cnt) OR (fullerene)) AND ALL=(composite structural part) AND ALL=((deicing) OR (emi shielding) OR (stealth) OR (lightning protect*)) AND ALL=(nanocomposite) AND ALL=(electrical conduct*) AND ALL=(thermal conduct*);

Keyword search is a good method to refine the search. In this search we have been focused to aerospace industry, so we have been used “aircraft” and “aerospace” to get the patents about the topic. And we have been used to “carbon”, “graphene”, “cnt” and “fullerene” which mostly used to improve thermal and electrical conductivities in composite sutructural aerospace parts due to literature search. So

we could get suitable documents. And we have been used the “composite structural part” because we have been focused to this parts due to search. Another keyword combination is that “deicing”, “emi shielding”, “stealth” and “lightning protect*”. These are the prior art applications that are mostly used with carbon reinforced nanocomposites in composite structural parts in aerospace industry according to patent search. To get a better results, these keywords must be used. Also “nanocomposite” keyword have been used because we have been focused to this type of materials and finally “electrical conduct*” and “thermal conduct*” have been used because they are in focus of this study.

For metal matrix composite materials:

ALL=((aircraft) OR (aerospace)) AND ALL=((carbon) OR (graphene) OR (cnt)) AND ALL=(metal AND part) AND ALL=(metal AND matrix AND nanocomposite) AND ALL=(electrical AND conductivity) AND ALL=(thermal AND conductivity) AND ALL=((deicing) OR (emi AND shielding) OR (lightning AND protection));

The both keywods have been chosen and have been optimised for eliminate accurate results in this study and to obtain most related patents, the search query can be refined due to literature search.

Table 2.2 Keywords that used in patent database analysis of patent database analysis for carbon reinforced nano-composites used as conductivity surfaces for aerospace industry

Aerospace	Aircraft, Aerial, Aerospace
Carbon	Carbon, graphene, graphite, fullerene, CNT, carbon black
Nanotechnology	Nanomaterial, nanocomposite, nanoscience, nanoparticle
Structural Elements	Composite surface, metallic surface, structure, surface
Conductivity	Thermal conductivity, electrical conductivity, conductor

CHAPTER 3

APPLICATIONS OF CARBON REINFORCED NANO COMPOSITE MATERIALS FOR AIRCRAFT INDUSTRY

In the aircraft industry, polymer matrix composites are generally used. Polymer matrix composite materials have relatively low conductivity because of existing polymer in the structure. But their electrical conductivity can be improved by addition of nano-sized carbons such as CNT (carbon nanotube) and graphene that have improved electrical conductivity.

Polymer matrix composite materials are used in aircraft industry because of their EMI shielding, radar absorbent and lightning protection ability. Some patented materials are described as following.

In some aircraft applications, there must be the electrical and thermal conductivity. Conductivity is a requirement for EMI shielding, ice protection systems, radar absorbent application, some avionics systems applications and thermal applications. There are some sample patents regarding for these purposes.

3.1. Patents of Applied Nanostructured Solutions LLC

3.1.1. CNT-Reinforced Resistive Heating for Deicing Composite Structures

US8664573B2 numbered and “CNT-reinforced resistive heating for deicing composite structures” titled, the assignee of “Applied Nanostructured Solutions LLC” and the priority date of 2009-04-27 patent is about composite materials modified with carbon nanotubes. Composite material mentioned above includes a matrix material and a fiber material. This fiber material contains a large number of carbon nanotubes (CNTs) infused onto it. The composite material can conduct heat and electricity thanks to the conductive carbon particles inside.

The icing problem is critical in aviation. It may cause damage to important parts of the aircraft and deteriorate aerodynamic surfaces as seen in Figure 3.1. Composite materials, which are effective and light materials, have been used to get rid of icing problem. Such Composite materials used in aviation for icing protection and other purposes are mostly insulators. However, by adding conductive reinforcement to composites, they can become a conductive material. Deicing material should be conductor, because deicing mechanism is provided with electrical heating. In this invention, deicing composite material is heated with electrical energy. The CNT-infused fiber composite is a composite material that is itself a resistance heating element. CNT-grafted fiber composite can use any fiber substrate, including, for example, carbon, glass, alumina, silicon carbide, or Kevlar. The composite material of the invention can be used in a structure that is part of an aircraft wing, part of a helicopter wing, part of an aircraft engine drive wing. Structures with moving parts with surface sensitive properties in cold weather environments can also use the composites of the present invention.

For the production of above mentioned material, carbon nanotubes can generally be grown in-situ on the outer surface of the fiber. The glass fiber is placed in the growth chamber then gas containing carbon at a temperature between 500 ° to 750 ° C on the fiber is sent to the growth chamber. Carbon radicals decompose in the chamber and initiate the formation of carbon nanotubes on the fiber in the presence of catalyst nanoparticles. In another alternative method of the invention, CNT-impregnated fibers are placed in a resin bath. In another alternative method, a fabric can be woven from CNT-impregnated fibers and the fabric is placed in a resin bath. The resin bath contains resin for the production of composite material containing CNT-infused fibers and matrix. This material is adapted as structural materials for an aircraft which the body carries a portion of a load induced by flight of the aircraft. The usage of this material is a CNT-infused fiber material; and a first electrode and a second electrode that are electrically coupled to the portion of the body that comprises the CNT-infused fiber material, wherein application of an electric current through the first and second electrodes and the intervening CNT-infused fiber

material. After this, CNT-infused fiber material generates heat within the CNT-infused fiber material, thereby heating the body of the composite structure, thereby deicing or preventing ice formation on a surface of the composite structure. The mentioned material creates an electric current when 1 to 24 Volts are applied.

In the prior art of this document, US6194685B1 numbered and “De-ice and anti-ice system and method for aircraft surfaces” titled and the priority date of 1997-09-22 patent is about a thermal de-icing and anti-icing system is mentioned for aircraft surfaces. Graphite-layered sheets of insulating inner and outer conductive foils are used in the structural parts of the aircraft. The graphite layer in the middle of the plate generates heat electrically by electrothermal method. Nanocomposite is not used here. Larger size graphite is used. CNT is a more efficient material than graphite. In the system, the conductor layer has a thermal conductivity of 0.5 W/mK to about 4 W/mK.

In the other cited US10863586B2 numbered and “Electrical conductive resin matrix for CNT heater” titled and priority date of 2016-12-20 patent is about a heater containing carbon nanotubes has been mentioned. Heater is obtained by combining a conductive resin matrix with a carbon nanotube fiber matrix. Unlike the previous technique, this material contains particle filling material. In addition, conductive polymer is used to prevent CNT particles from interrupting the transmission. In this material, both the matrix material and the reinforcement material are conductive. In this patent, similar or equal performance is obtained but different methods have emerged to avoid patent infringement.

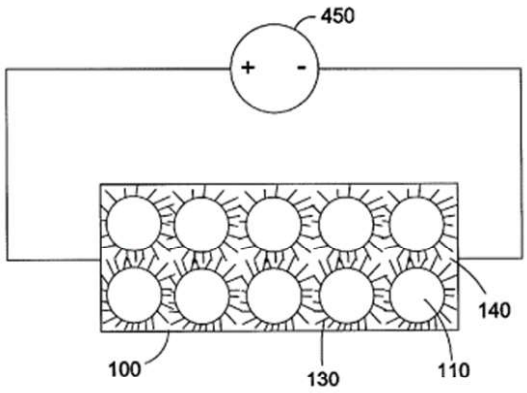

Figure 3.1 Figure of the US8664573B2 number patent. According to invention the electrical current that comes from the voltage source (450) is passing through the composite material (100) that contain fiber (130) on material (110).

3.1.2. CNT-Infused Fiber As A Self-Shielding Wire For Enhanced Power Transmission Line

Another sample is US9167736B2 number, assignee of "Applied Nanostructured Solutions LLC" and title of patent is "CNT-infused fiber as a self-shielding wire for enhanced power transmission line". The priority date of this patent is 2010-01-15. This patent is about a carbon nanotube infused fiber that used for power transmission systems of structural parts of aerial vehicles. The wire has a structure that provides electromagnetic shielding. The carbon nanotubes can be grafted by aligning parallel, radial or perpendicular to the fiber axes. In the grafted wire, the carbon nanotube length should be uniform in all regions as seen in Figure 3.2. To manufacture this wire, the fiber material is taken into the carbon nanotube growth chamber. Growth is controlled in this room. Carbon nanotube length can be controlled through modulation of the carbon feedstock and carrier gas flow rates and reaction temperature. Additional control of CNT properties can be achieved, for example, by controlling the size of the catalyst used to prepare the CNTs. 1 nm transition metal nanoparticle catalysts can be used to specifically provide SWNTs during manufacture. Larger catalysts can be used to prepare predominantly MWNTs. The barrier coating is formed on the fiber by curing. In this way, a catalyst is formed in the barrier coating. Carbon nanotubes are formed on the barrier coating. for catalyst

deposition. Then, carbon nanotubes are oriented according to the catalyst structure. The chemical vapor deposition (CVD) process for carbon nanotube synthesis takes place at high temperatures. The specific temperature is a function of catalyst selection, but will typically be in the range of about 500 to 1000°C. The CVD process is carried out with a carbon-containing feedstock gas such as acetylene, ethylene and/or ethanol. Carbon nanotube synthesis uses an inert gas (nitrogen, argon, helium) as the primary carrier gas. The carbon feedstock is provided in the range of about 0% to about 15% of the total mix. During production of the wire, a carbon nanotube (CNT)-infused fiber core comprising a plurality of CNT-infused fibers arranged in a composite matrix carries a film of thermo-plastic material formed onto an outermost layer of the CNT-infused fiber core. The film surrounds the CNT-infused fiber core, wherein for at least one of the plurality of CNT-infused fibers of the CNT-infused fiber core and each CNT of the respective plurality of CNTs and the respective composite fiber material are in contact with the composite matrix. Advantage of this material is provide an effective electrical or thermal conductivity for composite material.

In the prior art of this document, US6225565B1 numbered and “Flexible cable providing EMI shielding” titled, the priority date of 1999-06-07, patent is about a flexible electromagnetic shielding cable that a conductive material has high magnetic permeability. The material consists of a plurality of separate conductor cable subassemblies. Conductive cables include a metallic conductor, an insulating sheath around the conductor, and a Faraday shield sheath made of elastomeric conductive matrix coupler placed around the insulating sheath. In this prior art, the EMI Shielding cable is produced by elastomer- metal wire composite. But the mentioned material in US9167736B2, the EMI Shielding material produced by CNT infused composite wire, so it will be effective and lightweight than the prior art. In this patent, similar or equal performance is obtained but different methods have emerged to avoid patent infringement.

In the citing of this document, US10177471B2 numbered and “Composite and nanowire conduit” titled patent is about electrical wiring system. The priority date of

this patent is 2014-11-14. The system includes an electrical channel, a plurality of electrically conductive nanowires, and a carrier that wraps and electrically insulates the wires from each other. Nanowires are composed of carbon nanotubes. The nanowires in the system are held together in a single direction and in a rigid matrix material such as resin. In this way, conductivity is provided. Unlike the aforementioned document, this material consists only of CNT and resin. In this patent, similar or equal performance is obtained but different methods have emerged to avoid patent infringement.

