



POLITECNICO
MILANO 1863



Carbon allotrope-based textile biosensors: a patent landscape analysis

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Politecnico di Milano

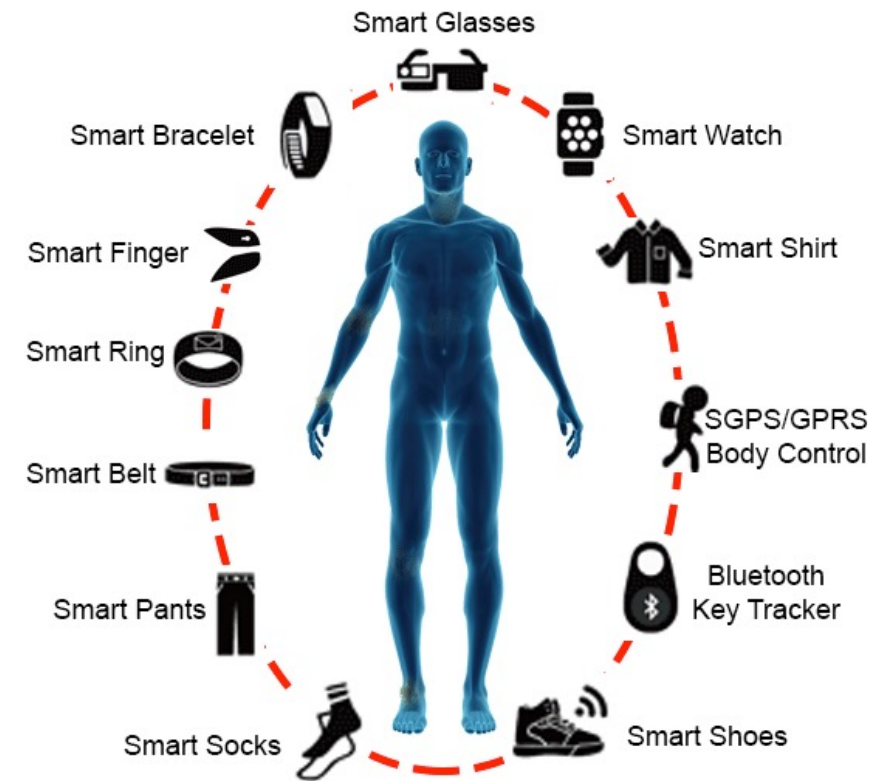
Introduction

Wearable sensors are a wide category of products and body-worn accessories to provide human data about health status and behaviour.

Textile sensors can be directly embedded in our garments and usually dedicated to bioelectrical signals.

Among the the explored and exploited conductive fibres, **carbon allotrope based yarns** have been widely used.

Graphene is one of the last material.



Introduction

In research, it is important to provide a wide and complete analysis for applications and production processes.

Patent landscape analysis (PLA) → a tool able to provide an overview of a specific technical field.

- To find out the most recent inventions;
- To study the development of a particular technology.

Documents searched:

- Granted patents / Utility models;
- Patent applications.

Methods: Patent databases

Free of charge sources

✓ (provided by national or regional patent offices)

Espacenet, Patentscope

✓ (provided by independent producers)

GOOGLE PATENTS, Free Patents Online, The Lens

Fee-based sources

✓ Orbit Intelligence, Derwent Innovation, Patbase, Octimine, etc...

Methods: Patent databases

- **Coverage** [Countries (EP, US, CN) and number and types of documents] (<https://www.epo.org/searching-for-patents/technical/patent-additions.html>)

Type of data (bibliographic or full-text)

Search engine

Search for «Textile electrode and carbon nanotube» in the Title/Abstract/Claims field


Espacenet: (ctxt=("textile" prox/distance<3 "electrode?") OR ctxt=("textile " prox/distance<3 "sensor?")) AND ftxt=("carbon " prox/ordered "nanotube?")

```
(C)QUESTEL
Base : FAMPAT
SEARCH STRATEGY
-----
SS Results
3      154      1 AND      2
2      242213  (CARBON 1D NANOTUBE?)/TI/AB/CLMS/DESC/ODES/ICLM
1      1501   ((TEXTILE 3D SENSOR?)/TI/AB/CLMS/ICLM OR (TEXTILE 3D ELECTRODE?)/TI/AB/CLMS/ICLM)
```

Database	Results
Espacenet	110
Orbit	154

Methods: Patent databases - coverage

Espacenet patent search



With its worldwide coverage and search features, Espacenet offers free access to information about inventions and technical developments from 1782 to today.

[Open Espacenet](#) > [Open classic Espacenet](#)

> [National patent offices' databases](#)

Espacenet is accessible to beginners and experts and is updated daily. It contains data on more than 140 million patent documents from around the world. Supporting information can help you understand whether a patent has been granted and if it is still in force.

FullText Database		FullPat Database		FamPat Database		Design Database	
For full text coverage details available in the FamPat Database, please refer to the FullText Database section, as FamPat aggregates all such content.							
Week 2023-32 - Updated on August 14, 2023							
CC	Authority	From	Until	Publications	Kind Codes	Last Input Week	
AM	Armenia	2001/06/10	2006/09/15	Patent Publication	A2	2021-15	
		2009/10/26	2010/04/26	Utility model	U	2020-08	
AP	ARIPO	1985/07/03	2017/03/29	Patent	A	2023-32	
		1971/03/07	2017/07/31	Application filed, as announced in the Gazette published by this office	A0	2023-32	
		1971/03/07	2017/07/31	Patent application filed	D0	2023-32	
		1998/03/13	2019/06/03	Design application	S	2023-29	
		1991/01/11	2019/06/24	Registered design	S1	2023-32	
		2002/06/06	2002/06/06	Utility model	U	2022-02	
		1963/03/27	2023/06/28	Independent patent application	A1	2023-32	
		1991/02/28	2023/06/28	Divisional patent application	A2	2023-32	
		1990/05/31	2023/05/03	Additional patent application	A3	2023-32	
		AR	Argentina	1996/03/20	2023/06/21	Independent utility model application	A4
1996/03/20	2022/06/08			Divisional utility model application	A5	2023-03	
1996/03/20	2017/12/13			Additional utility model application	A6	2023-32	
1973/02/08	1991/11/29			Patent of importation	Q	2023-32	
1914/05/01	2006/09/15			Published application	A	2023-32	
2005/10/15	2023/07/15			Revocation of published examined application	A1	2023-32	
		2005/10/15	2023/07/15	Published application w / o search report	A2, A4	2023-32	

https://static.orbit.com/imagination/orbit_welcome/prd/coverage/coverage.htm

Bibliographic coverage: <https://www.epo.org/searching-for-patents/technical/patent-additions.html>

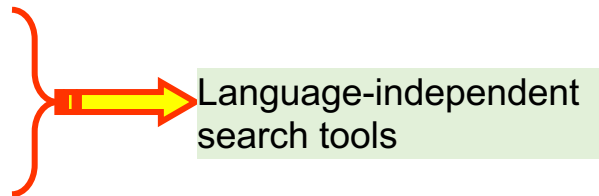
Full text coverage: <https://www.epo.org/searching-for-patents/technical/full-text-additions.html>

Patent searching

Scope of patent searches: to find out documents that claim similar technical features and not a mere match of words.

