Sample Patent Landscape Study

Diamond Like Carbon Coatings (DLC)

IIPRD

Table of Contents

1. Introduction

1.1. Diamond Like Carbon Coatings (DLC)

Diamond like carbon (DLC) coating is a nanocomposite coating, that has unique properties of natural diamond low friction, high hardness and high corrosion resistance. DLC is a metastable form of amorphous carbon containing a significant amount of sp3 bonds. DLC coatings can be deposited as thin films over a range of surfaces. They are used to improveme the mechanical frictional and tribological performance of several components and parts.

DLC coatings can be deposited using a number of different techniques which can generally be divided into two categories namely chemical vapor deposition (CVD) and physical vapor deposition (PVD). The physical processes that have been proposed to deposit DLC coatings include direct ion beam (IB) and ion beam assisted deposition (IBAD), filtered cathodic vacuum arc (FCVA), DC and RF sputtering, pulsed laser deposition (PLD) and plasma immersion ion implantation (PIII). Techniques which involve chemical processes include plasma enhanced chemical vapor deposition (PECVD) and electron cyclotron resonance plasma chemical vapor deposition (ECR-CVD).

DLC coatings are environment friendly and can be used to reduce friction, wear, fretting, galling and corrosion. They can also be used to modify electrical conductivity and wettability.

DLC coatings are used in wide range of application areas. Some of the uses include cutting tools for aluminum, aluminum-silicon alloys, powder metallurgy alloys, tools for metal forming & blanking, plastic molds & extrusion components, hydraulic components such as cylinders, pistons, gear pumps, valve components such as balls, gates, seats, actuatorsand housings, automotive components such as crank shafts, cam shafts, gears, bearings, piston rings, tappets, wrist pins, fuel injectors.

1.2. Growth Prospects of DLC

The global DLC coating market was valued at around USD 1.4 billion in2016. It is anticipated to reach USD 2.4 billion by 2025 with a CAGR of 6.4 during the period of 2017-2025.

The major driving factors for the growth of the global DLC coating market are the rise in demands for DLC coating in wear resistant,high performing automotive engine components and increase in demand for advanced DLC coatings in the medical industry owing to high biocompatibility.

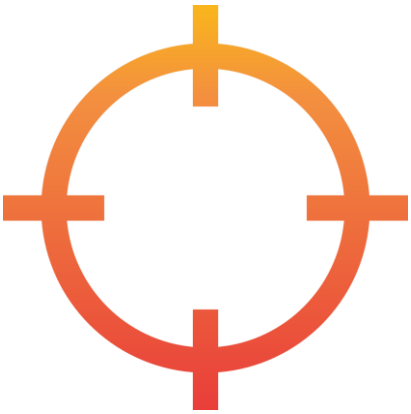
DLC coatings are made out of carbon atoms whichresult in the emission of carbon dioxide when exposed to oxygen. Implementation of stringent regulations on the emission of carbon dioxide is likely to hamper the growth of the global DLC coating market.

It is a critical time to understand the global competitive environment of diamond like carbon coating market from a patent perspective and in-depth patent analysis of key technologies and players can help anticipate changes, detect business opportunities, mitigate risks and make strategic decisions to strengthen one's market position and maximize return on one's IP portfolio.

Some of the prominent participants in the global market of DLC coatings are Oerlikon Groups, Morgan Advanced Materials, Miba AG, IBC Coatings Technologies, Richter Precision, Acree Technologies, Norseld Pty Ltd, Micromatter Technologies, Wallwork Heat Treatment Ltd and Renishaw Advanced Materials Ltd.

2. Objectives

- To perform detailed analysis of granted patents and published applications pertaining to DLC coatings and to understand underlying technologies.
- In depth analysis of patents/applications, in order to categorize them and to understand areas of interest to the applicants.
- Graphical representation of trends (Filing, Publication, etc.) from the mined data of relevant