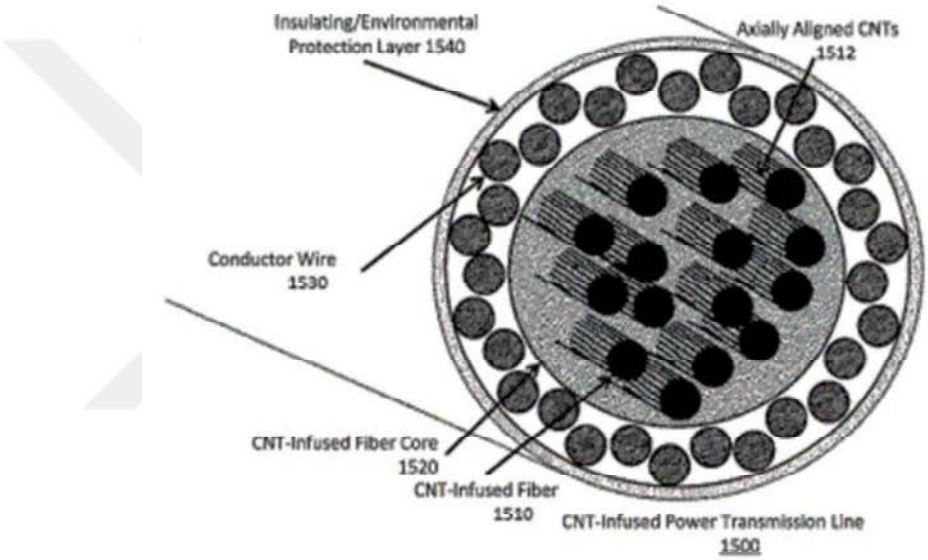

Figure 3.2 Figure of the US9167736B2 number patent. Axially aligned CNT's (1512) is used to direct power transmission of the system**.**

3.2. Patents of Global Graphene Group Inc

3.2.1. Highly Conductive Graphene Foams and Process For Producing Same

There another sample is number as "US10748672B2", the assignee is "Global Graphene Group Inc" and title of the patent "Highly conductive graphene foams and process for producing same" about a porous graphene material production method. This patent has a priority date 2014-07-17. This material is also referred as

“graphene foam”. The invention mentioned in the patent describes a solid graphene foam composed of multiple pores and pore walls. The pore walls are composed of pure graphene or graphene oxide, reduced graphene oxide, graphene fluoride, graphene chloride, graphene bromide, graphene iodide, hydrogenated graphene, nitrogenous graphene, chemically functionalized graphene and combinations thereof. The pore walls contain stacked graphene planes with an interplanetary spacing of 0.3354 nm to 0.36 nm as measured by X-ray diffraction. The mentioned material has a thermal conductivity of at least 250 W/mK per unit of specific gravity, and/or an electrical conductivity no less than 2,500 S/cm per unit of specific gravity. A number of processes are required to prepare graphene foam. First, the graphene material is selected from pure graphene, graphene oxide, reduced graphene oxide, graphene fluoride, graphene chloride, graphene bromide, graphene iodide, hydrogenated graphene, nitrogenous. The selected graphene material is dispersed in a liquid medium. In this way, a graphene dispersion is prepared. Graphene is chemically functionalized in this dispersion as seen in Figure 3.3. The graphene dispersion is deposited on the surface of a substrate such as plastic film, rubber sheet, metal foil, glass sheet, paper sheet to form a graphene layer. When forming the graphene layer on the substrate, volatile gas molecules are induced from non-carbon elements at a first heat treatment temperature of 100°C to 3,200°C. The subsequent high temperature process creates volatile gas species that produce pores or cells in the solid graphene material structure, allowing the majority of these non-carbon elements to be removed from the graphene material. Non-carbon metal elements act as blowing agents, creating pores in graphene. This material is used for increase the thermal conductivity of surfaces of aerospace to reduce ice formation.

The prior art of this document is numbered as “US20110189452A1” and the titled as “Cross-linked Graphene and Graphite Oxide”. This document has a priority date 2009-07-31. This document is about cross-linked graphene sheets and/or conductive polymer material containing graphite oxide. The compositions can be made by crosslinking graphene sheets and/or coatings containing graphite oxide. Graphene sheets are made of graphite oxide. Graphite structure is produced by exfoliation

method or oxidation. Graphene layers can be formed by ultrasonically exfoliating suspensions of graphite and/or graphite oxide (which may contain surfactants and/or interstitials) in a liquid. Exfoliated graphite oxide dispersions or suspensions can then be reduced to graphene sheets. The compositions can have a thermal conductivity of about 0.1 to about 50 W/mK, or of about 0.5 to about 30 W/mK , or of about 1 to about 30 W/mK , or of about 1 to about 20 W/mK , or of about 1 to about 10 W/mK , or of about 1 to about 5 W/mK , or of about 2 to about 25 W/mK , or of about 5 to about 25 W/mK .

The citing document is numbered as “US9742001B2” and titled as “Graphene foam-protected anode active materials for lithium batteries” has a priority date 2014-08-07. This patent is about the production method of anode layer containing graphene foam protected anode active material used for lithium batteries. The aforementioned material can also be used in applications such as icing. For fabrication of the material, a solid graphene foam is formed consisting of multiple particles of the anode active material and multiple pores and pore walls. These pores have a pore size of 2 nm to 10 μm. The pore walls comprise a pure graphene material having less than 0.01% by weight non-carbon elements or an impure graphene material having 0.01 to 5% by weight non-carbon elements. This material have a thermal conductivity of at least 100 W/mK per unit of specific gravity, or an electrical conductivity no less than 1,000 S/cm per unit of specific gravity.

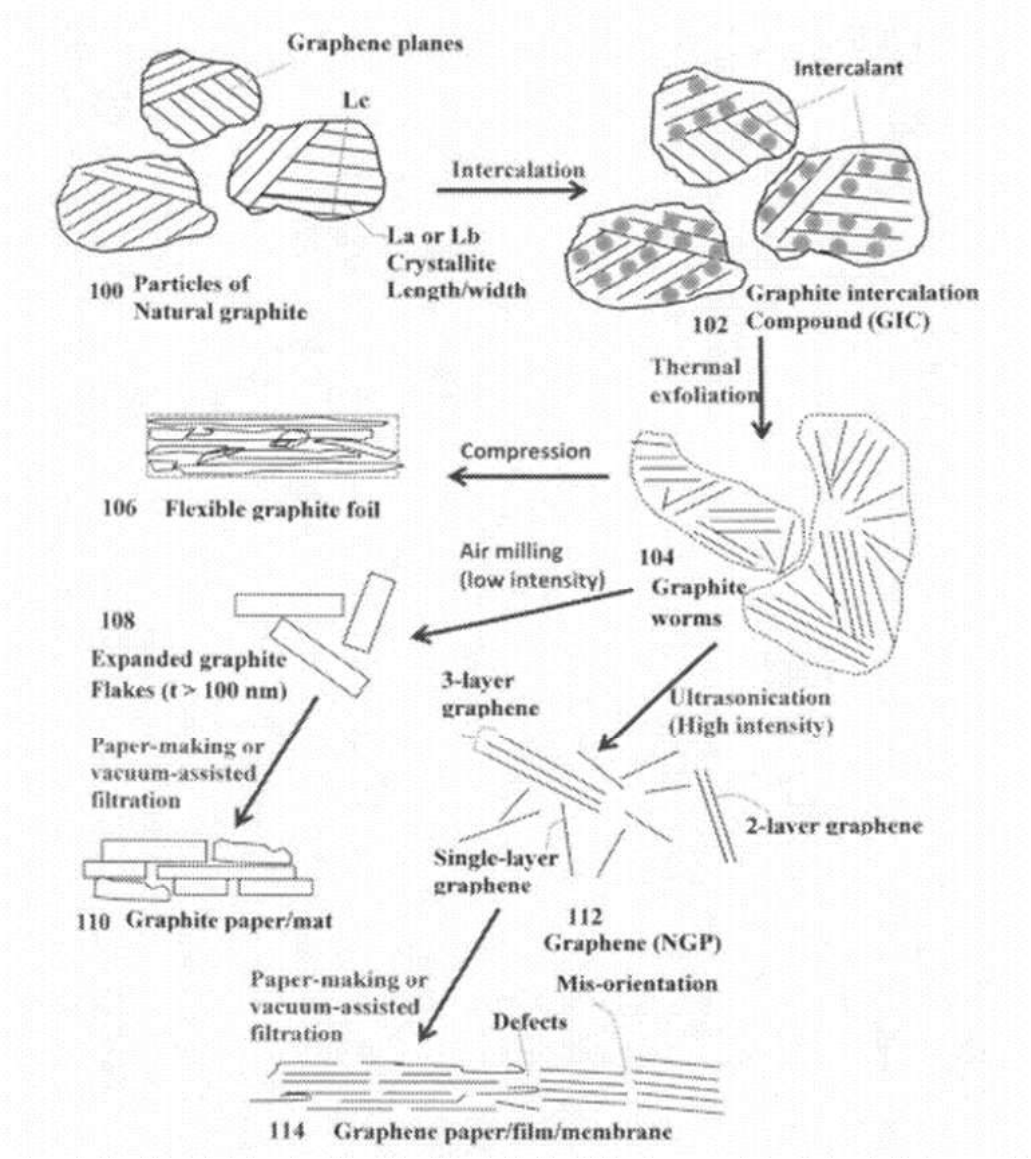

Figure 3.3 Figure of the US10748672B2 number patent. Graphene paper / film / membrane (114) production process is shown.

3.2.2. Metal Matrix Nanocomposite Containing Oriented Graphene Sheets And Production Process

Another patent application document, that is the number of US20190292671A1, the title of “Metal matrix nanocomposite containing oriented graphene sheets and production process” and the applicant of “Global Graphene Group Inc” is about a metal matrix nanocomposite containing highly oriented graphene sheets and a

process for that material to increase electrical and thermal conductivity on a metallic structural surface and to increase mechanical strength. This patent has a priority date 2018-03-26. In the prior art of this patent application, graphene particles are produced with expanding, exfoliation and intercalation of the graphene oxide. In this invention, there are various metals can be used as metal matrix such as high conductivity metals (gold, copper, silver), titanium, platinium, zinc cobalt etc and their allyos. Especially this method can be used in structural parts of the aerospace vehicle. In the matrix material, the graphene sheets as reinforcement materials are aligned in parallel having an average space of between 1 nm to 300 nm and completely dispersed in the structure as seen in Figure 3.4. The graphene material can be graphene oxide, graphene florude, graphene chloride, graphene bromide, graphene iodide, hydrogenated graphene, nitrogenated graphene, doped graphene, chemically functionalized graphene in the amount of %10 to %95 by volume. During processing of this material, the graphene solution is prepared as dispersed in a liquid adhesive resin. In the solution, graphene particles are brought into physical contact with a solid substrate surface. The graphene sheets begin to align on the solid surface which are supported and attached. Metal matrix is coated onto the aligned graphene sheets to form a thin layer of metal or metal alloy with a thickness of 0.5 nm to 10 μm. After the consolidation, the layer of metal coated graphene sheets are separated from the substrate surface. This method can be used to increase the thermal and electrical conductivity of metal aerospace vehicle parts.