A patent search may be carried out:

- by keywords (intuitive but subjective)
- by classification codes
- by citations



Operators:

- 📌 Boolean (AND OR NOT)
- 📌 proximity (prox/distance<nr; Kw1 nd Kw2)

Language used: English

Operators

Operator	Example in Smart search	Description
Boolean operators ³	AND pa=bosch AND pa=siemens	will retrieve documents where both Bosch and Siemens are applicants
	OR in=smith OR in=huber	will retrieve documents where the inventor's name is Smith or Huber
	NOT txt=laser NOT semiconductor	will retrieve documents containing laser, while excluding documents containing semiconductor
Proximity operators	prox/distance<nr mouse prox/distance<3 trap	will retrieve documents where mouse and trap are fewer than three words apart, independently of the order in which mouse and trap appear
	prox/distance<nr/ordered mouse prox/distance<3/ordered trap	will retrieve documents where mouse and trap occur in that order and are fewer than three words apart
	prox/ordered mouse prox/ordered trap	will retrieve documents where mouse appears before trap
	prox/unit=sentence mouse prox/unit=sentence trap	will retrieve, in the first example, documents where mouse and trap occur in the same sentence
	cpc=(C08F220/38 prox/unit=sentence (EP)) cpcc=(C08F218/08 prox/unit=sentence (C08F220/06, US, EP))	will retrieve, in the second example, documents with the classification symbol C08F220/38 assigned by EP will retrieve, in the third example, documents with the C-sets C08F218/08 and C08F220/06 assigned by US and EP
prox/unit=paragraph mouse prox/unit=paragraph trap	will retrieve documents where mouse and trap occur in the same paragraph	
Comparison operators ⁴	all ti all "paint brush head"	will retrieve documents containing all words entered within quotes but not necessarily in the order in which the words appear
	any ⁵ ti any "motor engine"	will retrieve documents containing any of the words entered within quotes
	= pa=siemens pa = "siemens ag"	will retrieve documents where either Siemens or Siemens AG are applicants
	> pd > 1998	will retrieve documents having a publication date after 1998
	>= pd >= 1998	will retrieve documents having a publication date in or after 1998
	< pd < 1998	will retrieve documents having a publication date before 1998
	<= pd <= 2018	will retrieve documents having a publication date in or before 2018
	within pd within "1998 2018" pd within "1998, 2018"	will retrieve documents published between 19980101 and 20181231.

Classification systems

Classification is a system of sorting inventions and their patent documents into technical fields covering all areas of technology. Every patent document is given a classification symbol by the examiner.

Patent offices developed classification systems in the 19th century in order to cope with the growing volume of patents and non-patent literature.

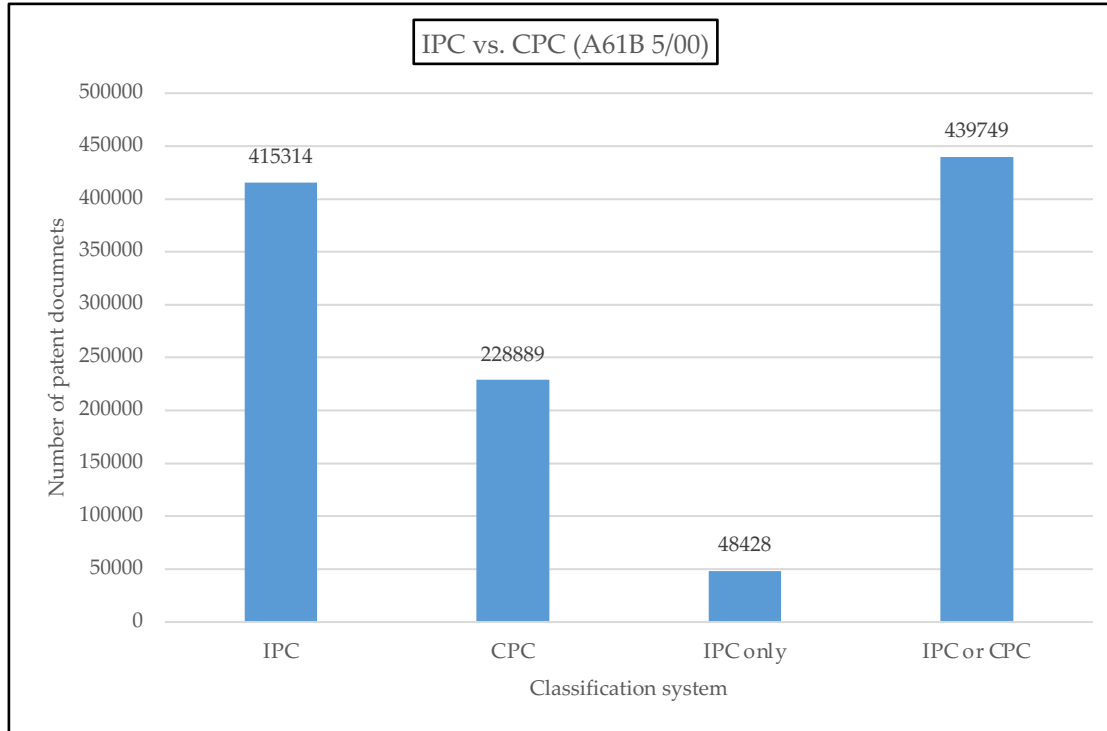
The most used patent classifications today are the IPC and the CPC.

The IPC is a **hierarchical classification** systems. The top level consists of 8 sections (A – H) which are divided into 80,000 subdivisions called classes, subclasses, groups and subgroups.

The CPC is an enhanced version of the IPC, uses the same structure as the IPC but with more subdivisions.

Classification system	No. of subgroups
IPC	80,000
CPC	250,000
File Index (FI)	190,000
F-terms	350,000

IPC vs CPC (Espacenet)



Query used on Espacenet to obtain patent documents classified with IPC symbols only:

```
ipc = "A61B5/00" NOT (cpc = "A" OR  
cpc = "B" OR cpc = "C" OR cpc = "D"  
OR cpc = "E" OR cpc = "F" OR cpc =  
"G" OR cpc = "H")
```

48,428 patent documents do not have any CPC code

Therefore, the exclusion of the IPC would lead to a limited patent search.

Resources and methods

Espacenet (<https://worldwide.espacenet.com>)
Orbit (<https://www.orbit.com>)

Field searched: **Title/Abstract/Claims/Full Text**

Classification systems: **IPC and CPC**

Espacenet search query

cl any "A61B5" AND ctxt=("textile" prox/distance<3 "sensor?") OR (cl any "A61B5" AND ctxt=("textile" prox/distance<3 "electrode?") OR (cpc any "D03D1/0088" AND (ftxt=("textile" prox/distance<3 "electrode?") OR ftxt=("textile" prox/distance<3 "sensor?")))) OR (cpc any "A41D1/002" AND (ftxt=("textile" prox/distance<3 "electrode?") OR ftxt=("textile" prox/distance<3 "sensor?")))) OR (cpc any "G06F1/163" AND (ftxt=("textile" prox/distance<3 "electrode?") OR ftxt=("textile" prox/distance<3 "sensor?")))) OR (cpc any "H01L23/5387" AND (ftxt=("textile" prox/distance<3 "electrode?") OR ftxt=("textile" prox/distance<3 "sensor?")))) OR (cpc any "H05K1/038" AND (ftxt=("textile" prox/distance<3 "electrode?") OR ftxt=("textile" prox/distance<3 "sensor?")))) OR (cpc any "A41D13/1281" AND (ftxt=("textile" prox/distance<3 "electrode?") OR ftxt=("textile" prox/distance<3 "sensor?")))) OR (cpc any "A61B2562" AND (ftxt=("textile" prox/distance<3 "electrode?") OR ftxt=("textile" prox/distance<3 "sensor?")))) OR (cpc any "A63B2230" AND (ftxt=("textile" prox/distance<3 "electrode?") OR ftxt=("textile" prox/distance<3 "sensor?")))) OR (cpc any "H05K2201" AND (ftxt=("textile" prox/distance<3 "electrode?") OR ftxt=("textile" prox/distance<3 "sensor?")))) OR (cl any "D06M" AND (ftxt=("textile" prox/distance<3 "electrode?") OR ftxt=("textile" prox/distance<3 "sensor?")))) AND (ftxt all "graphene" OR ftxt all "carbon nanotube?" OR ftxt all "carbon black" OR ftxt all "CNTs" OR ftxt all "SWCNTs" OR ftxt all "MWCNTs" OR ftxt all "graphene oxide" OR ftxt all "reduced graphene oxide" OR ftxt all "graphene nanosheet?" OR ftxt all "carbon allotrope?" OR cl =/low "C01B32/00" OR cpc =/low "C01B2204/00" OR cl =/low "B82Y"). [Query 1] → 227 results