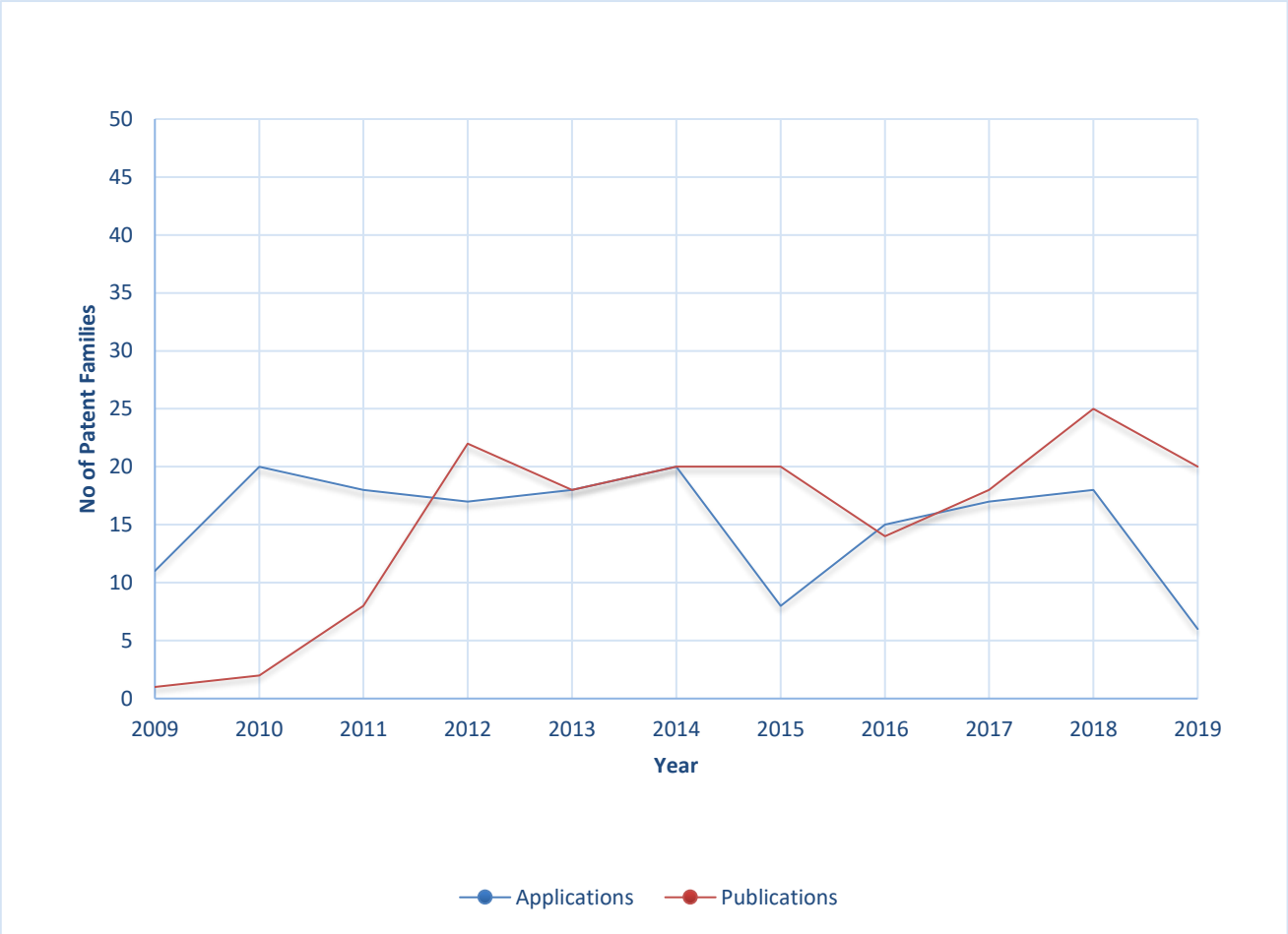
3. Search Methodology

The first step is to create and define a patent set that will serve as the basis of this analysis. Using renowned patent database, Derwent Innovation as our data source, we extracted data set of patents/published applications filed during the last ten years (2009-2019) by performing search in Abstract, Title and Claims fields using keywords and International Patent Classifications.

4. Non-Technical Analysis

4.1. Application, Publication Year Based Trend Analysis

Below graph represents application year and publication year based trends for the patent publications pertaining to DLC coatings.

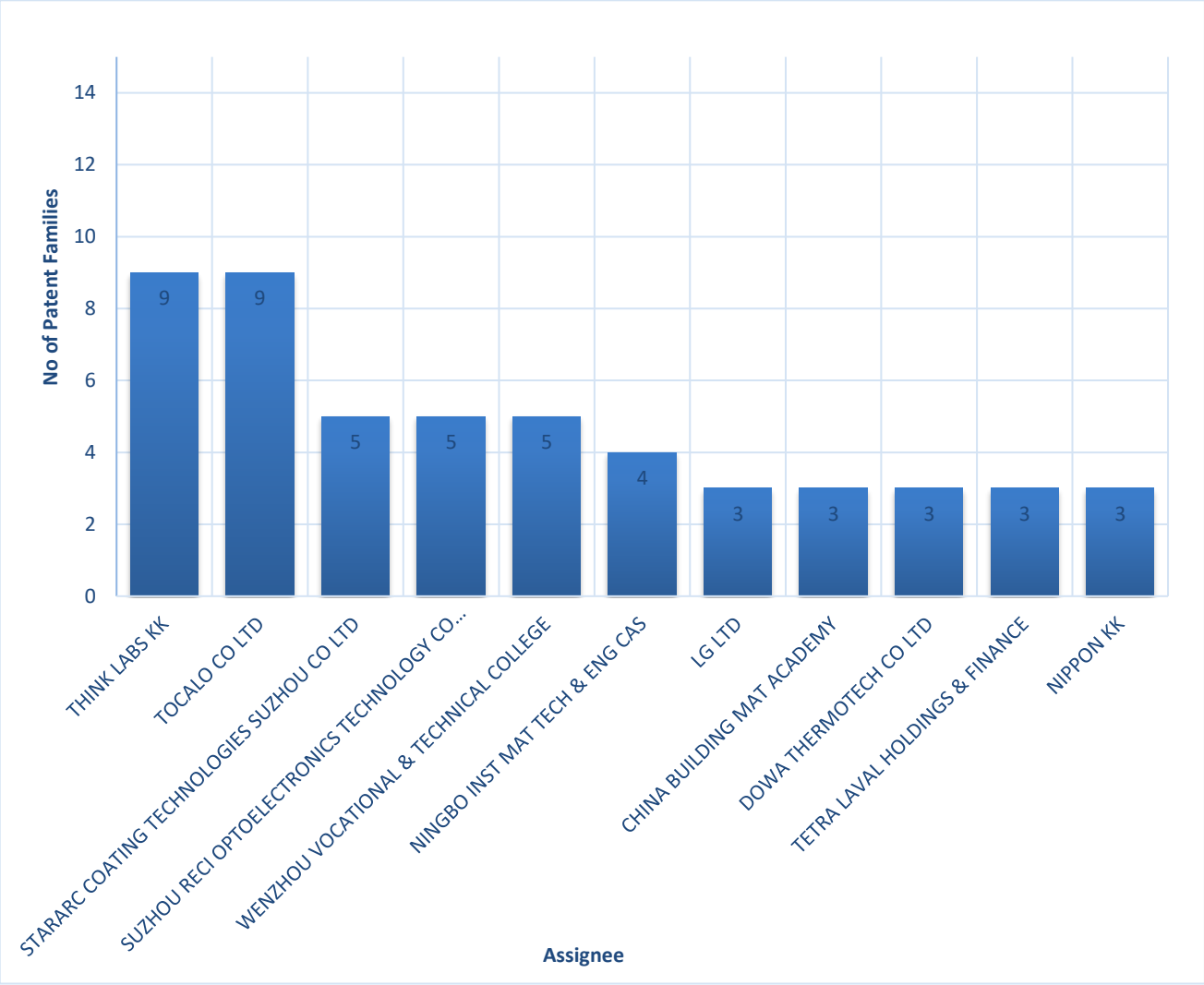


Filing year trend provides insights for the number of applications filed during the period 2009-2019. As depicted in the graph, there is an overall rise in patent applications filing during the last 3-4 years, wherein the maximum number of patent applications (20) were filed in the year 2018.

Publication trend provides insights for the number of applications published during the period 2009-2019. As indicated in the graph, there is a gradual rise in publication over the years, wherein the maximum number of patent applications (25) were published in the year 2018.

4.2. Assignee Based Trend Analysis

The below graph represent major assignees in the domain.