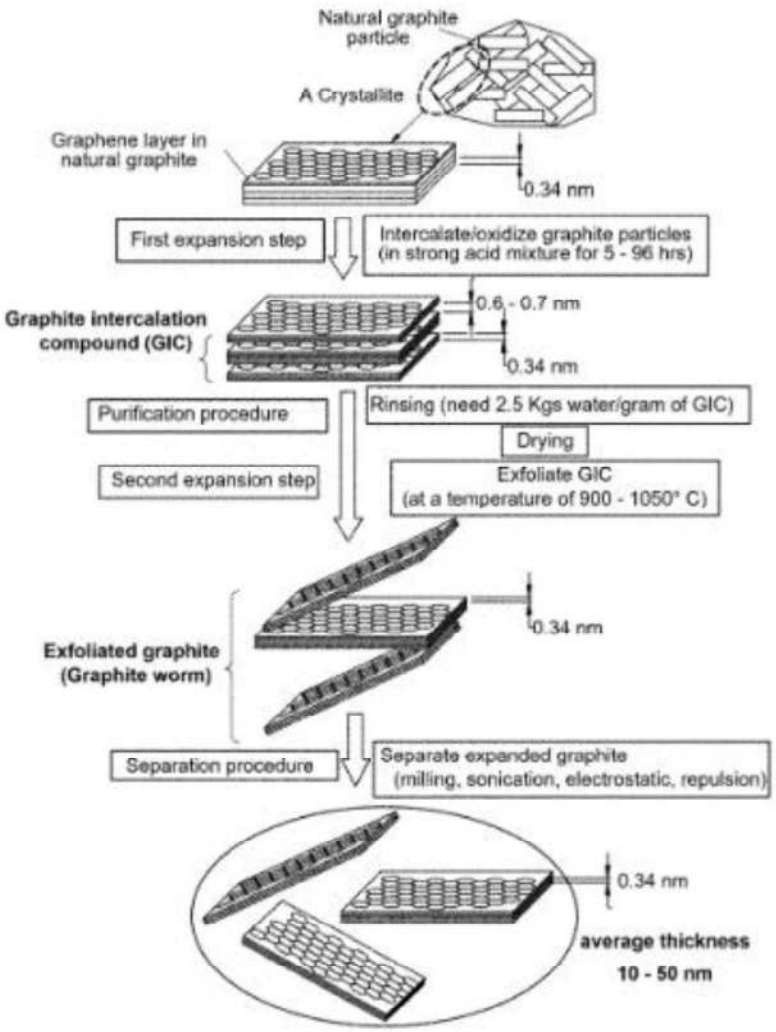

Figure 3.4 A production method of metal matrix nanocomposite. Graphene particles are aligned parallel in the metal matrix material to increase electrical and thermal conductivity of metal parts.

3.3. Patents of Some Universities and Intuitions

3.3.1. Hydrophobic Surface Coating Systems and Methods For Metals

Another example is the patent that number of "US9670060B2" and the title of "Hydrophobic surface coating systems and methods for metals" and the assignee of "University of Akron" is about a metallic surface production method that hydrophobic or superhydrophobic surface. This document has a priority date 2008-

11-14. This surface type has a metallic substrate having a CNT or carbon fibers configuration that have a hierarchical structure formed to have a good hydrophobic structure. Also this surface is easily cleaned and prevents from ice formation. In the method according to invention, metal part used for micro patterning on at least one surface that pattern contain peaks, valleys and similar topological different shapes. These peaks, valleys and similar topological different shapes can be imaged with etching or acid treatment of the surface. This is a nanoscopic architecture on the surface. After this imaging, the CNT structure is grown on surface with CVD with existence of catalyst and a controlled temperature. After the production, surface can be hydrophobic and electrically and thermally conductor. This material especially used for ice production preventing of critical parts of aircrafts such as nose, fuselage, wings and control surfaces as seen in Figure 3.5. The document claims the producing of this material.

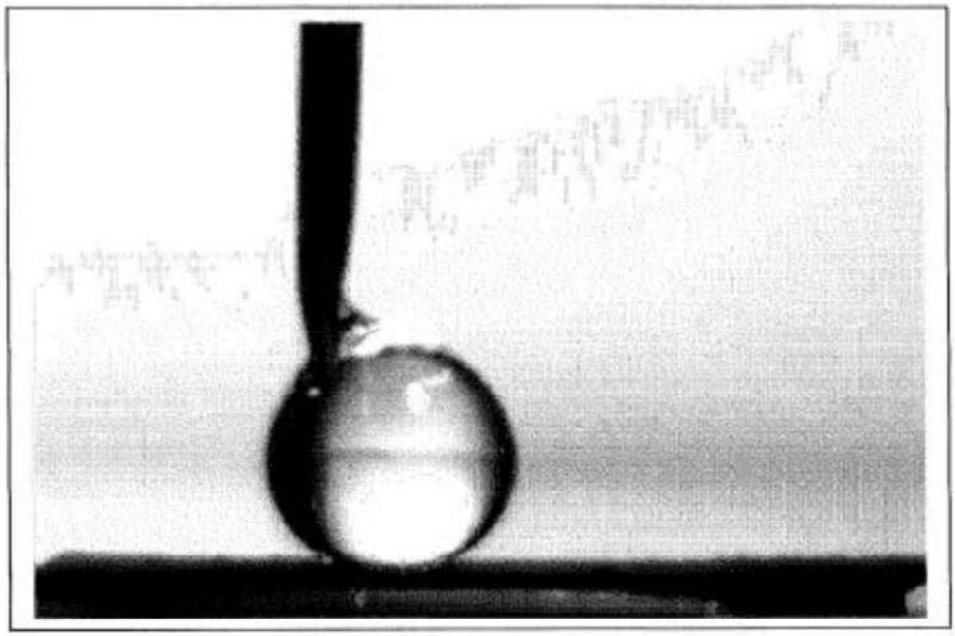

Figure 3.5 The figure of the mentioned hydrophobic material surface.

3.3.2. Graphene Nanoribbon Layers for De-Icing and Anti-Icing Applications

The another example of the patent application number of “WO2016081690A1”, the

applicant is “William Marsh Rice University” and the title of “Graphene nanoribbon layers for de-icing and anti-icing applications” is about production a surface that comprise graphene nanoribbon contain to prevent ice formation. This patent has a priority date 2014-11-19. The graphene nanoribbons contained layer includes a network of graphene nanoribbons that occur an electrical pathway. This layer repels the water from the surface. According to different embodiments of the invention that, the ice formation can be reduced by repulse the water from surface or melting the ice with termo-electrical functions or electro-magnetic field heating of the surface. On the surface layer, there are conductive path can be passed. When the voltage is applied the surface will be heated. The conductive surface can be succeeded by processing capillary CNT on to the surface as seen in Figure 3.6. This method is useful for aircrafts and rotorcrafts. The document claims that the method for ice formation preventing comprises graphene nanoribbon layer composition forming on any metal surfaces. This method can be beneficial for increasing surface electrical and thermal conductivity of the surfaces.

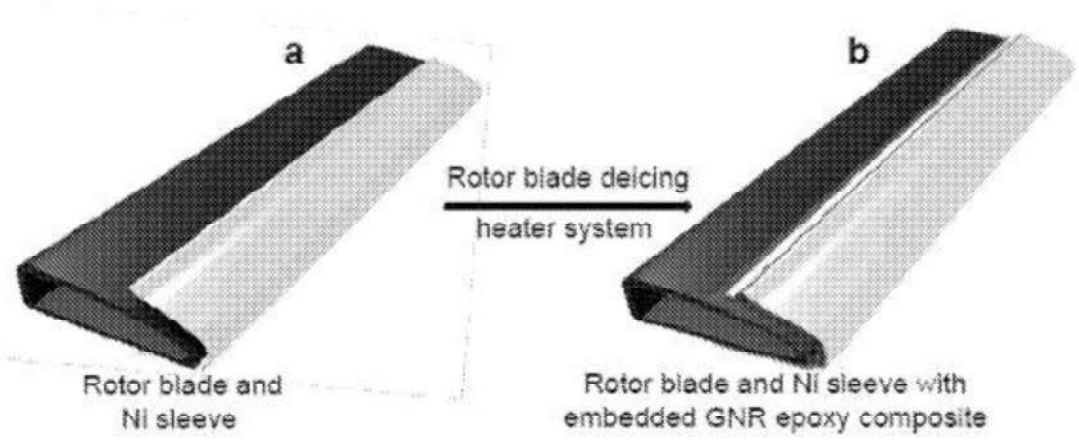

Figure 3.6 The de-icing nanoribbon coating on Ni sieeve of the rotor of the helicopter.

According to another patent application document that number of WO2020043590A1, and the title of “Metal-cnt composite, production method and materials therefor” and the applicant of “Luxembourg Institute Of Science And Technology” is about production method for metal matrix nanocomposites that

include CNT particles that can be used as lightning protector aerospace vehicle structural metal parts which have a high resistance to high current density that can withstand high current and voltage values without any damage. This patent has a priority date 2018-08-27. These type of materials are vital critically because lightnings can cause fatal damages on the aircrafts. But according to prior arts of this applications, the metal-CNT nanocpomposite production methods can be costly and hard. This method can be a beneficial manufacturing for metal-CNT nanocomposites. According to the invention, a method for producing a metal-CNT composite material is described as seen in Figure 3.7. In this method CNT particles are coated with polyphenol or poly (catecholamine) to provide a CNT layer by depositing it on a substrate, then, the cavities in the CNT layer are filled with electro-precipitation or nonelectric precipitation to create a metal matrix in which the CNT particles are embedded. In this method, the use of polyphenol or poly (catecholamine) coated CNT particles is mentioned instead of CNT particles alone. These coatings can form metal-organic complexes through chelation and / or crosslinking with metal ions. During crosslinking, CNT layer can be tangled that can be three dimensional clusters. Coated CNT particles can be provided in a suspension, and deposition of CNT particles is achieved by spraying the suspension onto a substrate and evaporating the dispersion medium. Polyphenol or poly (catecholamine) coatings of CNT particles contain metal particles to allow adhesion and / or growth of the metal matrix during the filling steps. Metal particles contain metal ions crosslinking polyphenol or poly (catecholamine). The presence of metal seeds leads to a more uniform filling of the CNT layer with metal and improves the interface between the metal phase and the CNT. This is expected to improve the thermal and electrical conductivity of the composite material.