Classification code	Classification system	Definition
A61B 5	IPC/CPC	Measuring for diagnostic purposes
D03D 1/0088	CPC	Fabrics having an electronic function
A41D 1/002	CPC	Garments with embedded cable or connector
G06F 1/163	CPC	Wearable computers
H01L 23/5387	CPC	Flexible insulating substrates
H05K 1/038	CPC	Printed circuits - textiles
A41D 13/1281	CPC	Garments with incorporated means for medical monitoring
A61B 2562	CPC (orthogonal indexing)	Details of sensors
A63B 2230	CPC (orthogonal indexing)	Measuring physiological parameters of the user
H05K 2201	CPC	Printed circuits
D06M	IPC/CPC	Treatment of fibers, yarns
C01B 32/00	IPC/CPC	Carbon compounds
C01B 2204/00	CPC	Structure or properties of graphene
B82Y	IPC/CPC	Specific uses or application of nanostructures
C08K 3/042	CPC	Uses of inorganic substances as compounding ingredients- Graphene or derivatives
C08K 3/041	CPC	Uses of inorganic substances as compounding ingredients- Carbon nanotubes
C01B 32/158	IPC/CPC	Carbon nanotubes
C01B 32/182	IPC/CPC	Graphene
C01B 32/198	IPC/CPC	Graphene oxide
C01P 2004/13	CPC (orthogonal indexing)	Particle morphology - Nanotubes

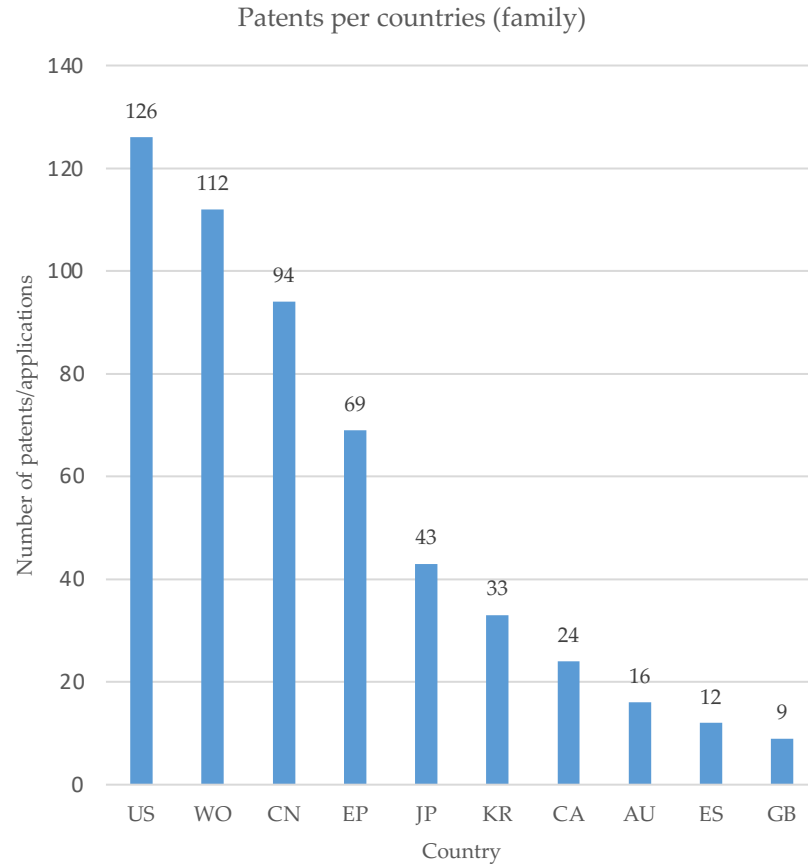
Orbit search query

Query No.	Results	Query
1	435	(((TEXTILE 3D SENSOR?)/TI/AB/CLMS/ICLM OR (TEXTILE 3D ELECTRODE?)/TI/AB/CLMS/ICLM) AND (A61B-005+)/IPC/CPC)
2	122	(((TEXTILE 3D SENSOR?)/TI/AB/CLMS/DESC/ODES/ICLM OR (TEXTILE 3D ELECTRODE?)/TI/AB/CLMS/DESC/ODES/ICLM) AND (D03D-001/0088)/CPC)
3	139	(((TEXTILE 3D SENSOR?)/TI/AB/CLMS/DESC/ODES/ICLM OR (TEXTILE 3D ELECTRODE?)/TI/AB/CLMS/DESC/ODES/ICLM) AND (A41D-001/002)/CPC)
4	49	(((TEXTILE 3D SENSOR?)/TI/AB/CLMS/DESC/ODES/ICLM OR (TEXTILE 3D ELECTRODE?)/TI/AB/CLMS/DESC/ODES/ICLM) AND (G06F-001/163)/CPC)
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7	86	(((TEXTILE 3D SENSOR?)/TI/AB/CLMS/DESC/ODES/ICLM OR (TEXTILE 3D ELECTRODE?)/TI/AB/CLMS/DESC/ODES/ICLM) AND (A41D-013/1281)/CPC)
8	444	(((TEXTILE 3D SENSOR?)/TI/AB/CLMS/DESC/ODES/ICLM OR (TEXTILE 3D ELECTRODE?)/TI/AB/CLMS/DESC/ODES/ICLM) AND (A61B-2562+)/CPC)
9	18	(((TEXTILE 3D SENSOR?)/TI/AB/CLMS/DESC/ODES/ICLM OR (TEXTILE 3D ELECTRODE?)/TI/AB/CLMS/DESC/ODES/ICLM) AND (A63B-2230+)/CPC)
10	69	(((TEXTILE 3D SENSOR?)/TI/AB/CLMS/DESC/ODES/ICLM OR (TEXTILE 3D ELECTRODE?)/TI/AB/CLMS/DESC/ODES/ICLM) AND (H05K-2201+)/CPC)
11	233	(((TEXTILE 3D SENSOR?)/TI/AB/CLMS/DESC/ODES/ICLM OR (TEXTILE 3D ELECTRODE?)/TI/AB/CLMS/DESC/ODES/ICLM) AND (D06M+)/IPC/CPC)
12	1167	1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11
13	1378171	(((GRAPHENE)/TI/AB/CLMS/DESC/ODES/ICLM OR (CARBON 1D NANOTUBE?)/TI/AB/CLMS/DESC/ODES/ICLM OR (CARBON 1D BLACK)/TI/AB/CLMS/DESC/ODES/ICLM OR (CNTS)/TI/AB/CLMS/DESC/ODES/ICLM OR (SWCNTS)/TI/AB/CLMS/DESC/ODES/ICLM OR (MWCNTS)/TI/AB/CLMS/DESC/ODES/ICLM OR (GRAPHENE 1D OXIDE)/TI/AB/CLMS/DESC/ODES/ICLM OR (REDUCED 1D GRAPHENE 1D OXIDE)/TI/AB/CLMS/DESC/ODES/ICLM OR (GRAPHENE 1D NANOSHEET?)/TI/AB/CLMS/DESC/ODES/ICLM OR (CARBON 1D ALLOTROPE?)/TI/AB/CLMS/DESC/ODES/ICLM) OR ((C01B-032+)/IPC/CPC OR (C01B-2204/00)/CPC OR (B83Y+)/IPC/CPC OR (C08K-003+)/IPC/CPC OR (C01P-2004+)/CPC)
14	288	12 AND 13
15	238	14 AND STATE/ACT=ALIVE