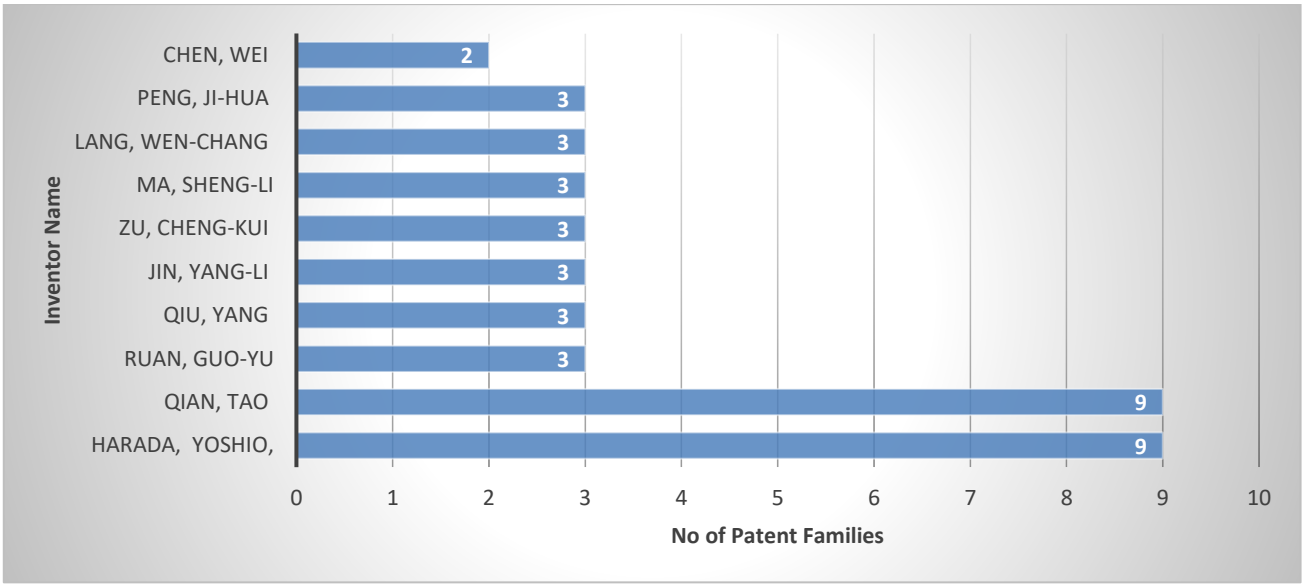


The Top Assignees:

- THINK LABS KK
- TOCALO CO LTD
- STARARC COATING TECHNOLOGIES
- SUZHOU RECI OPTOELECTRONICS TECHNOLOGY CO LTD
- WENZHOU VOCATIONAL & TECHNICAL COLLEGE
- NINGBO INST MAT TECH & ENG CAS
- LG LTD
- CHINA BUILDING MAT ACADEMY
- DOWA THERMOTECH CO LTD
- TETRA LAVAL HOLDINGS

4.3. Key Inventors

The below graph names the inventors with most number of innovations on their name.



The chart demonstrates top inventors, wherein 'QUIAN, Tao' & 'HARDA, Yoshio' emerged out as the leading inventors in DLC coatings domain.

4.4. Geography Based Trend Analysis

4.4.1. Geographical Distribution Of Patent Application Filings

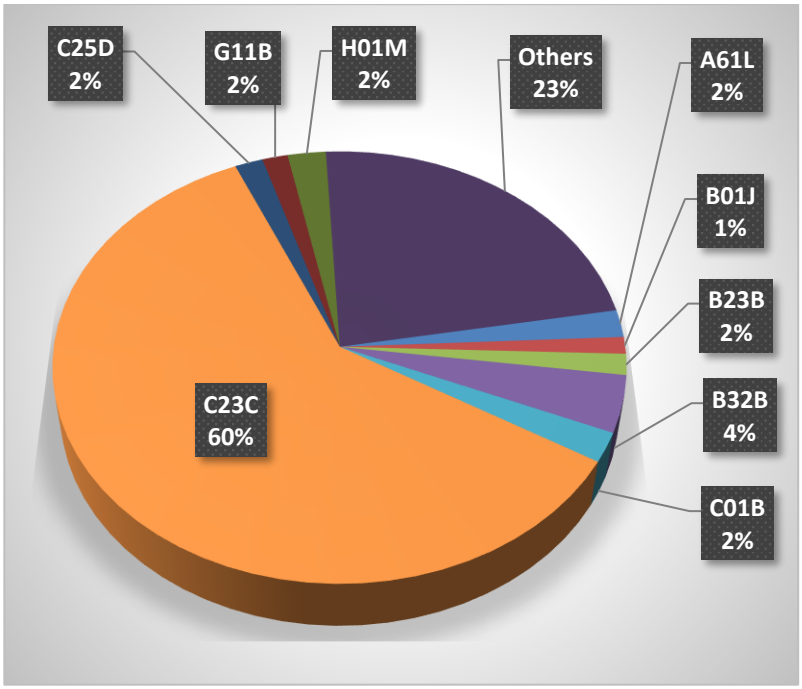
Priority Country → / Priority Year ↓	AU	CN	DE	EP	FR	GB	JP	KR	US	WO	Grand Total
2000									1		1
2003									1		1
2006									2		2
2007									1		1
2008							2				2
2009		2				1	5	3			11
2010		4	1				7	3		1	16
2011		9				1	5	1	3	1	20
2012		4	1		1		5	5			16
2013		7					13	2			22
2014		8					2	4	2		16
2015		3		3			1	1	1		9
2016		12					1		1		14
2017	1	12					1	2	2		18
2018		13									13
2019		6									6
Grand Total	1	80	2	3	1	2	42	21	14	2	168

Trend related to Geographical filing demonstrates that the maximum number of filings originated from CN jurisdiction (80) followed by JP (42), KR (21) and US (14) jurisdictions.

4.5. IPC Based Trends

The below graph represents frequently assigned international patent classes.

Majority of patent applications were assigned with ipc "C23C" related to 'coating metallic material; coating material with metallic material; surface treatment of metallic material by diffusion into the surface, by chemical conversion or substitution; coating by vacuum evaporation, by sputtering, by ion implantation or by chemical vapor deposition, in general'.