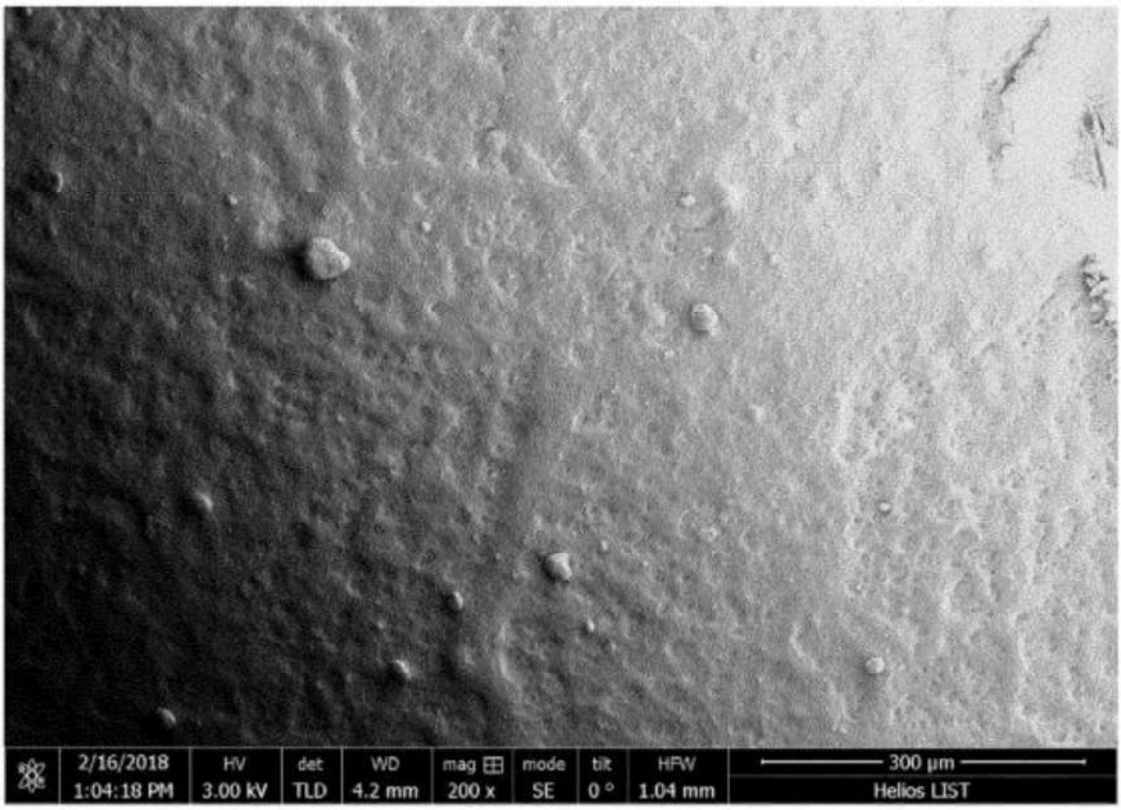

Figure 3.7 SEM image of a layer of metal-seeded pda-coated CNT obtained by

3.4. Patents of Other Firms

3.4.1. Aircraft Ice Protection System and Method

Another sample about this topic is that “US9193466B2” number, the assignees are “MRA Systems LLC” and “Kelly Aerospace Thermal Systems LLC and “Aircraft ice protection system and method” title patent is about anti-icing and de-icing systems for aircraft engine surfaces. This document has a priority date 2012-07-13. In this patent the said system for ice protection of a component, wherein the system is adapted to be adhesively bonded to a surface of the component as seen in Figure 3.8. The system comprising heating element layer, at least one thermally conductive adhesive layer that adhesively bonds a first side of the heating element layer to the component, an insulation layer, at least one thermally insulating adhesive layer that adhesively bonds a second side of the heating element to the insulation layer, an

electrical bus bar adapted to provide a connection between a power supply and the heating element layer and at least one temperature sensor incorporated into the system. This system can be useful for engine ice protection.

The prior art of this document is numbered as “US7291815B2” and the titled as “Composite ice protection heater and method of producing same”. This document has a priority date 2006-02-24. The assignees of this document are Goodrich Corp and Rohr Inc. which are important airplane vehicle engine producers. The invention in this document is especially related to the composite deicing production system that prevents ice formation in critical areas of the engine. In particular, icing in the nacelle area of the aircraft engine causes serious damage to the aircraft. In order to prevent this, an icing system was also needed in the composite structure. In the mentioned method, a conductive layer is placed between the first and second electrically insulating layers. The electrically conductive layer consists of a woven graphite fabric in fiber form. The graphite fiber threads in the fabric are attached end-to-end so that they are in electrical contact with each other. Graphite yarns start to heat up with the electricity supplied to the fabric. The ice formed around the composite material melts. Nano-technological methods are not used in this document. In this patent, similar or equal performance is obtained but different methods have emerged to avoid patent infringement. Later issued patent has difference from the previous issued one by means of production method.

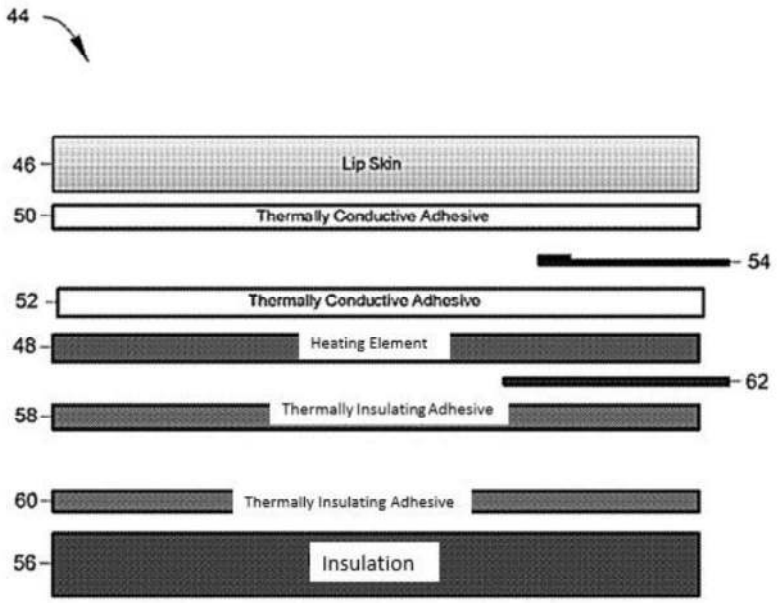

Figure 3.8 Figure of the US9193466B2 number patent. Cross-section of a heating element architecture of an ice protection system (44) is shown. Between lip skin (46) and insulation (56) layers, adhesive layers (50, 52, 58,60), thermal sensor (54) and electrical bus bar (62) are placed.

3.4.2. Multi-Functional Composite Structures

The another patent that number of "US10167550B2" and title of "Multi-functional composite structures" and the assignee of "Aurora Flight Sciences Corp." is about a structural composite material that contain matrix layer, fiber layer, connector, conductor assembly and insulator layers as seen in Figure 3.9. This document has a priority date 2014-06-03. This invention is advantageous for especially structural wiring systems of aircraft. CNT conductors are used between the insulators. This material can be used for as structural durable material and a structural conductor for general structural wiring systems of the aircraft. The material also called as "conductor sandwich assembly" so one or more conductors exist between the layers. The embedded conductor system is a carrier for signals and electricity. The embedded conductor material has advantageous for designing a light weight aircraft and increase the beneficial space in the aircraft with buried conductors in a rigid composite material. This document claims that multi-functional composite material

comprising that a material is useful for carrying structural load and a structural conductor as contain a wiring system. Fiber layer contain conductor material and this layer contact with electrical systems and carry their electrical signals between the systems.

The prior art of this document is numbered as “US20130319727A1” and the titled as “Apparatus and method for an aircraft conductor sandwich assembly embedded to an aircraft structure”. This document has a priority date 2012-05-29. The assignee of this document is Aurora Flight Sciences Corp. This patent application document is about a sandwich structure with deicing heater embedded in aircraft structural part. The conductive sandwich structure includes a plurality of carbon conductors sandwiched between two layers of insulating layers and a plurality of carbon conductors and connectors connecting the two sheets of insulating layers. In this patent, similar or equal performance is obtained but different methods have emerged to avoid patent infringement. Later issued patent has difference from the previous issued one by means of production method.

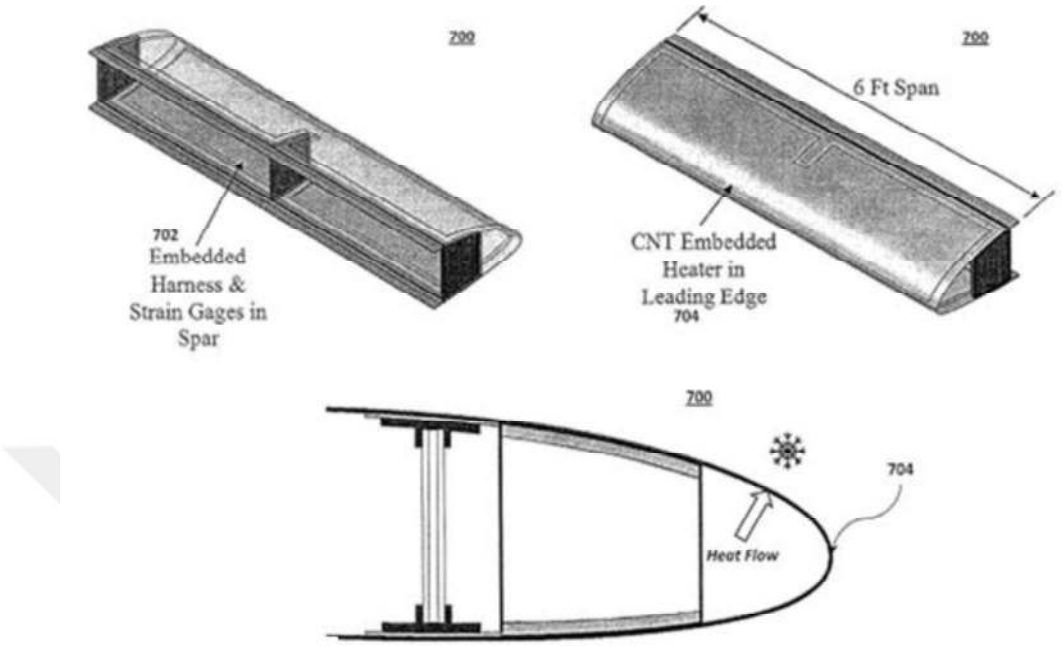

Figure 3.9 The composite material in span that is used as a conductor for the aircraft electrical systems such as ice protection system.

3.4.3. Conductive Composite Structure or Laminate

The another patent number "EP2758234B1" and title of "Conductive composite structure or laminate" and the assignee of "Hexcel Composites Ltd" is about a conductive layer production method. This Document has a priority date 2011-09-23. The fibrous layer in the material consists of a lightweight, non-woven fibrous material with a weight in the range of 1 to 20 g / m^2. The fibrous layer contains polyamide resin. The fibers are dispersed in a certain order in the polyamide matrix as seen in Figure 3.10.

The supporting layer preventing distortion of the conductive layer environmental factors. The fiber reinforcement layer is made from light weight nonwoven fiber that a density of 1 to 100 g/m^2 or 1 to 50 g/m^2 or 1 to 20 g/m^2. The fiber reinforcement

layer shows a better surface property during curing of whole composite material and can be melt to adhere to conductive layer. Conductive layer is a metal, carbon nanotube, graphite which connects the electrical systems such as lighting strike protection (LSP) and electromagnetic interference (EMI) shielding on the structural part of an aircraft. The support layer comprising a flexible polymer sheet, wherein the structure forms a strip, the strip having a rectangular cross-section. To produce this body, hand-lay up or resin transfer molding can be used.

The prior art of this document is numbered as “US5370921A” and the titled as “Lightning strike composite and process”. This document has a priority date 1991-07-11. This document is about a lightning protection system that used in aircraft vehicle. The system includes a prepreg layer, conductive metal wire, film or foil layer, and a composite layer made of thermoset material. Nanotechnology is not used in the aforementioned material. In the old technique, the lightning protection system was provided with metal mesh or foils. In this patent, similar or equal performance is obtained but different methods have emerged to avoid patent infringement. Later issued patent has difference from the previous issued one by means of production method.

Figure 3.10 The section view of the composite material (1). The material contains supporting material (12), conductive layer (14) and fibrous layer (16).

3.4.4. Thin Metal Coating Methods for High Conductivity Graphane-Metal Composites and Methods of Manufacture

Another patent application number “US20180100233A1” and title of “Thin metal coating methods for high conductivity graphane-metal composites and methods of manufacture” and the assignee of “Fourte' International Sdn. Bhd.” is about a graphene-metal composite that are a porous metal foam substrate which is graphene layer deposited on it as seen in Figure 3.11. This patent has a priority date 2015-11-20. To obtain this material, a metal layer is deposited on the graphene layer, after this the following graphene layer deposited to the first metal layer. The multilayered porous metal foam material is compressed to form a graphane-metal composite, and depositing a thin metal coating on the surface of the porous metal foam substrate or an outer surface of the graphane deposited with PVD or CVD. This technology increases the electrical and thermal conductivity of metals. Especially compression of metal-graphene composite is useful for this applications. The method can be especially used in EMI shielding, de-icing and lightning protection systems on aircraft surface.