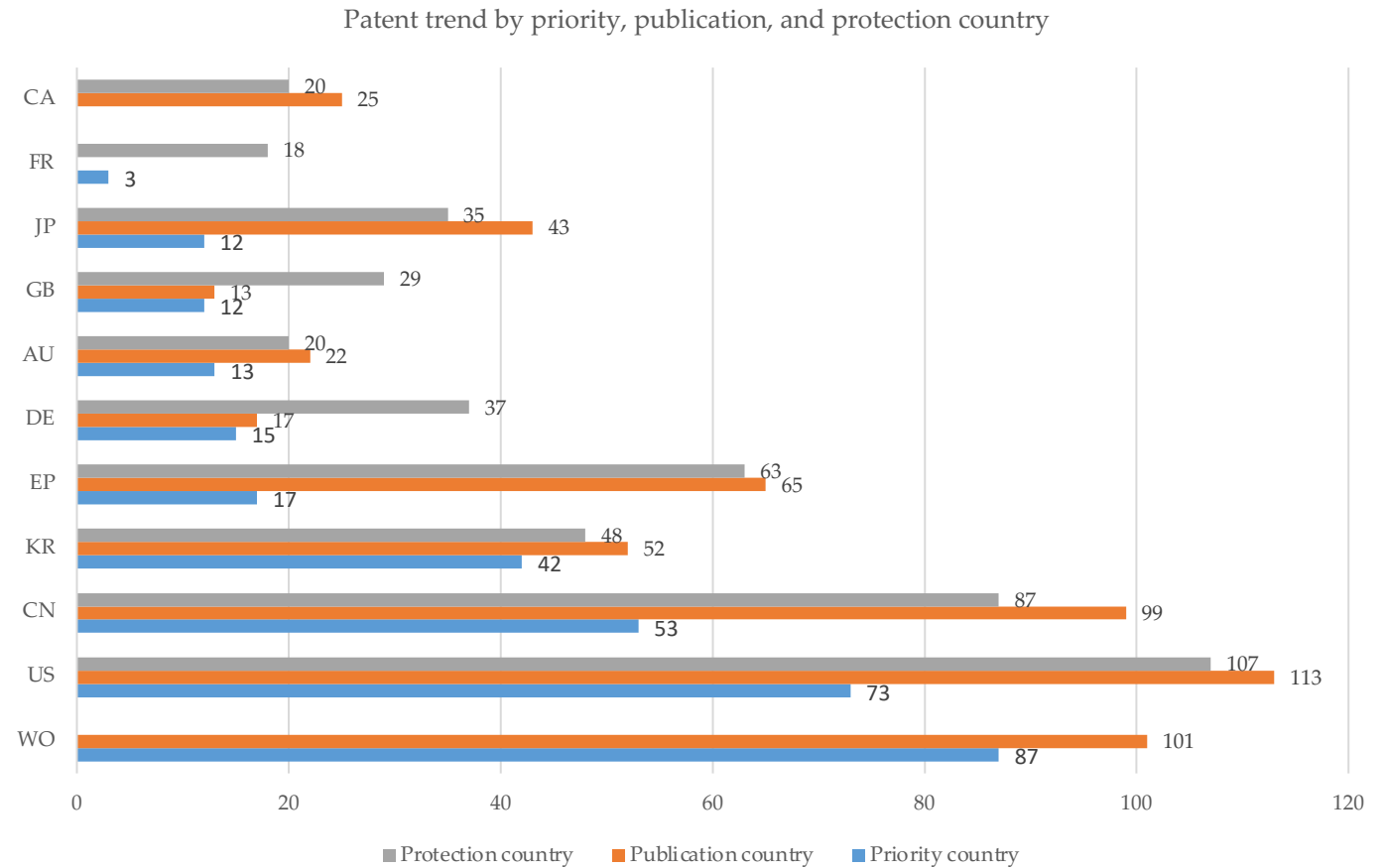
238 are active patents

148 granted and **90** pending applications

Results (publication country)