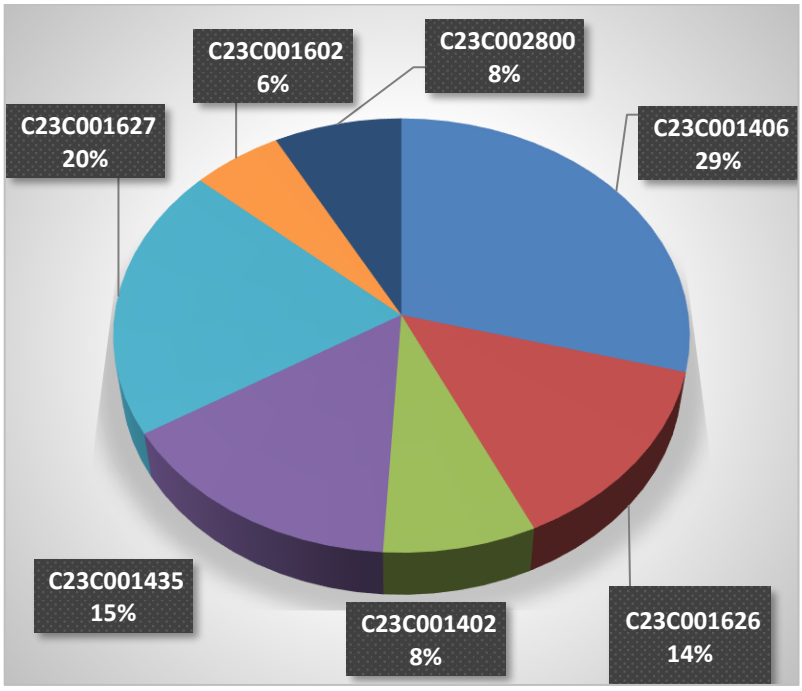


4.6. Patent Sub-Classification Based Trends

The below graph represents sub-classes pertaining to one of the top/main patent classes.

C23C Sub-Classification

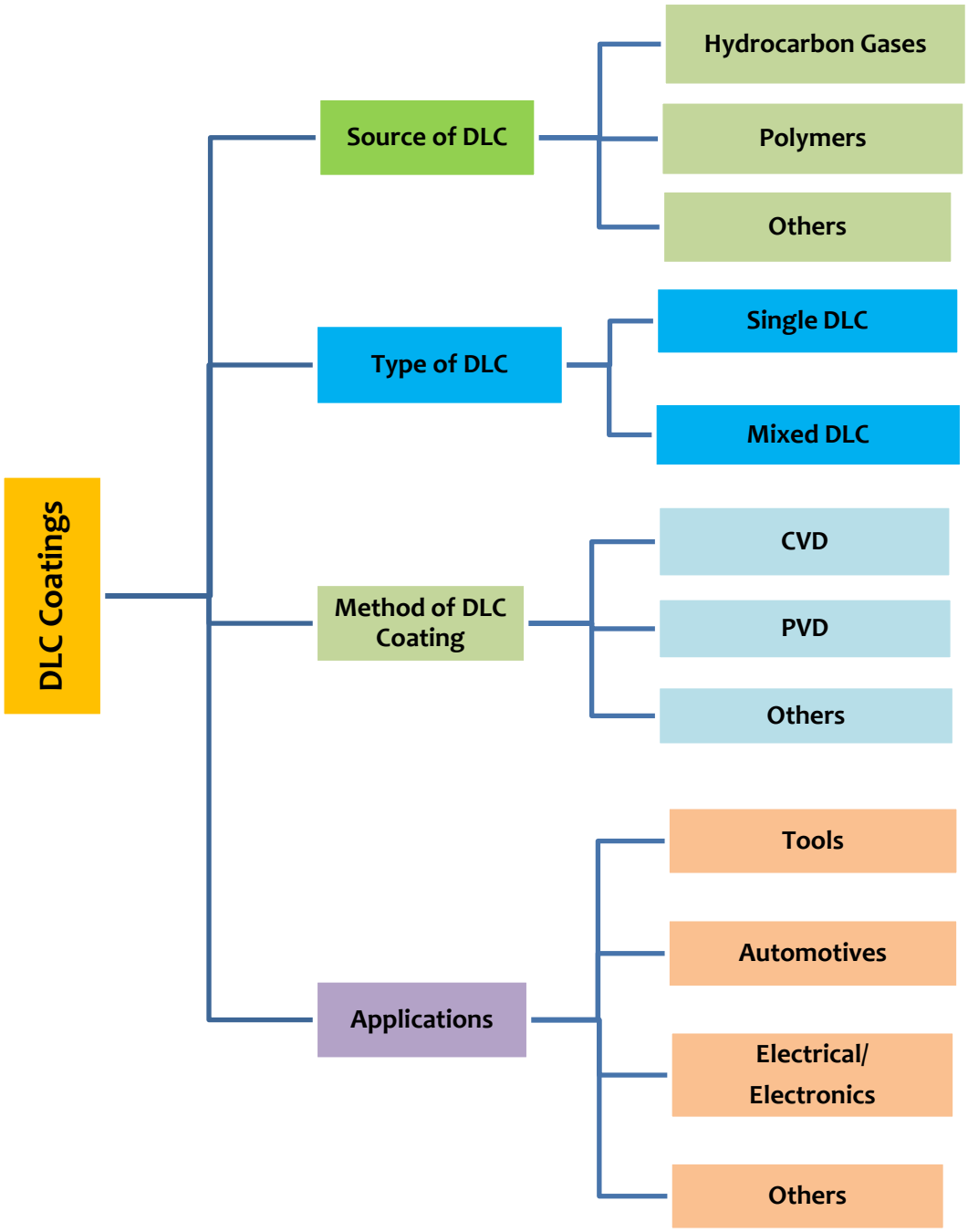
"C23C 14/06" emerged as major subclass which relates to "Coating by vacuum evaporation, by sputtering or by ion implantation of the coating forming material characterised by the coating material".



5. Technical Analysis

5.1. Taxonomy Developed For Bucketing Of Relevant Patent Documents

A set of 167 patent families were analyzed in depth to identify the focus areas of the patents related to Diamond Like Carbon Coatings domain.