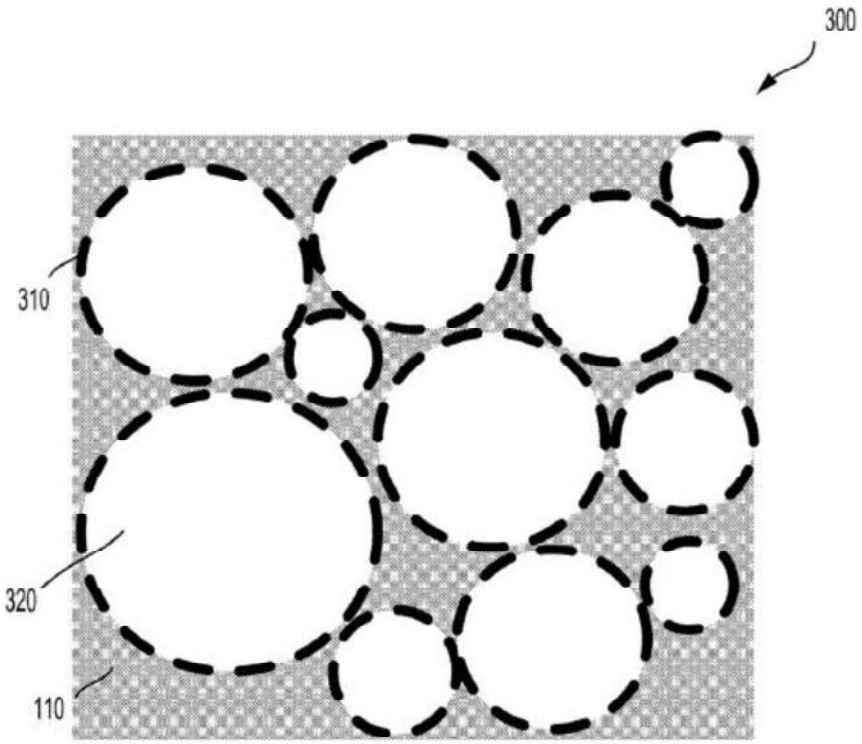

Figure 3.11 The section view of metal foam (300) that include graphene layer (310), metal matrix (110) and voids (320).

3.4.5. Functionally Graded Metal Matrix Nanocomposites, and Methods for Producing the Same

According to another patent application that number of US20200399739A1, tittle of "Functionally graded metal matrix nanocomposites, and methods for producing the same" and the applicant of "HRL Laboratories LLC" is about a production method of a metal nanocomposite material is seen in Figure 3.12. This patent has a priority date 2016-11-16. During the production of nanoparticle doped metal matrix nanocomposite, the dispersion of the particles dispersed in the metal melt, the amount of wetting and surface properties affect the general properties of the final material. The aim of this invention is to increase the conductivity and strength properties of the final material by improving the production technique. In the invention Al, Mg, Ni, Fe, Cu, Ti, V, Si metallic can be used as metal matrix so this invention can be used in aerospace structural parts. During the production of the

material, metal-containing micro particles and nanoparticles are integrated where the nanoparticles chemically and / or physically integrate with the metal surfaces. The metal particles and nanoparticles of the lead compound are then consolidated into an intermediate composition in a three-dimensional architecture throughout the intermediate composition by pressing, binding, sintering, or a combination thereof. After consolidation, the material is used to transform the intermediate compound into a metal nanocomposite by pressing, sintering, mixing, dispersing, friction stir welding, extrusion, binding, melting, semi-solid melting, capacitive discharge sintering, casting, or a combination thereof. According to invention there are another variation of method as nanoparticles are chemically and / or physically placed on the surfaces of powder micro particles containing metal. Then, the lead compound into an ingot-size intermediate composition containing metal micro particles and nanoparticles into a three-dimensional architecture are consolidated, melting the intermediate compound, wherein the molten metal is separated into a first phase containing micro particles and a second phase containing nanoparticles and solidifying the melt to obtain a metal matrix nanocomposite having a concentration of nanoparticles of at least one size at the concentration of nanoparticles. By this invention, a high conductive and strength aerospace structural parts can be produced that used for deicing, lightning protection or EMI shielding.

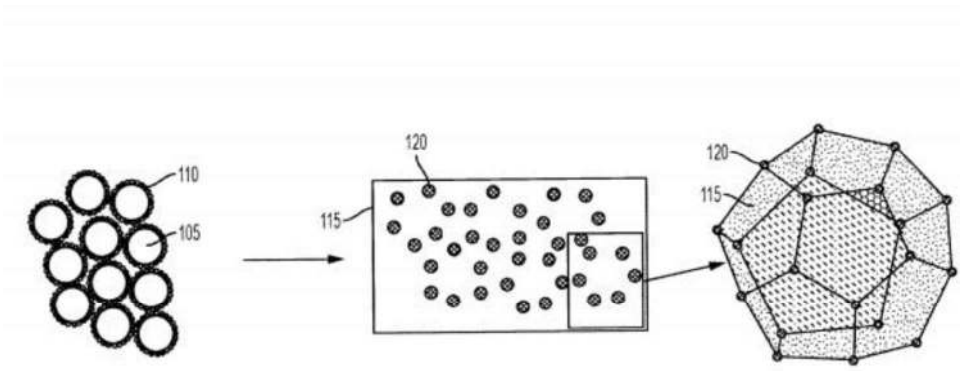

Figure 3.12 Functionalized powder containing metal microparticles coated with nanoparticles is converted to an ingot (or other material) with the nanoparticles oriented in a three-dimensional structure.

3.5. Technological Evolution of Electrically and Thermally Conductive Aircraft Applications

As can be seen in the applications mentioned on Chapter 3, the use of nanocomposites in aviation applications has become widespread, especially in the last 10 years. In particular, effective solutions have been applied to lightning strike, EMI shielding and deicing problems.

In the prior art, systems such as heater placement and cabling have been used as larger and higher weight solutions, especially in ice protection functions. According to patent documents, graphene and CNT reinforced nanocomposites have been improved and employed for ice protection systems for last decade. In this way, benefits are obtained by providing more effective heating with less electrical energy as well as less weight and preventing the formation of corrosion. Icing is a fatal and dangerous problem for aircrafts, but carbon reinforced nanocomposites offer good solutions for this problem.

Superhydrophobic surfaces can be obtained by graphene reinforced composite surfaces and this material can also be a solution for ice production on critical parts. The use of Superhydrophobic surfaces has been seen also in last decade. These applications are given Table 4.1.

Electromagnetic interference shielding and radar absorption were being used by using the Faraday cage method. In this method, heavier metal structures, coils and cables were used in structural parts. Graphene or CNT reinforced structural surfaces have been used for electromagnetic interference shielding and radar absorption. They also protect the structural parts from metal corrosion. Carbon reinforced nanocomposite paints are also used for Electromagnetic interference shielding.

Aircrafts were being protected from lightning strike by mesh structures, foils and cables. These mesh structures, foils and cables were weak by means of corrosion of structural parts of the aircraft. For a lighter and more effective solution, graphene and CNT reinforced nanocomposites have been introduced into the application area of structural parts of aircraft. Carbon reinforced nanocomposites such as graphene or CNT reinforced nanocomposites also have better conductivity than metal mesh so they conduct lightning strike voltage faster than metal mesh and cables as given in Table 4.1.

In addition, easier and lower cost production methods have been employed by using methods such as Chemical Vapor Deposition and Physical Vapor Deposition instead of exfoliation as a production method.

Table 4.1: Differences between novelty and previous applications of Technologies of carbon breinforced nano-composites used as conductive surfaces for aerospace industry.

Patent Number and Title	Prior Art	Novelty
US8664573B2: CNT-based resistive heating for deicing composite structures	Large size graphite layer sheets or foils, thermo heaters,	Lighter and smaller graphene reinforced nanocompoistes, lower electricity, better deicing performance
US9167736B2: CNT-infused fiber as a self-shielding wire for enhanced power transmission line	Faraday cage-like structures was used for EMI shielding.	Aligned, paralel carbon nanotube infused structures that desired electrical conductivity and EM absorbance.
US10748672B2: Highly conductive graphene foams and process for producing	Cross linked graphene oxide reinforcad material has thermal conductivity	High conductive graphene foam composite materiak has thermal conductivity at least 250

same	between 0.5-50 W/mk.	W/mk.
US20190292671A1: Metal matrix nanocomposite containing oriented graphene sheets and production process	The use of metals that are not resistant to corrosion and wear	Metal matrix composites are used for better corrosion and wear resistance.
US9670060B2: Hydrophobic surface coating systems and methods for metals	In the prior art the hydrophobic surfaces are not thermally or electrically condurtive.	Superhydrophobic and conductive surface is obtained with CNT structure is grown on surface with CVD with existence of catalyst and a controlled temperature. So nanosize peaks and valleys are occured.
US10167550B2: Multi-functional composite structures	Bigger size heaters that embaded in sandwich structure systems were used for wing deicing systems.	CNT conductor particles are used for deicing function. CNT particles are embaded in sandwich structure that are carrier for signals and electricity.
US20180100233A1: Thin metal coating methods for high conductivity graphane-metal composites and methods of manufacture & US20200399739A1: Functionally graded metal matrix nanocomposites, and methods for producing the same	For lightning protection system, metal mesh foils was used on wing and fuselage of the aircraft.	Graphene high conductive layer obtained on metal surface by PVD or CVD processes. This later used for lightning strike and EMI Shielding.

EP2758234B1: Conductive composite structure or laminate	Copper wires, mesh and foils were used for EMI shielding and lightning strike. But these systems are less strength, so they can damage during lightning strike.	Heavier and stronger graphene or CNF embaded nanocompoistes are used for more effective lightning strike and EMI Shielding.

CHAPTER 4

RESULTS AND DISCUSSION

According to this analysis, this can be clearly seen that patents about "Carbon Reinforced Nano-Composites That Used as Conductivity Surfaces for Aerospace Industry" include the technologies about "resin, thermoplastics, thermosets, nanomaterials, composites, electronic elements, additive manufacturing methods" as seen in in Figure 4.1.