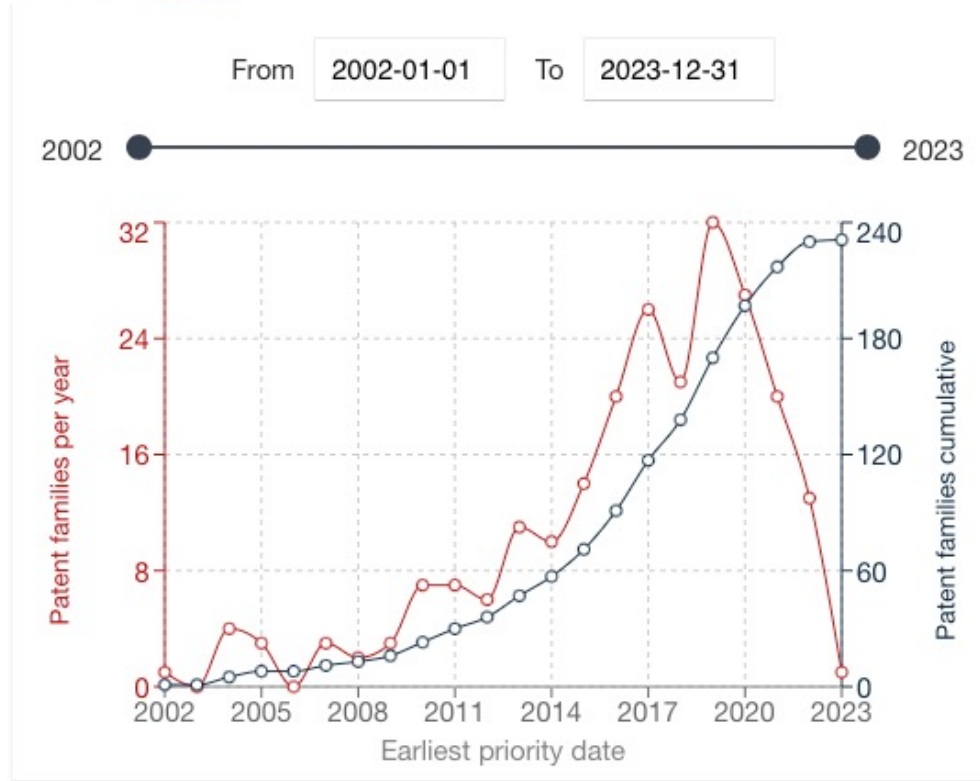
Espacenet results



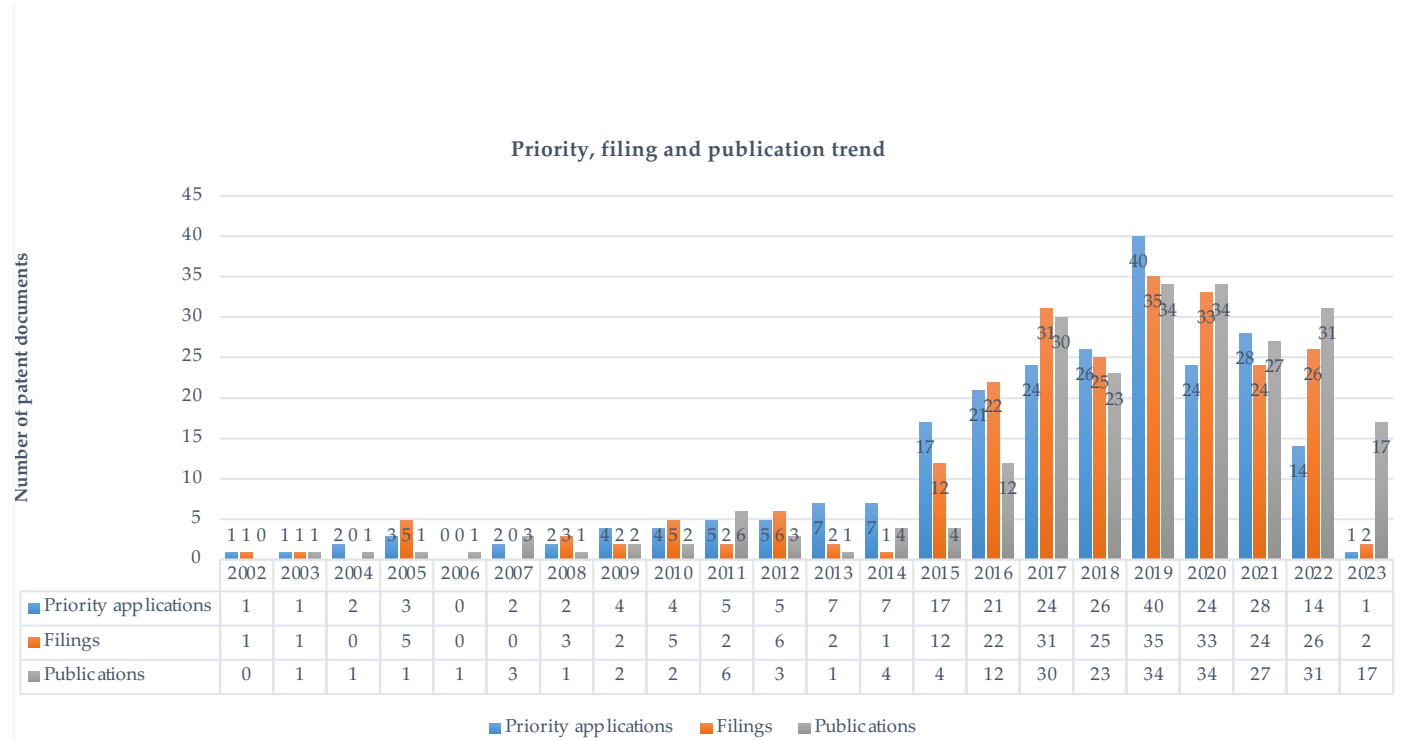
Orbit results

Results (filings trend)

Home > Results

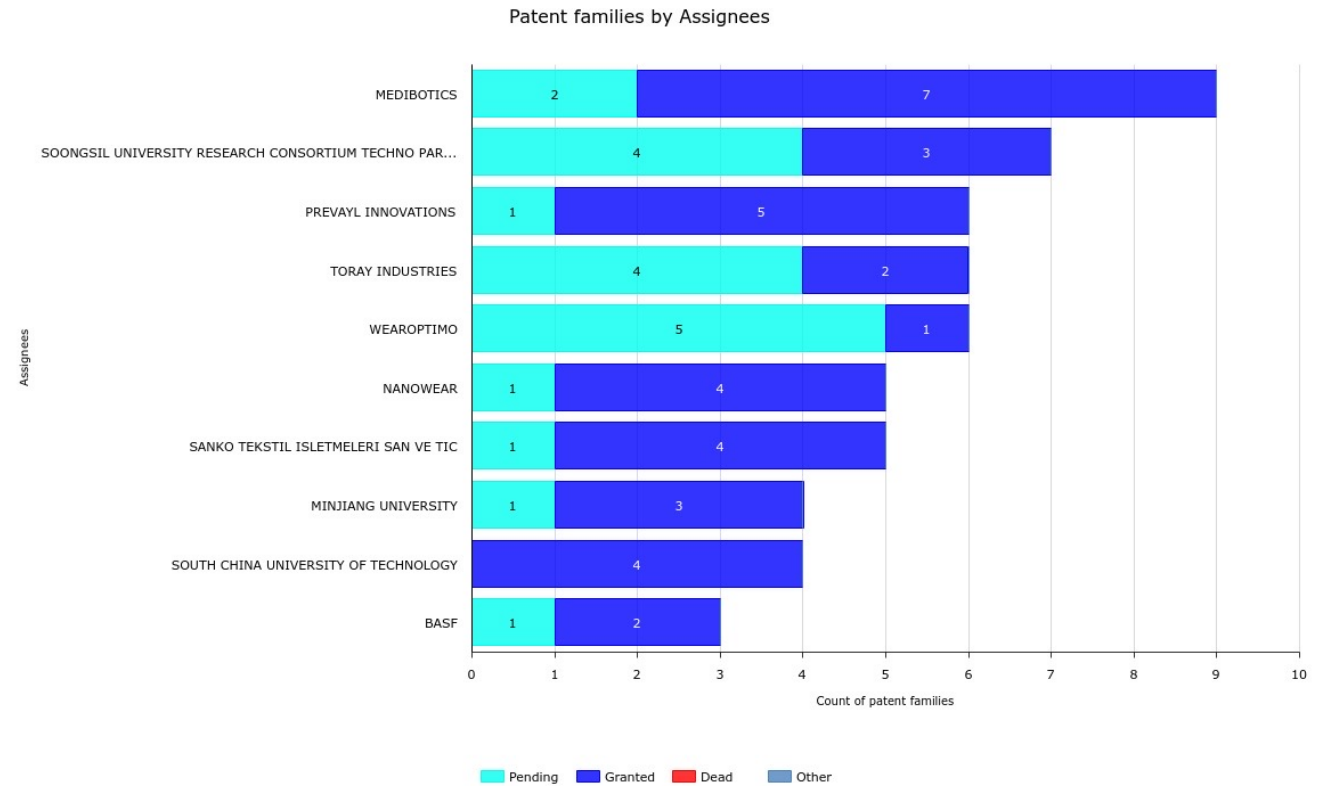
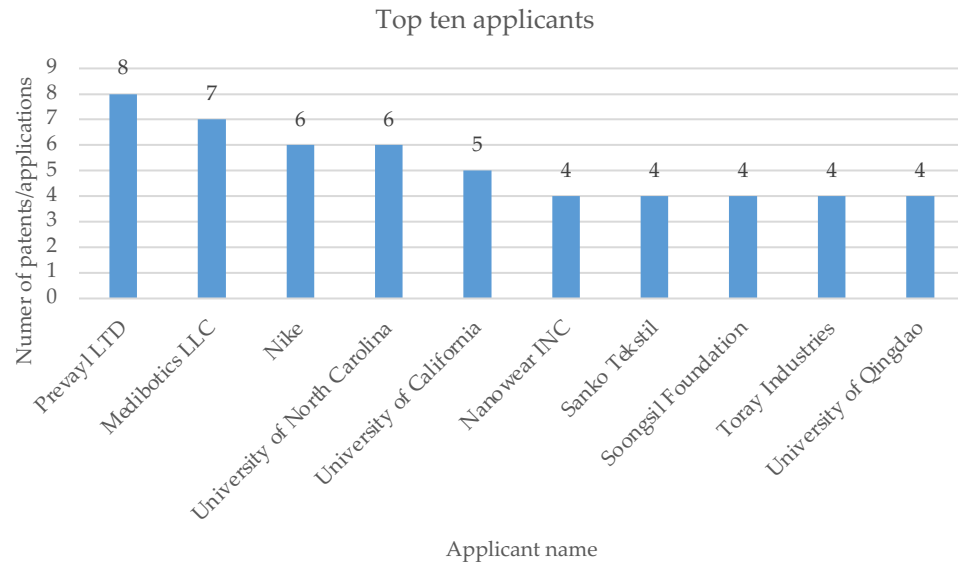