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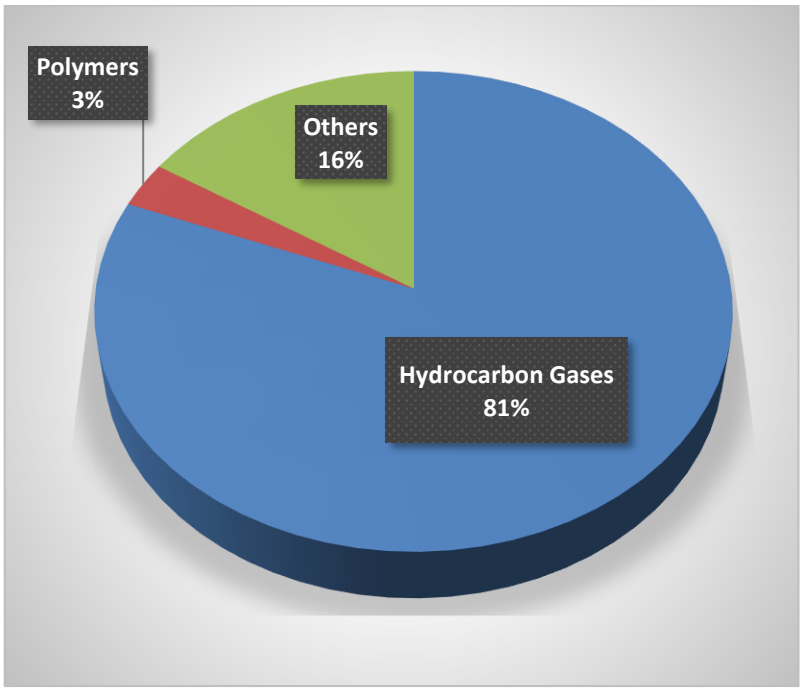
5.2. Distribution Of Patents/Applications Pertaining To Source Of DLC Coatings

Below representation shows the dissection in terms of source of carbon material that would be used for DLC coatings.

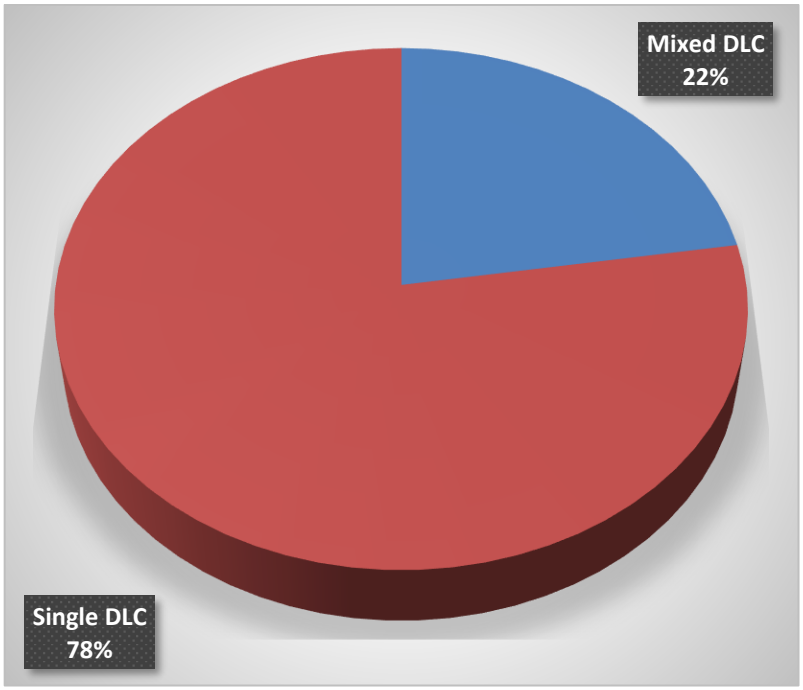
As evident from the graph, 81% of patents/applications disclosed use of hydrocarbon gases as the carbon source for DLC coatings.



5.3. Distribution Of Patents/Applications Pertaining To Type Of DLC Coatings

This category deals with patents/applications pertaining to the dissection of type of DLC coatings.

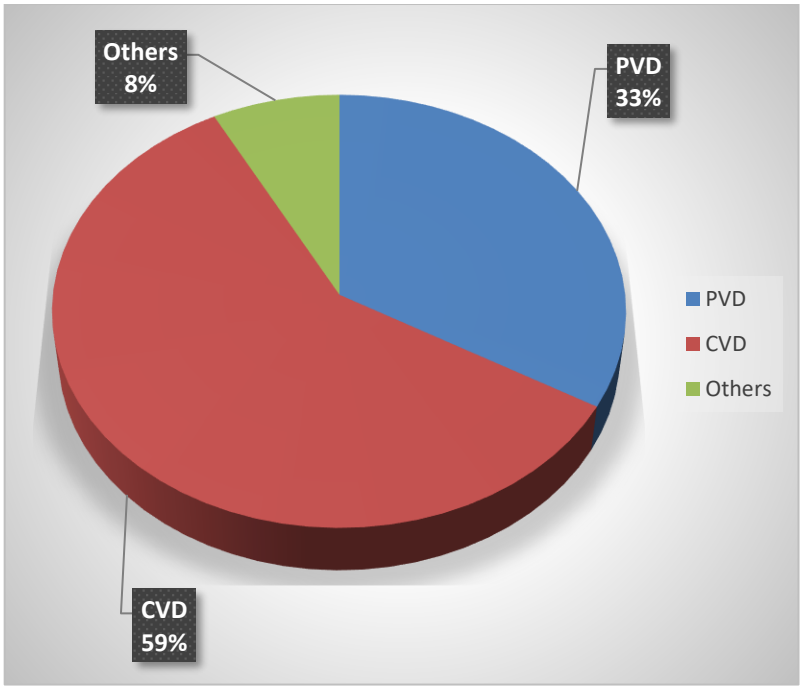
As evident from the graph, majority (78%) of the patents/applications disclosed single DLC coatings while 22% of patents/applications disclosed mixed DLC coatings.