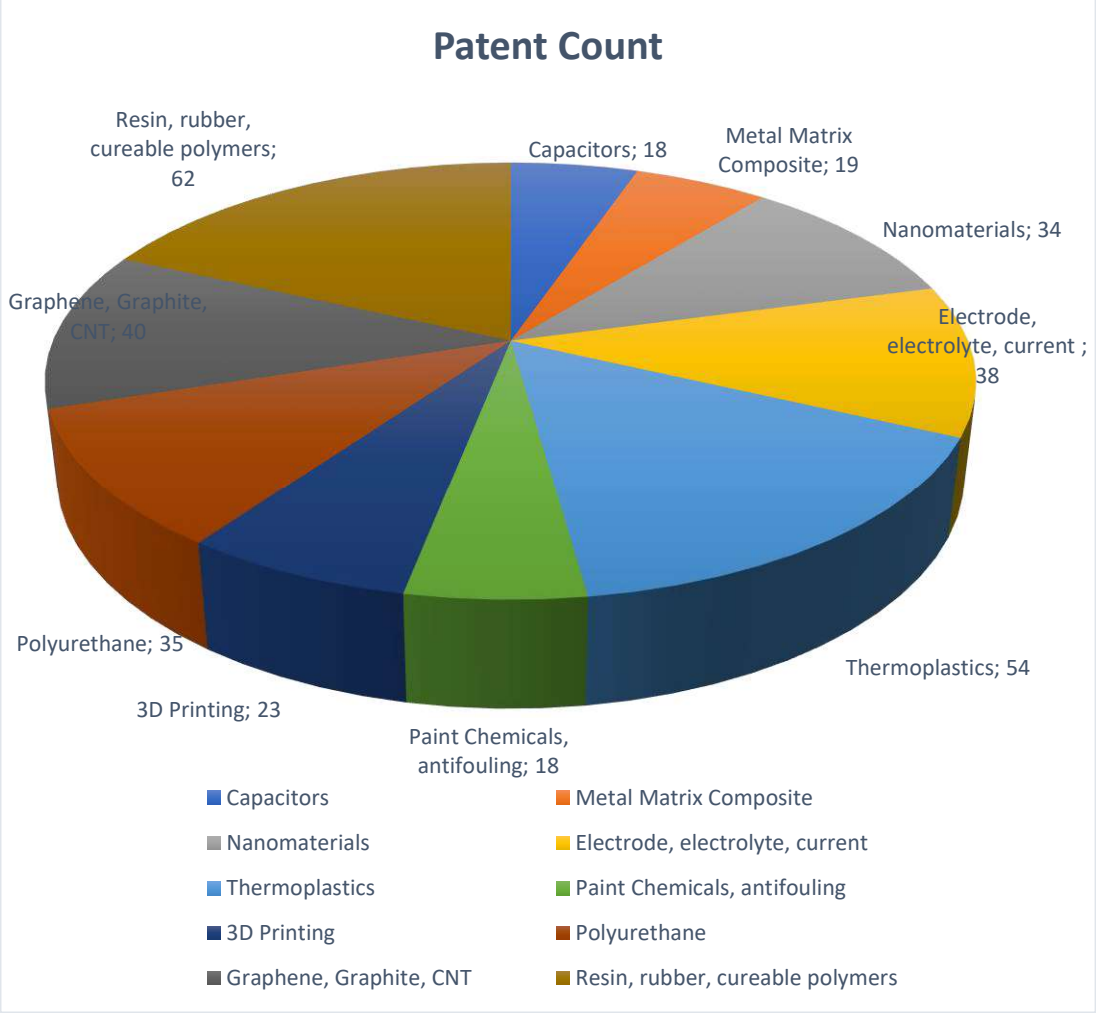

Figure 4.1 Dispersion of Technologies due to patent counts of Carbon Reinforced Nano-Composites Used As Conductivity Surfaces For Aerospace Industry

Also nanoscience is important because of production, characterization, and implementation of nano-sized carbon particles that dispersed in a matrix material. The improvements on the technology about carbon reinforced nano composites used as conductivity surfaces for aerospace industry are generally about advanced technologies such as composite production technology, nanotechnology, 3D printing.

4.1. Results of Last-10 Year Patents

4.1.1 Results of Polymer Composite Parts

The results of the carbon reinforced polymer matrix nano composites that used for improving electrical and thermal conductivity of composite aerospace structural parts obtained with the patent database analysis were explained in this section. According to search, companies and institutes with the most patents on the subject are Florida State University, Niagara Bottling, Nanotek, Sapienza University and the others for last 10 years are seen in Figure 4.2.

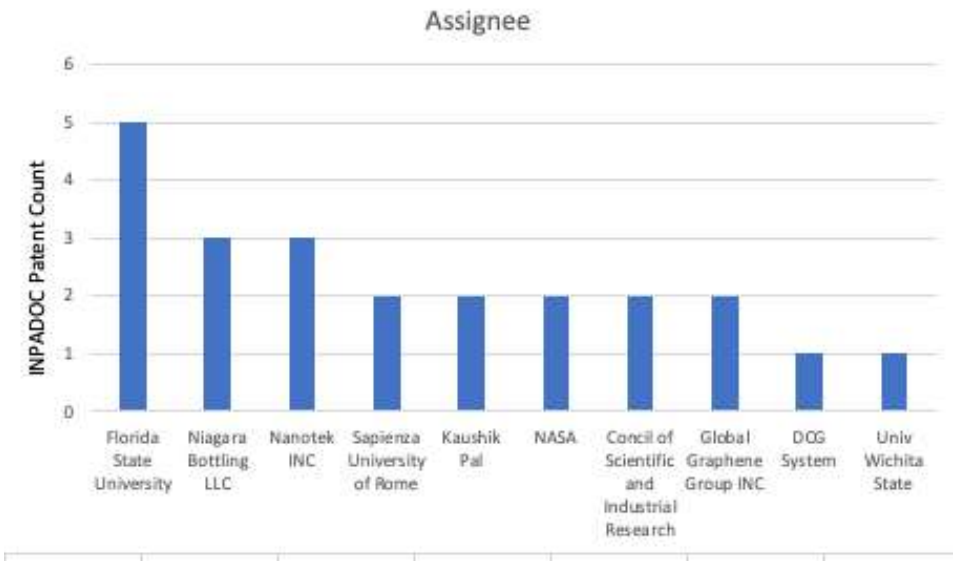

Figure 4.2 Dispersion of Optimized Assignees and operators of the patents about Carbon Reinforced Nano-Composites That Used for Improving Conductivity Composite Parts Aerospace.

These companies, universities and institutes also have studies and production activities about carbon reinforced polymer matrix nano composites used as conductivity surfaces for aerospace industry and the same advanced technologies. According to these studies, production activities and the R&D actions, there are new technologies and the innovations are seen and so the patents are filed. The institute has performed well for the dissemination of technical knowledge. There are environments that produce useful inventions in these companies, universities and institutes where patents are applied. In the Florida State University, the inventors closely study with IP Office of the institute. The IP office and the research foundation of the institute encourages the students and the lecturers to file patents about their studies. [13]

This analysis suggest that the patent count is increasing by the time. There are decreasing in the 2021. This is because of the filed patents are released after 18 mounts shown in Figure 4.3.

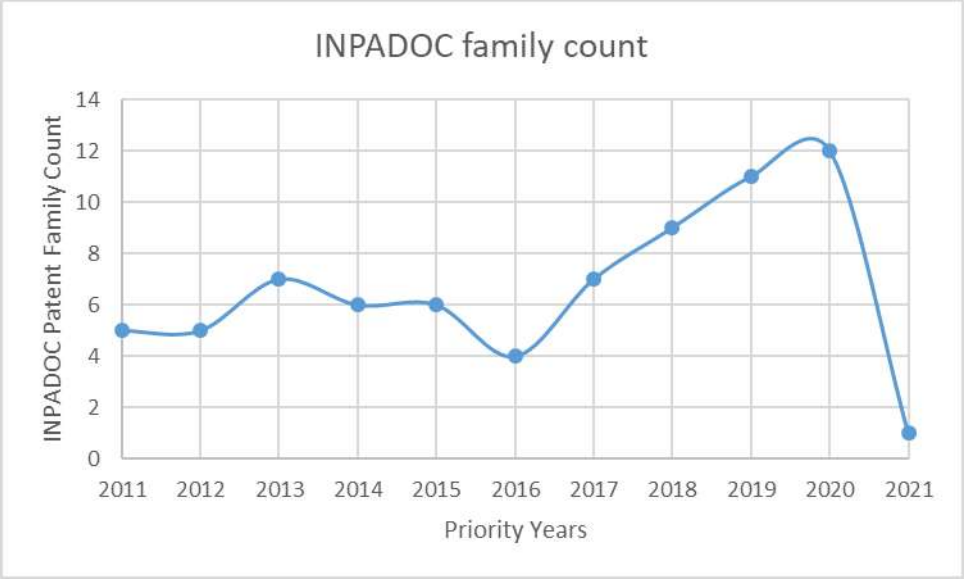

Figure 4.3 Dispersion of Publication Years of the patents about Carbon Reinforced Nano-Composites That Used for Improving Conductivity Composite Parts Aerospace.

In addition, covid-19 pandemic can affect the studies on this sector. A real indication for improvement in materials science and aerospace technologies is the number of

patents about them. The increase in the number of patents over the years also shows that the academic studies on this subject have increased. Production also increases with the number of patents. This increase also shows that the investments made in this subject have increased.

According to analysis for last 10 years filed patents, the countries that have most patent count are USA, China, India, Korea and Japan. These patent counts a strong proof that these countries have advanced technologies about aerospace and materials science in the world as seen in Figure 4.4.

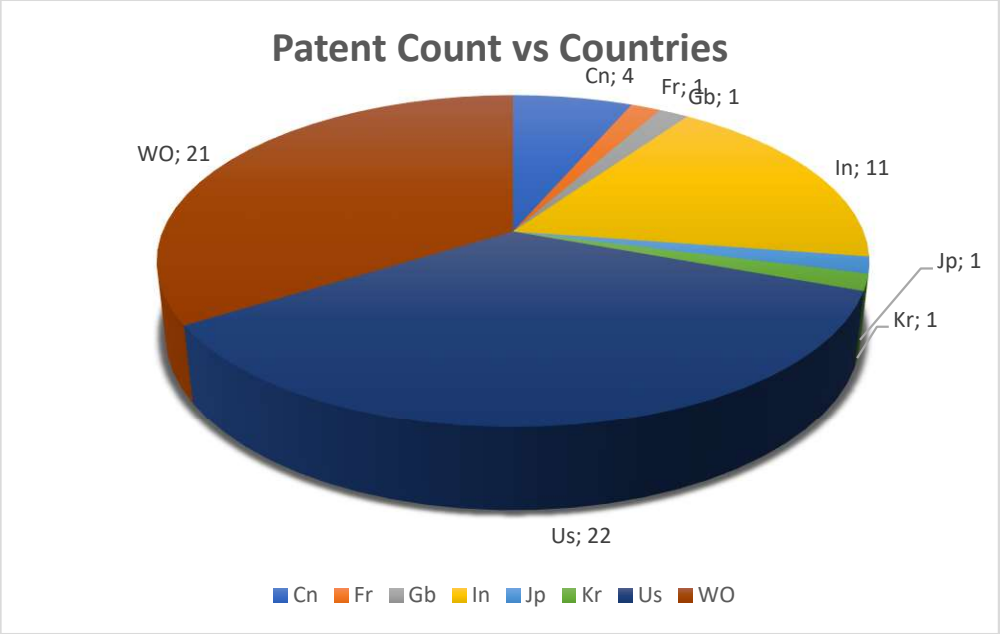

Figure 4.4 Dispersion of Countries of patents about Carbon Reinforced Nano-Composites That Used for Improving Conductivity Composite Parts Aerospace.

Academic studies and industrial developments, especially in the USA and China, are also seen in this field. It can be said that the countries that give the most importance to aviation.

4.1.2 Results of Metal Matrix Composite Parts

The results of the carbon reinforced nano composites that used for improving conductivity of metallic aerospace structural parts obtained with the patent database analysis were explained in this section.

According to the analysis, applicants with the most patents on the subject are Florida State University, Global Graphene Group, United States Navy and the others for last 10 years in Figure 4.5.