Espacenet results



Orbit results

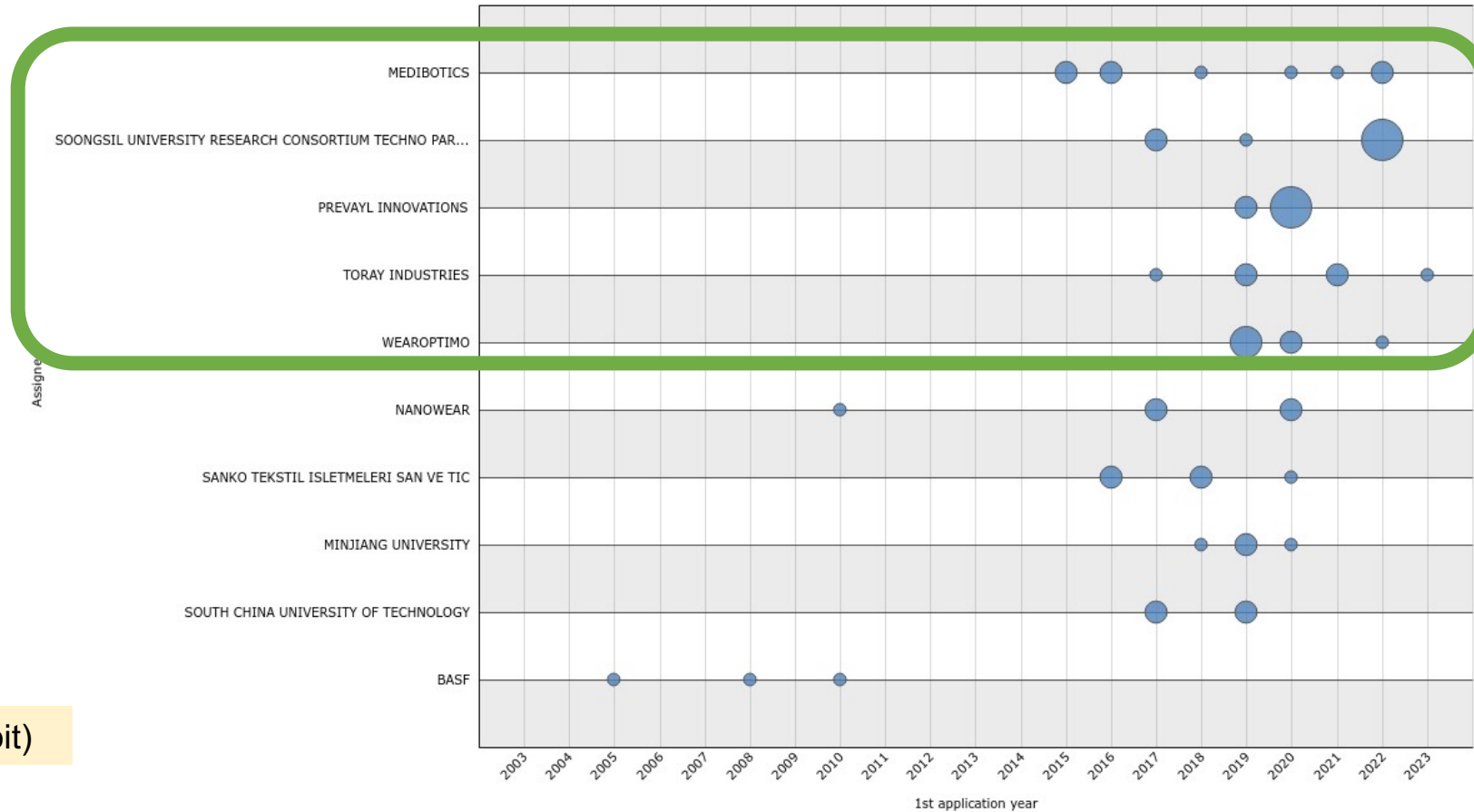
Results (top applicants)