5.4. Distribution Of Patents/Applications Pertaining To The Methods For Depositing DLC Coatings

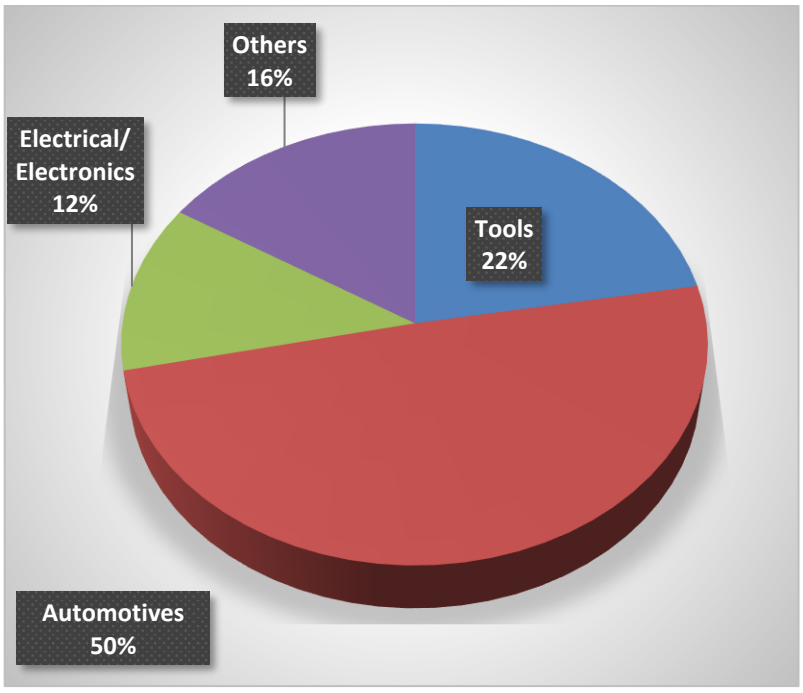
This category deals with patents/applications pertaining to the dissection of the methods employed for depositing DLC coatings.

As evident from the graph, 59% of patent filings disclosed chemical vapor deposition (CVD) as the method of depositing DLC coatings followed by physical vapor deposition (PVD) method (33%) while 8% of the filings disclosed other coating methods.



5.5. Distribution of Patents/Applications Based On Application Area Of DLC

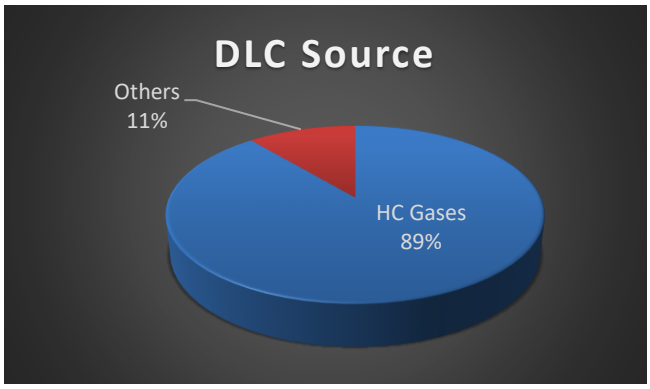
As evident from the graph, 50% of patent filings focused on Automotive components with DLC coatings while 23% of the filings focused on DLC coatings on Tooling components.

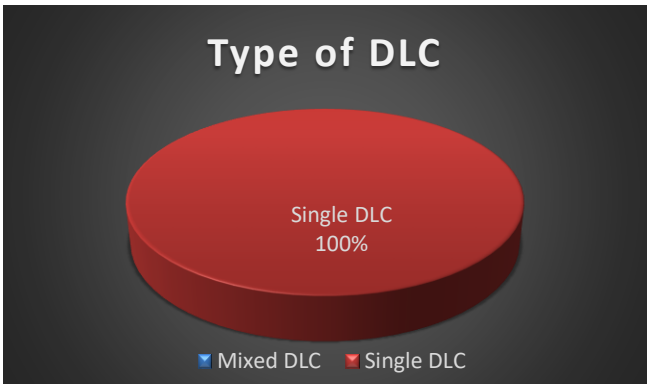


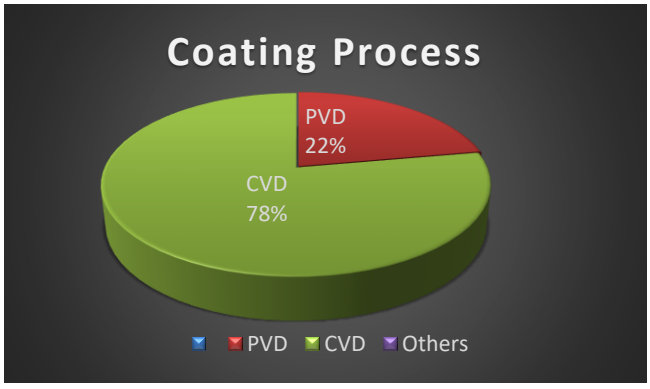
6. Patent Portfolio Analysis

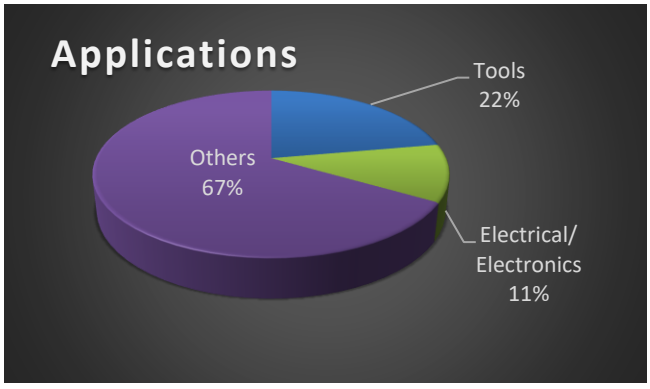
6.1. Think Laboratory Co., Ltd.

Think Laboratory Co. Ltd. is a manufacturer of FXIJ - Ink Jet Printer for Water Based Ink, targeting instant short-run production with the latest high-speed image processing software. They also provide services ranging from imaging to DLC coating using environment friendly coating processes.







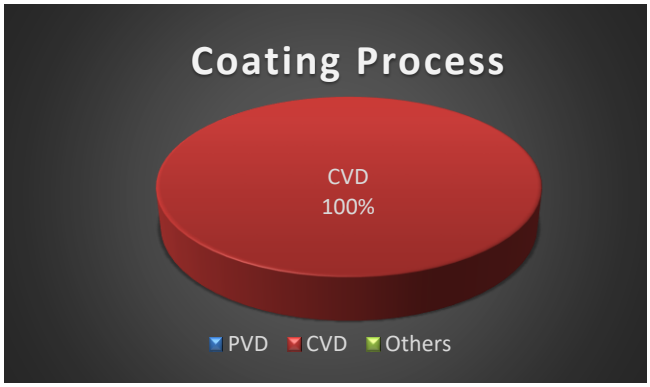


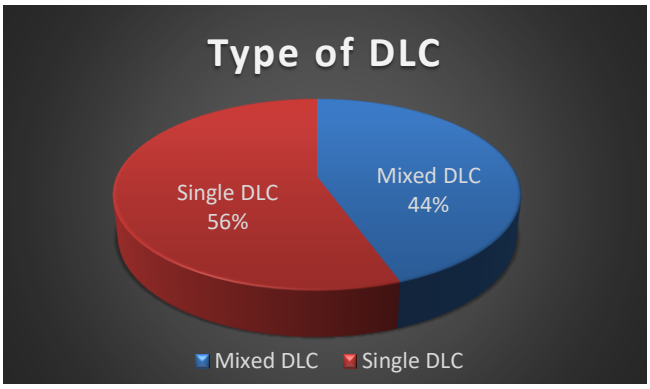
6.1.1. Key Patents – Think Laboratory Co., Ltd.