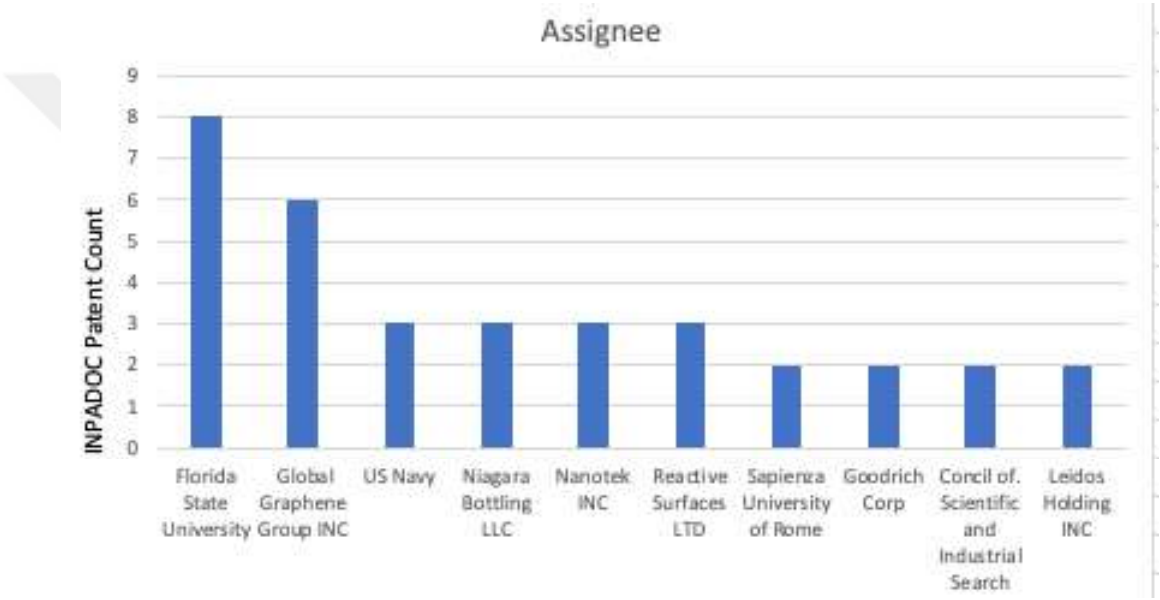

Figure 4.5 Dispersion of Optimized Assignees and operators of the patents about Carbon Reinforced Nano-Composites That Used for Improving Conductivity Metallic Parts Aerospace.

Not only companies but also universities and institutes also have patents about this topic. Because this is an advanced materials technology which is continue to improve. This analysis shows that not only industry and industry organizations, but also universities and institutes work intensively in this area. Academic studies are also adapting to the increase in technological trends. Along with aviation companies, companies that produce electronic devices, universities and institutes are also technology centers that produce ideas for the solution of this problem.

According to analysis, with increasing years also the patent count is increasing. Because if improvements in materials science and aerospace technologies, we can see the improving studies and technologies about the topic in Figure 4.6.

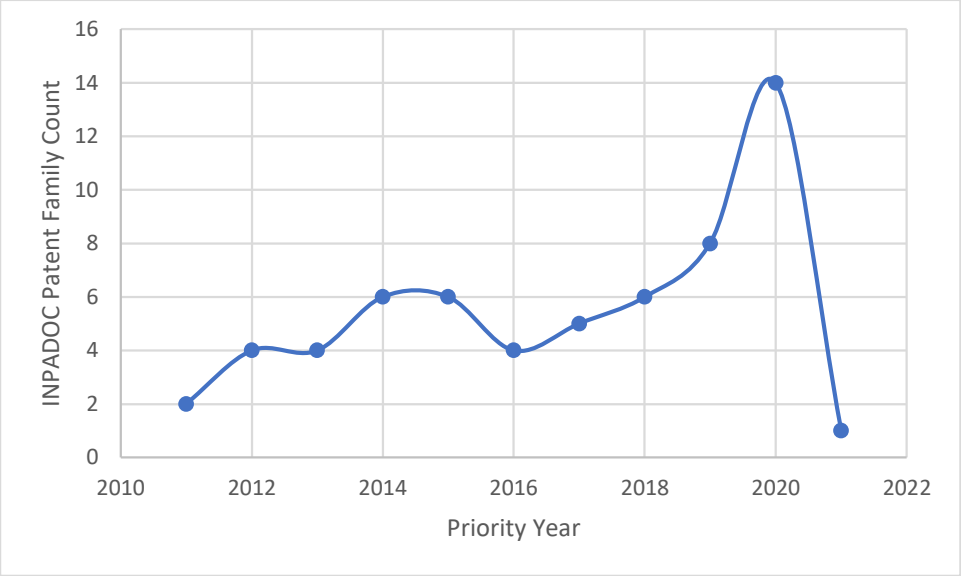

Figure 4.6 Dispersion of Publication Years of the patents about Carbon Reinforced Nano-Composites That Used for Improving Conductivity Metallic Parts Aerospace.

There are decreasing in the 2021. This is because of the filed patents are released after 18 mounts. Additionally, covid-19 pandemic can affect the studies on this sector. The increase in the number of patents over the years also shows that the academic studies on this subject have increased. Production also increases with the number of patents. This increase also shows that the investments made in this subject have increased.

According to analysis of last 10 years, the countries that have most patent count are USA, China, India, Korea and France as seen in Figure 4.7.

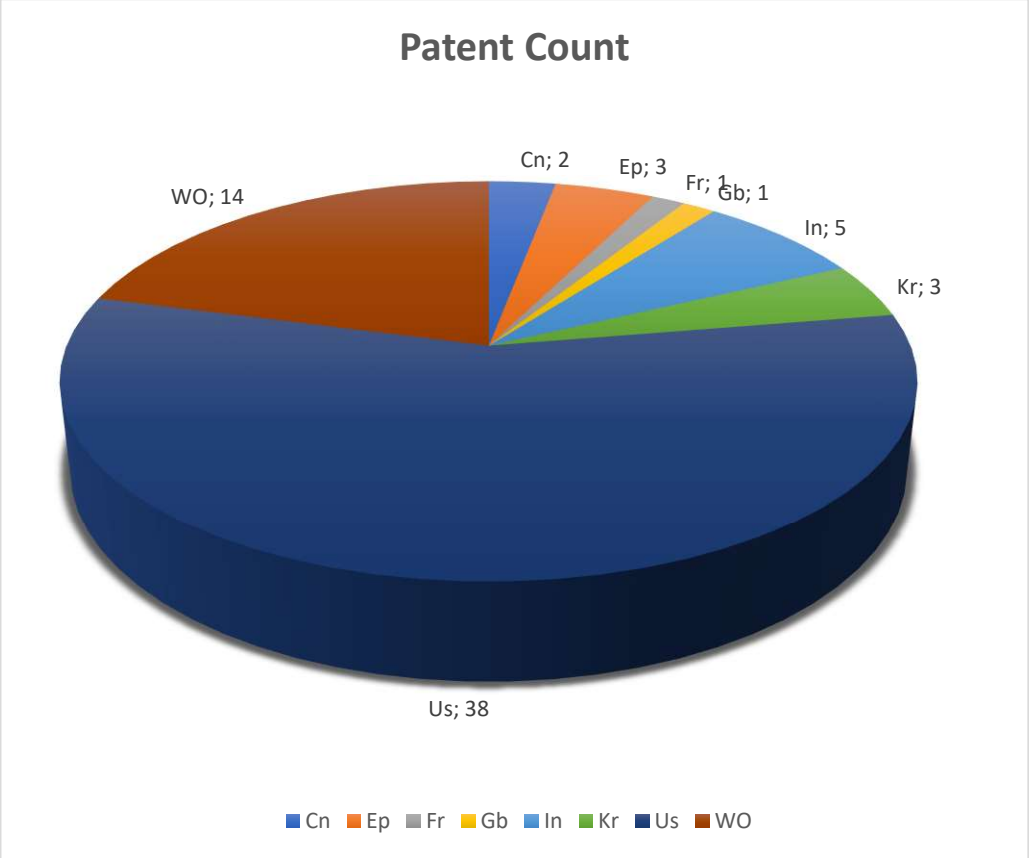

Figure 4.7 Dispersion of Countries of patents about Carbon Reinforced Nano-Composites That Used for Improving Conductivity Metallic Parts Aerospace.

These countries have advanced technologies about aerospace and materials science. Academic studies and industrial developments, especially in the USA and China, are also seen in this field. It can be said that the countries that give the most importance to aviation.

4.2. Results of Last 5-Year Patents

4.2.1 Results of Polymer Matrix Composite Parts

According to Figure 4.8 nearly the same companies, universities and industries have been studied and have been produced products of carbon reinforced nano composites that used for improving electrical and thermal conductivity of composite aerospace structural parts.

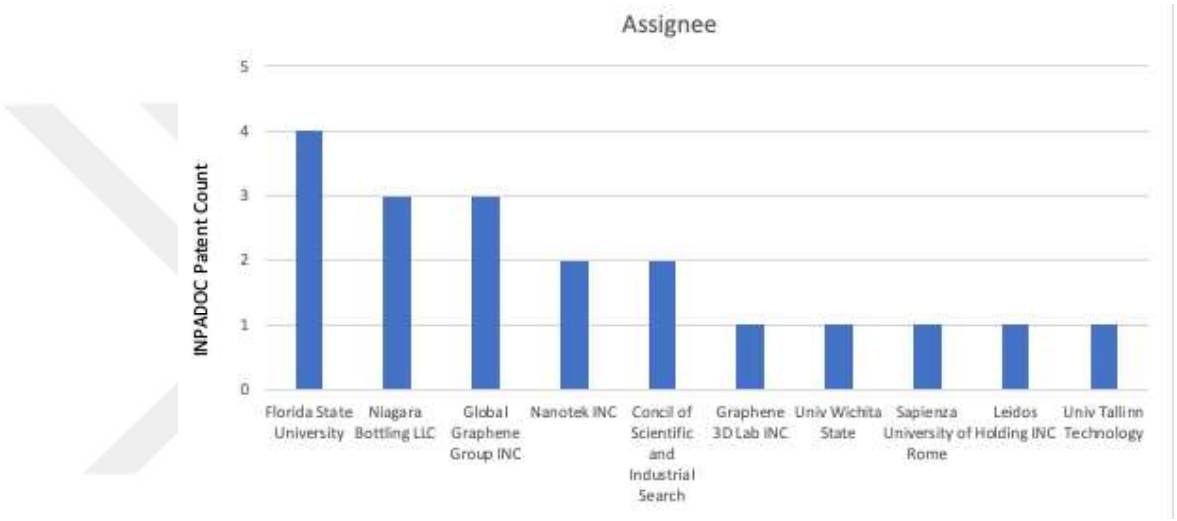

Figure 4.8 Dispersion of Optimized Assignees and operators of the patents about Carbon Reinforced Nano-Composites That Used for Improving Conductivity Composite Parts Aerospace of last 5 years.

This analysis shows that not only industry and industry organizations, but also universities and institutes work intensively in this area. Academic studies are also adapting to the increase in technological trends. Along with aviation companies that produce electronic devices, universities and institutes are also technology centers that produce ideas for the solution of this problem.

Also same countries have been studied to carbon reinforced nano composites that used for improving electrical and thermal conductivity of composite aerospace structural parts with last 10-year patents as seen Figure 4.9.

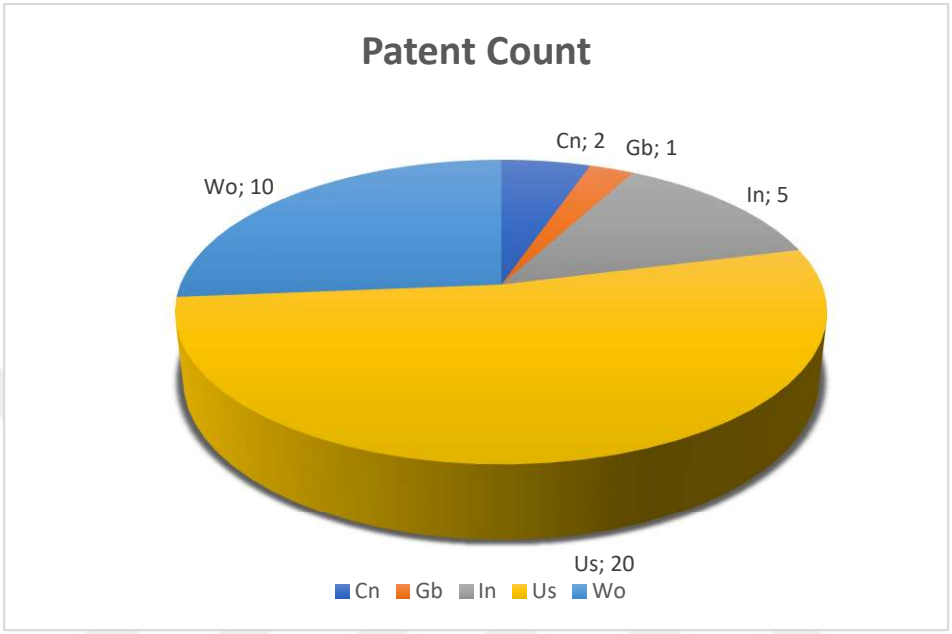

Figure 4.9 Dispersion of Countries of patents about Carbon Reinforced Nano-Composites That Used for Improving Conductivity Composite Parts Aerospace.