Espacenet results

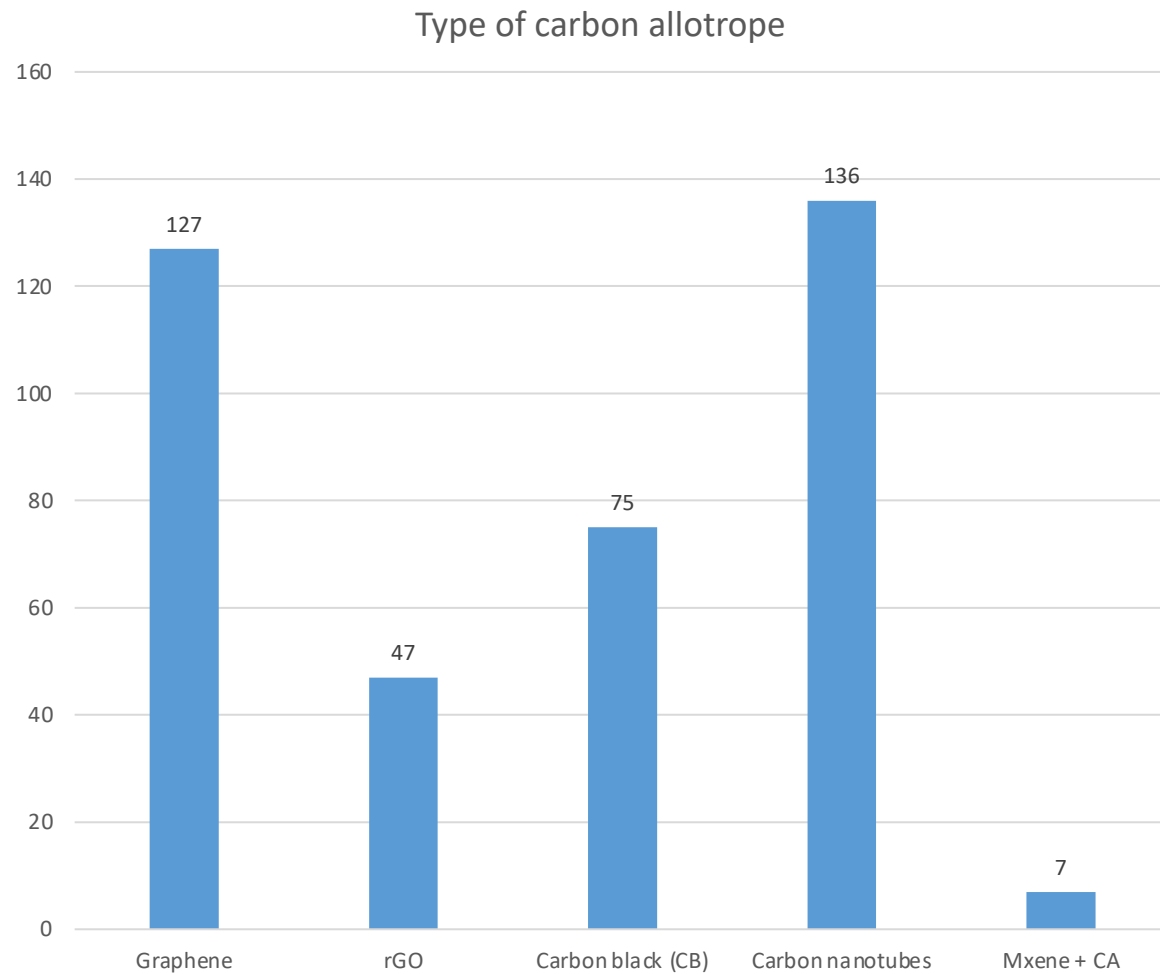
Orbit results

Investment trend for key players

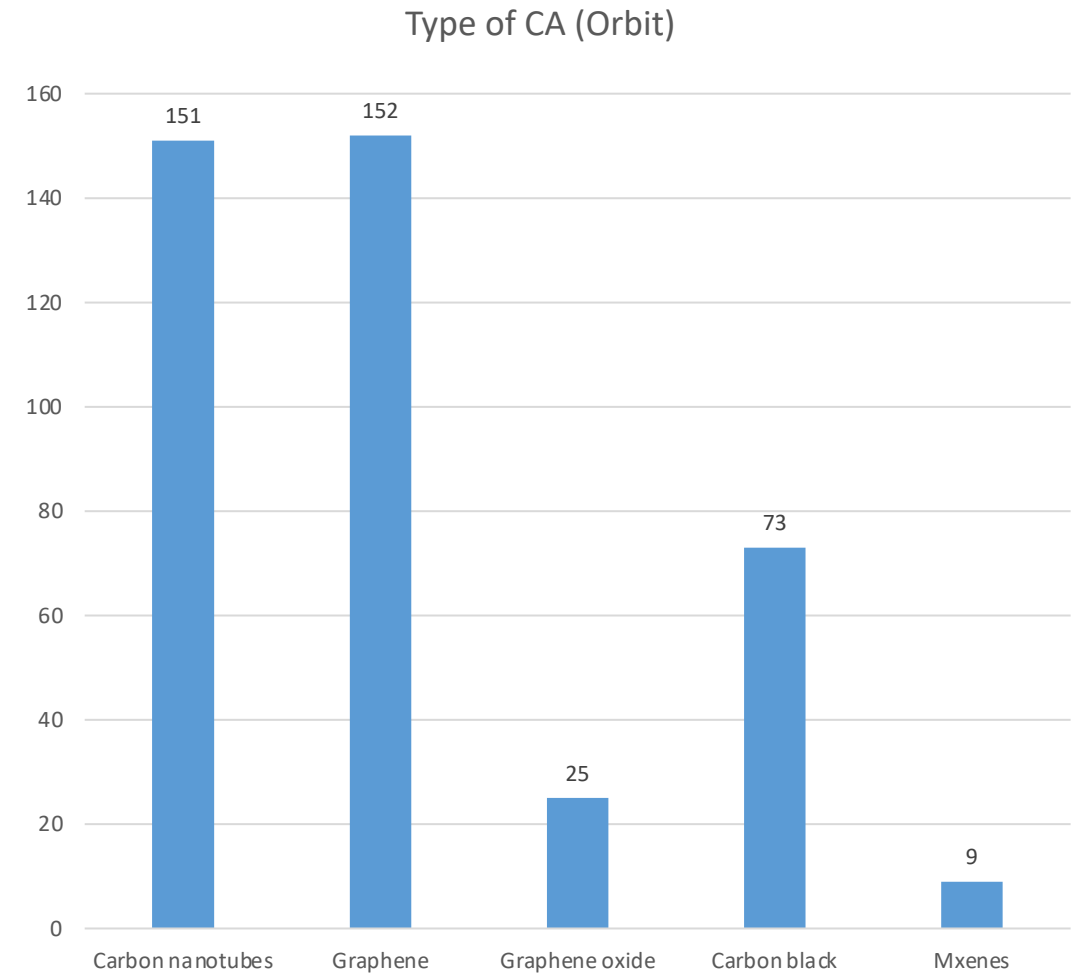


Data: FamPat (Orbit)

Results (type of carbon allotrope)