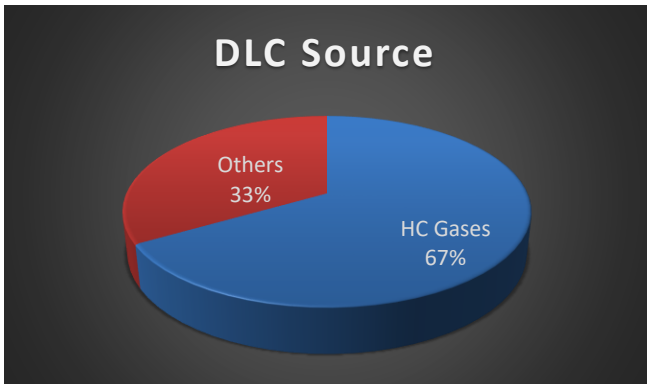
Patent No.	Key Features
WO2012108464A1	The patent application relates to diamond like carbon (DLC) coated substrate for industrial products as electronic components such as semiconductor components and printed circuit board.
JP06144907B2	The patent document relates to fabricated slide metal surface sheet by continuous plating using a roll DLC pattern. The DLC coating is conducted by CVD method and toluene is used as carbon source.

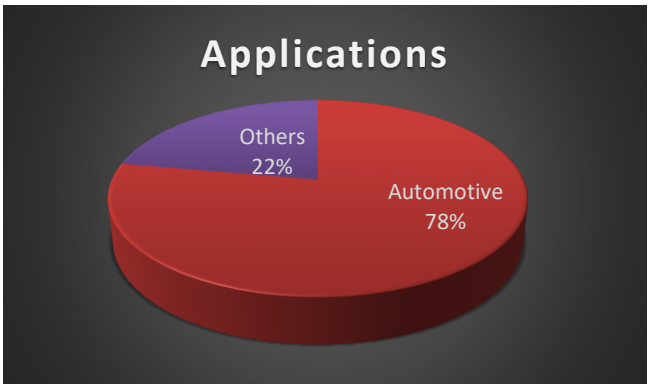
6.2. Tocalo Co Ltd

Toclao Co Ltd is a metal processor company providing surface modification services in metals, alloys, ceramics, cermets and non-metals by using thermal spraying technology.







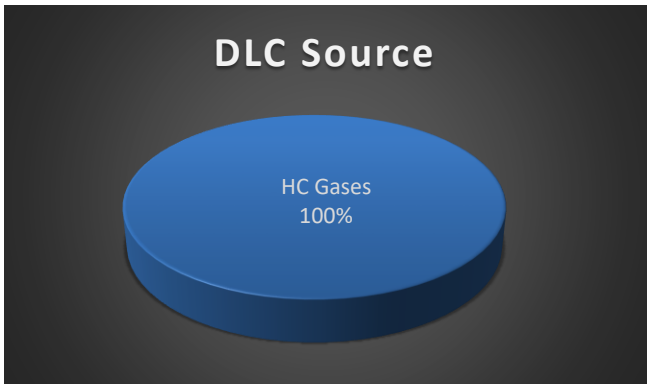


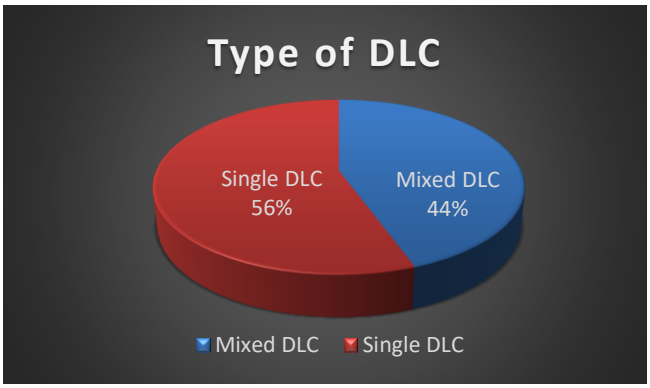
6.2.1. Key Patents – Tocalo Co Ltd

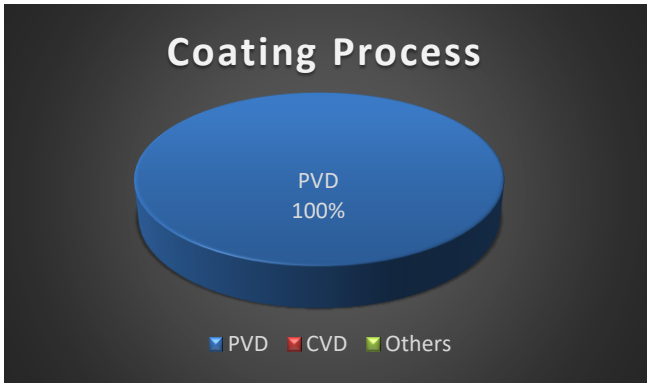
Patent No.	Key Features
JP05727569B2	The patent document relates to a method for producing an anti-corrosion DLC film-coated member. The DLC film coated with the plasma CVD method on the surface of the substrate using hydrocarbon gas (methane or acetylene or toluene) as carbon source.
JP05792257B2	The patent document relates to process for the preparation of antimicrobial DLC film-coated member. The DLC film coated with the plasma enhances CVD method on the surface of the substrate using hydro-carbon based gas (methane or acetylene or toluene) as carbon source.