4.2.2 Results of Metal Matrix Composite Parts

In the Figure 4.10, nearly the same companies, universities and industries have been studied and have been produced products of carbon reinforced nano composites that used for improving electrical and thermal conductivity of metallic aerospace structural parts.

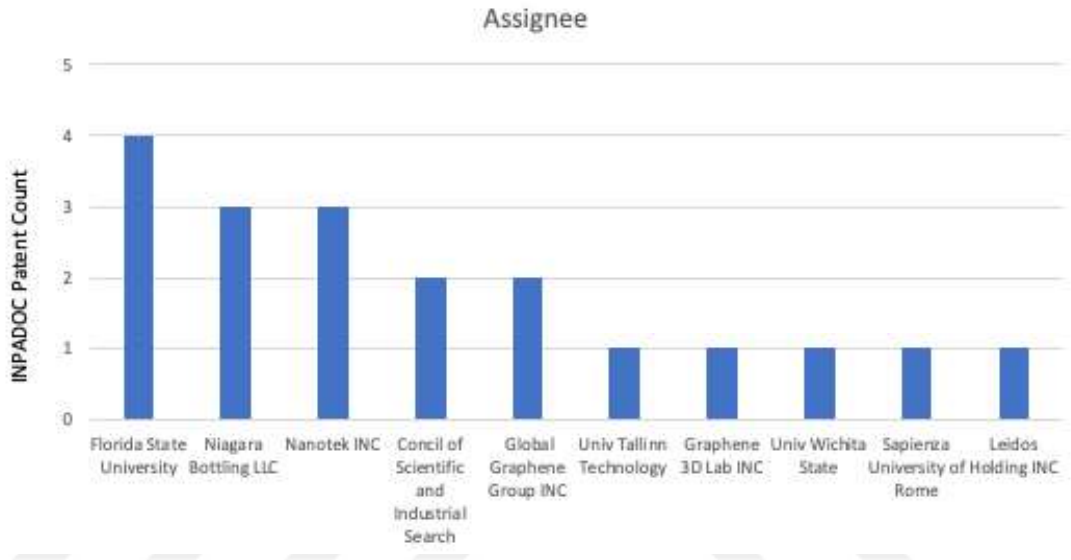

Figure 4.10 Dispersion of Optimized Assignees and operators of the patents about Carbon Reinforced Nano-Composites That Used for Improving Conductivity Metallic Parts Aerospace of last 5 years.

This analysis shows that not only industry and industry organizations, but also universities and institutes work intensively in this area. Academic studies are also adapting to the increase in technological trends. Along with aviation companies, companies that produce electronic devices, universities and institutes are also technology centers that produce ideas for the solution of this problem.

Also, same countries have been studied to carbon reinforced nano composites that used for improving electrical and thermal conductivity of metal aerospace structural parts with last 10-year patents as seen in Figure 4.11.

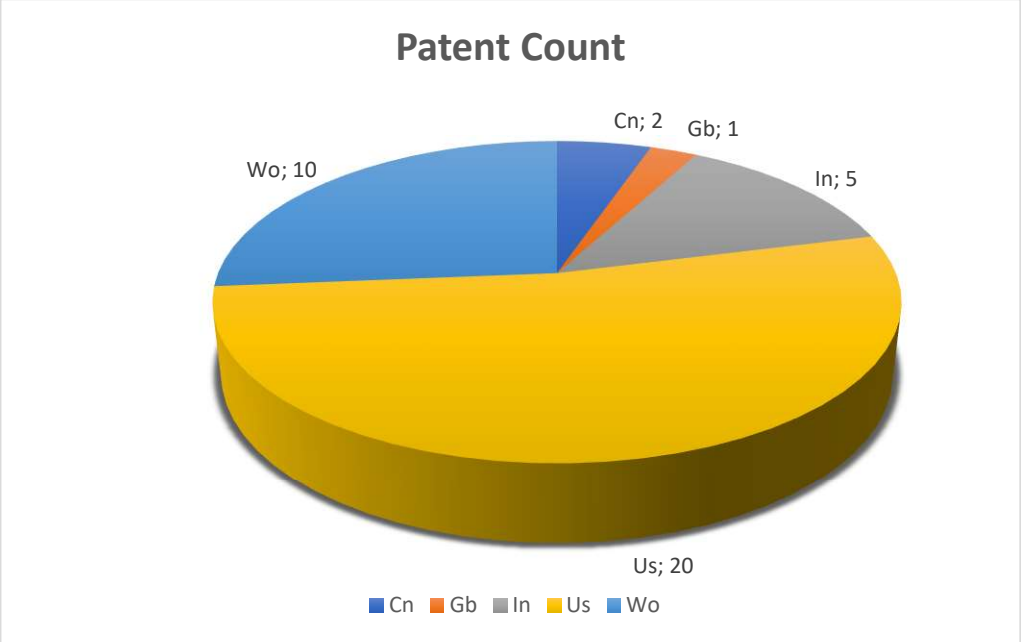

Figure 4.11 Dispersion of Countries of patents about Carbon Reinforced Nano-Composites That Used for Improving Conductivity Metallic Parts Aerospace.

CHAPTER 5

CONCLUSION

- In this study, patent database analysis of carbon reinforced nano-composites which are used as conductive of surfaces for aerospace industry was carried out. For analyzing, four different patent databases were taken into account. These databases were used for searching, reading and analyzing the patents about carbon reinforced nano composites used as conductivity of surfaces for aerospace industry.

- Patent analysis plays a key role in the development of companies and in directing the technologies to be gained through R&D and innovation studies. In recent years, it is seen that universities and institutions take more consideration into patent database analysis during their R&D studies.

- Developments and discoveries in nano technology have made the use of nano-sized carbon materials widespread. In this analysis, we see that the aviation industry is also transforming into nanotechnological production methods. It has also shown that higher performance is achieved with the usage of carbon reinforced nano composites.

- It can also be concluded patent analyses can be used as a guide for researchers about which topics and elements should be on the latest advances. Researchers can direct their research by being inspired by the result of this study. In this way, it can both gain an advantage in the competition with its competitors and dominate the technology.

- As can be understood from the patent database analysis, instead of complex systems, novel and functional materials such as nanocomposite materials have been used in solution of EMI, lightning strike, radar visibility and icing problems and in some functional applications.

- As the use of functional materials has increased, the use of carbon-reinforced nanocomposites such as CNT and graphene has become popular..
- With the use of functional materials, the importance of academic knowledge and R&D in this field has increased, and studies have shifted to research centers and universities rather than industrial companies.
- While the flight efficiency was carrying out by the development of engineering applications and complex systems/devices, focusing on functional materials have come to the importance recently.
- The number of researchers and research centers conducting research in the field of functional CNT reinforced nanocomposite development has increased with usage of the functional nanocomposite materials in aircraft industry.
- Market analysis, advanced technology patent database analysis and keyword analysis of patent database search can be future works of this study.

REFERENCES

[1] Egbo, M.K., “A fundamental review on composite materials and some of their applications in biomedical engineering”, “Journal of King Saud University - Engineering Sciences”, 2020

[2] Nangai, E. K., Saravanan, S., “Synthesis, fabrication and testing of polymer nanocomposites: A review”, “Materials Today: Proceedings.”, 2021.

[3] Rathod, V. T., Kumar, J. S., Jain, A., “Polymer and ceramic nanocomposites for aerospace applications”, “Applied Nanoscience”, 7(8), 519-548, 2017.

[4] Abbasi, H., Antunes, M., Velasco, J. I., “Recent advances in carbon-based polymer nanocomposites for electromagnetic interference shielding”, “Progress in Materials Science”, 103, 319-373, 2019.

[5] Gagné, M., Therriault, D., 1Lightning strike protection of composites”, “Progress in Aerospace Sciences”, 64, 1-16, 2014.

[6] Zhang, B., Soltani, S. A., Le, L. N., Asmatulu, R., “Fabrication and assessment of a thin flexible surface coating made of pristine graphene for lightning strike protection”, “Materials Science and Engineering: B” , 216, 31-40, 2017.

[7] Sanjinés, R. , Abad, M.D., Vâju, C., Smajda, R., Mionić, M., Magrez, A., “Electrical properties and applications of carbon based nanocomposite materials: An overview”, “Surface & Coatings Technology”, (11), 727–733, 2011

[8] Gupta, V. K., Pangannaya, N. B., "Carbon nanotubes: bibliometric analysis of patents.", “World Patent Information” 22 (3), 185-189, 2000.

[9] Hart David Carson LLP, “Advantages and Drawbacks of Patents[online]”, https://www.hartdavidcarson.com/news/advantages-and-drawbacks-of-patents/ , [Accessed: 10-11-2020].

[10] Upcounsel, “Advantages and Disadvantages of Patents [online]” https://www.upcounsel.com/advantages-and-disadvantages-of-patents [Accessed: 15-01-2021]

[11] Makkonen, T., van der Have, R.P., “Benchmarking regional innovative performance: composite measures and direct innovation counts.”, “Scientometrics”, 94, 247–262, 2013.

[12] USPTO, “General information concerning patents [online]” https://www.uspto.gov/patents-getting-started/general-information-concerning-patents [Accessed : 08-09-2020].

[13] Espacenet , “Espacenet [online]” https://worldwide.espacenet.com/?locale=en_EP. [Accessed : 08-09-2020]

[14] Google Patents, “Google Patents [online]” https://patents.google.com/advanced [Accessed : 08-09-2020]

[15] Derwent Innovation Tool, “Derwent Innovation Tool [online]” https://www.derwentinnovation.com/ [Accessed : 08-09-2020]

[16] Lens.org, “Lens.org” [online] https://www.lens.org/lens/search/patent/structured [Acessed: 02.02.2021]

[17] Liu Shang-Jyh, & Joenson Shyu, "Strategic planning for technology development with patent analysis.", “International journal of technology management”, 13 (5-6), 661-680, 1997.

[18] Huang Z., Chen H, Chen Z., Roco M. C., “International nanotechnology development in 2003: Country, institution, andtechnology field analysis based on USPTO patent database” , “Journal of Nanoparticle Research”, 6, 325–354, 2004.

[19] WIPO, “The role of patents in the history of aviation [online]”, USA, https://www.wipo.int/wipo_magazine/en/2018/06/article_0007.html , [Accessed: 10-09-2020].

[20] Anderson S., Love J., “The Strategic Use of Intellectual Property Within the Aerospace & Defense Industry [online] ”, https://www.natlawreview.com/article/strategic-use-intellectual-property-within-aerospace-defense-industry , [Accessed: 10-09-2020].

[21] Jewell C., “Giving Innovation Wings: How Boeing Uses its IP [online]” https://www.wipo.int/wipo_magazine/en/2014/01/article_0004.html , [Accessed : 15-09-2020]