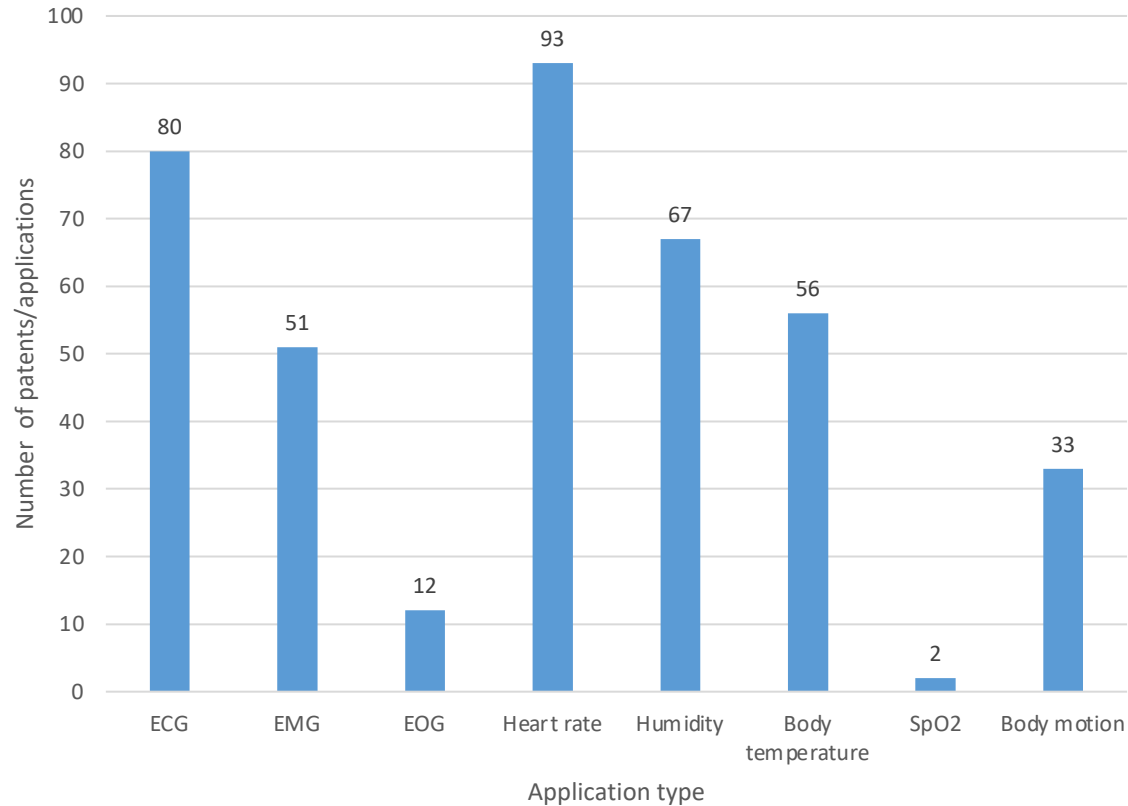
Espacenet results



Orbit results

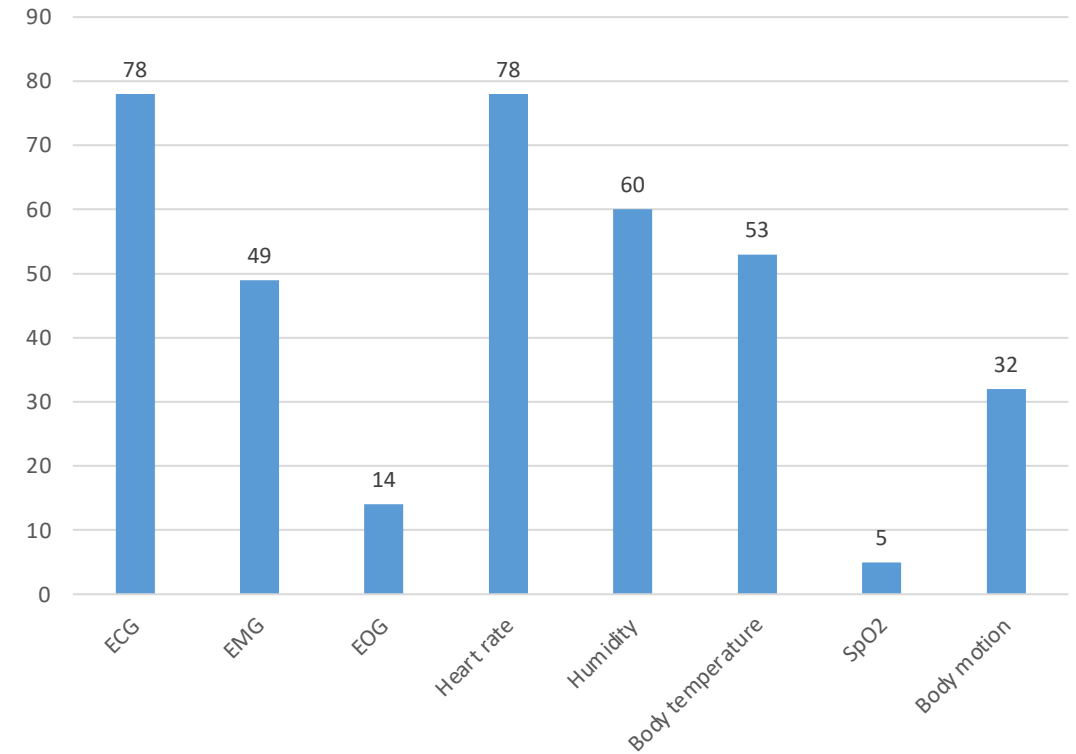
Results (type of application)

Number of patents per application



Espacenet results

Type of application



Orbit results

Results (top cited patents)

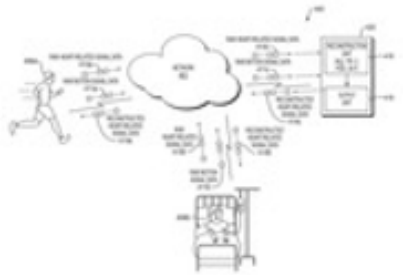
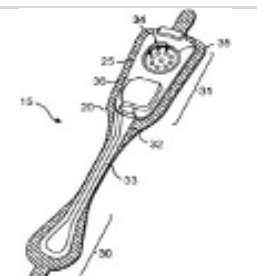
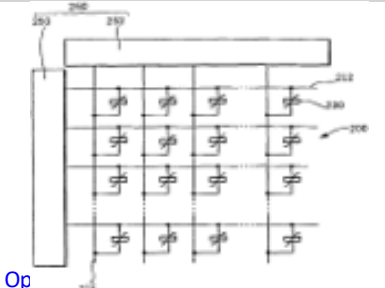
Patent number	Filing year of the earliest priority	Geographical scope of protection	Forward citations	Applicant
EP2404148	2008	14	8	PatienTech
EP1578482	2002	9	7	Philips
EP3116395	2015	4	6	L.I.F.E.
US11300551	2004	1 (US)	6	Rondevoo Technologies
EP2866596	2013	22	4	Smart Solutions Technologies
EP3202317	2012	7	4	Nippon T&T
WO2011103808	2010	2	4	Hong Kong Institute of Textile and Apparel
EP1814713	2004	7	3	University of Texas
US10321873	2013	1	3	Medibotics
US8191433	2008	2	3	Hong Kong Polytechnic University

Considering the geographical scope of protection, the number of forward citations and the expiration dates, the most valuable patents are

- **EP2404148** (“*Elastically stretchable fabric force sensor arrays and methods of making*”)
- **EP3116395** (“*Physiological monitoring garments*”)
- **EP2866596** (“*Electronic textile assembly*”)

Data: FamPat (Orbit)

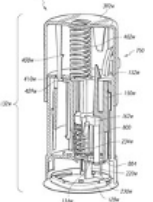
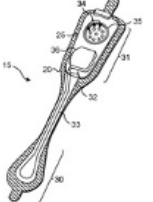
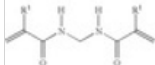
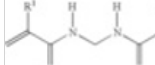
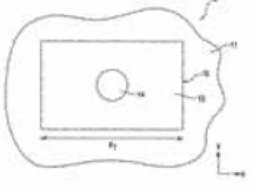
Litigated patents

Earliest priority number	Earliest priority date	Title	Current assignees	Images
2004US-60626314	09/11/04	(EP1814713) The fabrication and application of nanofiber ribbons and sheets and twisted and non-twisted nanofiber yarns	CSIRO - COMMONWEALTH SCIENTIFIC & INDUSTRIAL RESEARCH ORGANISATION UNIVERSITY OF TEXAS	
2015US-62172862	2015-06-09	(EP3307141) Method and apparatus for heart rate monitoring using an electrocardiogram sensor	UNIVERSITY OF CONNECTICUT	 <p>Open</p>
2013US-14080717	2013-09-25	(EP3847966) Electrocardiography monitor configured for self-optimizing ecg data compression	ALLEN MEDICAL SYSTEMS BARDY DIAGNOSTICS BREATHE TECHNOLOGIES HILL ROM HILL ROM HOLDINGS HILL ROM SERVICES VOALTE WELCH ALLYN	 <p>Open</p>
2004US-60560053	06/04/04	(US11300551) Nano sensor	AVAILABLEIP COM TRAN, BAO	 <p>Op</p>

Opposed patents

EP2126190: Opposition rejected

EP1966431: Patent maintained as amended

Earliest priority number	Earliest priority date	Title	Current assignees	Images
2015US-62272983	30/12/15	(EP4026488) Transcutaneous analyte sensor systems and methods	DEXCOM	 Open
2013US-14080717	2013-09-25	(EP3847966) Electrocardiography monitor configured for self-optimizing ecg data compression	ALLEN MEDICAL SYSTEMS BARDY DIAGNOSTICS BREATHE TECHNOLOGIES HILL ROM HILL ROM HOLDINGS HILL ROM SERVICES VOALTE WELCH ALLYN	 Open
2007EP-0102689	2007-02-20	(EP2126190) Method for producing metallised textile surfaces using electricity-generating or electricity-consuming elements	BASF	 Open
2005DE-10062028	2005-12-22	(EP1966431) Method for producing planar metallised textile structures, planar metallised textile structure and use of the thus produced planar metallised textile structure	BASF NORENBERG RALF	 Open
2002GB-0030361	2002-12-27	(EP1578482) Electrode arrangement	PHILIPS PHILIPS ELECTRONICS	 Open

Conclusions

- Global patenting on carbon allotrope fibres is led by US and China
- The patenting trend since 2002 shows an increase in filings number starting from 2015 until 2019, with a decline in 2020 and an upswing in 2021
- Medibotics, Prevalyl, Soongsil University, Toray and WearOptimo are the key players
- Graphene and carbon nanotubes are the most used CA
- Cardiac monitoring with ECG measurement and heart rate analysis are the principal applications