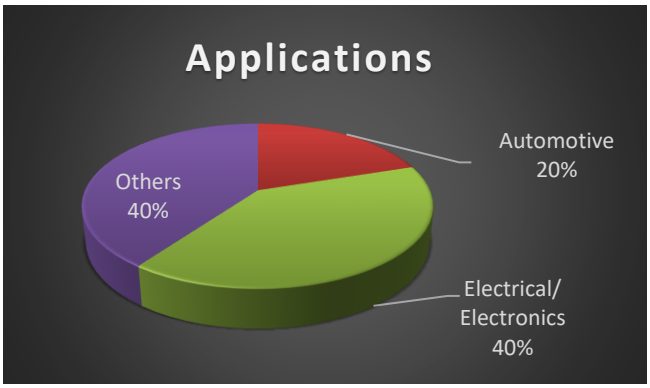
6.3. Star Arc Coating

Star Arc Coating New Materials Technology (Suzhou) Co. Ltd. is a high-tech enterprise that provides vapor deposition coating services,related equipment development, production and manufacturing. Its coating products include a full range of hard coatings such as diamond-like coatings (DLC) and other cermets (CrN, TiN, etc.).









6.3.1. Key Patents – Star Arc Coating

Patent No.	Key Features
CN102917534A	The patent application relates to a DLC (Diamond-like Carbon) thin film coating-based ceramic substrate. The coating technique comprises a PVD sputtering method and acetylene is used as the carbon source for coating.
CN102534614A	The patent application relates to a physical vapor deposition (PVD) coating method for a DLC (diamond-like carbon) coating on a spinning reed (textile reed) using a hydro-carbon based gas as the source for carbon.

7. Key Patents in the Domain

Patent No.	Key Features
CN102740591A Suzhou Reci Optoelectronics Technology Co Ltd	The patent application relates to a DLC coated double-sided aluminum base circuit board with super-high thermal conductivity properties. The DLC coating comprises by physical vapor deposition (PVD) method for thermal insulation with acetylene is used as raw material.
CN108441825A Wenzhou Vocational & Technical College	The patent application relates to metal-doped diamond-like coating and a product thereof and said metal comprises metal-doped titanium, chromium, or tungsten. The diamond-like coating is primarily deposited by PAVCD technology of motivating plasmas to be activated by arc electron stream using a hydrocarbon gas as precursor.
CN105525258A Ningbo Inst Mat Tech & Eng CAS	The patent application relates to corrosion resistant Cr-DLC coating for an aluminum alloy surface, which comprises a Cr underlayer is formed directly on the surface of the aluminum alloy substrate, and directly formed on the Cr underlayer doped with Cr in the DLC coating. The DLC coating is carried out by magnetron sputtering process.

8. Appendix

8.1. Appendix A: Sources

- https://www.sciencedirect.com/topics/materials-science/diamond-like-carbon-coating
- https://shodhganga.inflibnet.ac.in/bitstream/10603/10477/10/10_chapter1.pdf
- https://www.anton-paar.com/corp-en/services-support/document-finder/application-reports/characterization-of-hard-coatings-part-i-diamond-like-carbon-dlc-coatings/
- https://www.ibccoatings.com/dlc-coating-diamond-like-carbon-coating-ceratough-d
- https://www.ionbond.com/technology/dlc-coatings-diamond-like-carbon/
- An updated overview of diamond-like carbon coating in tribology
- https://www.marketwatch.com/press-release/global-diamond-like-carbon-coating-market-top-trends-growth-regional-overview-segments-demand-key-players-business-analysis-application-and-global-forecast-to-2028-2019-04-16
- https://www.prnewswire.com/news-releases/global-diamond-like-carbon-dlc-market-is-projected-to-reach-us-24-billion-by-2025-transparency-market-research-677370353.html
- https://www.transparencymarketresearch.com/diamond-like-carbon-market.html
- https://www.bloomberg.com/profile/company/3433:JP
- https://www.think-lab.com/en/about/#b03
- https://www.tocalo.co.jp/english/rd/index.html
- https://www.stararc-coating.com/about.asp?id=102

8.2. Appendix B: IPC Definitions

IPC	Definition
A61L	METHODS OR APPARATUS FOR STERILISING MATERIALS OR OBJECTS IN GENERAL; DISINFECTION, STERILISATION, OR DEODORISATION OF AIR; CHEMICAL ASPECTS OF BANDAGES, DRESSINGS, ABSORBENT PADS, OR SURGICAL ARTICLES; MATERIALS FOR BANDAGES, DRESSINGS, ABSORBENT PADS, OR SURGICAL ARTICLES
B01J	CHEMICAL OR PHYSICAL PROCESSES, e.g. CATALYSIS OR COLLOID CHEMISTRY; THEIR RELEVANT APPARATUS
B23B	TURNING; BORING (using an electrode which takes the place of a tool)
B32B	LAYERED PRODUCTS, i.e. PRODUCTS BUILT-UP OF STRATA OF FLAT OR NON-FLAT, e.g. CELLULAR OR HONEYCOMB, FORM
C01B	NON-METALLIC ELEMENTS; COMPOUNDS THEREOF
C23C	COATING METALLIC MATERIAL; COATING MATERIAL WITH METALLIC MATERIAL; SURFACE TREATMENT OF METALLIC MATERIAL BY DIFFUSION INTO THE SURFACE, BY CHEMICAL CONVERSION OR SUBSTITUTION; COATING BY VACUUM EVAPORATION, BY SPUTTERING, BY ION IMPLANTATION OR BY CHEMICAL VAPOUR DEPOSITION, IN GENERAL
C23C 14/00	Coating by vacuum evaporation, by sputtering or by ion implantation of the coating forming material
C23C 14/06	characterised by the coating material
C23C 14/35	by application of a magnetic field, e.g. magnetron sputtering
C23C 16/00	Chemical coating by decomposition of gaseous compounds, without leaving reaction products of surface material in the coating, i.e. chemical vapour deposition (CVD) processes
C23C 16/27	Diamond only
C25D	PROCESSES FOR THE ELECTROLYTIC OR ELECTROPHORETIC PRODUCTION OF COATINGS; JOINING WORKPIECES BY ELECTROLYSIS; APPARATUS THEREFOR
G11B	INFORMATION STORAGE BASED ON RELATIVE MOVEMENT BETWEEN RECORD CARRIER AND TRANSDUCER
H01M	PROCESSES OR MEANS, e.g. BATTERIES, FOR THE DIRECT CONVERSION OF CHEMICAL ENERGY INTO ELECTRICAL ENERGY

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