



POLITECNICO
MILANO 1863

Nanostructured Composites of 2D Materials and Proteins: a Patent Landscape Analysis

28.10.2025 | Massimo Barbieri



Materiali da Proteine
BIOECONOMY DIALOGUES 2025
SECOND EDITION

Agenda

1. Introduction

Patent searches (PLA)

Patent databases

2. Method

Search queries

3. Results

4. Discussion

Technology Transfer

Patentability



Introduction

01

Introduction

To avoid «reinventing the wheel» (waste of R&D resources)

To avoid infringement of other companies' patents

To write a better patent application

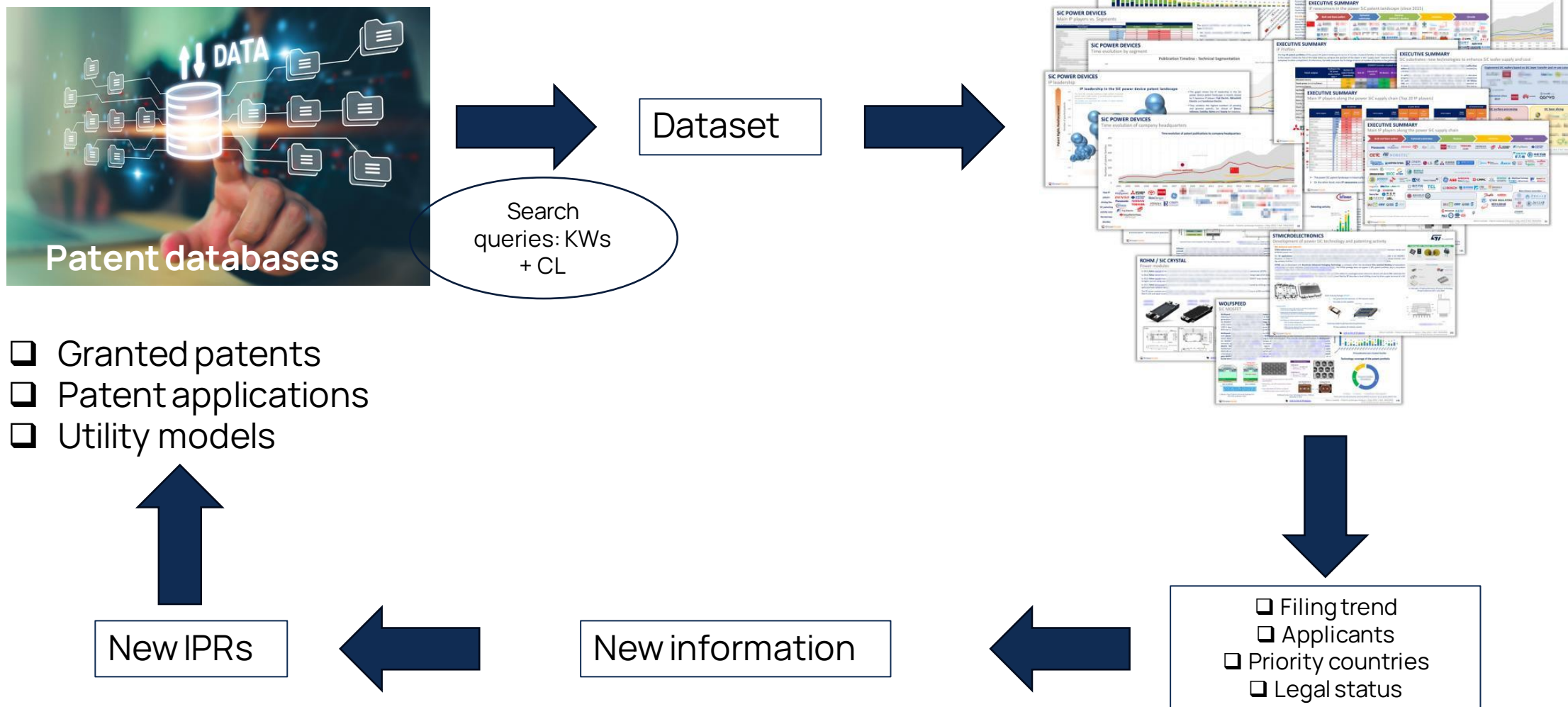
To speed up the prosecution of a patent

To find out the most recent inventions

To study the development of a particular technology

Patent landscape

Introduction (PLA)



Introduction (patent databases)

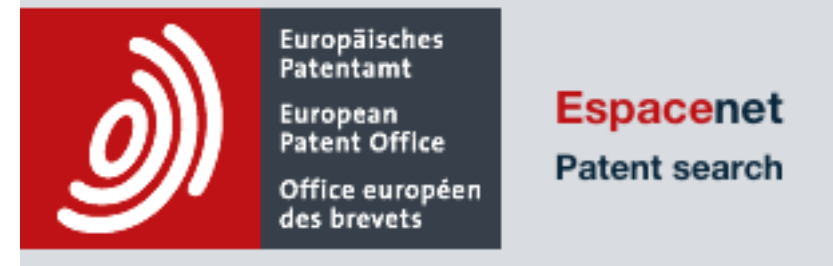
Free of charge sources

- ✓ (provided by national or regional patent offices)

Espacenet, Patentscope

- ✓ (provided by independent producers)

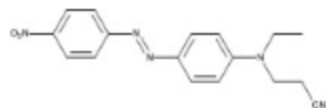
GOOGLE PATENTS, Free Patents Online, The Lens



Fee-based sources

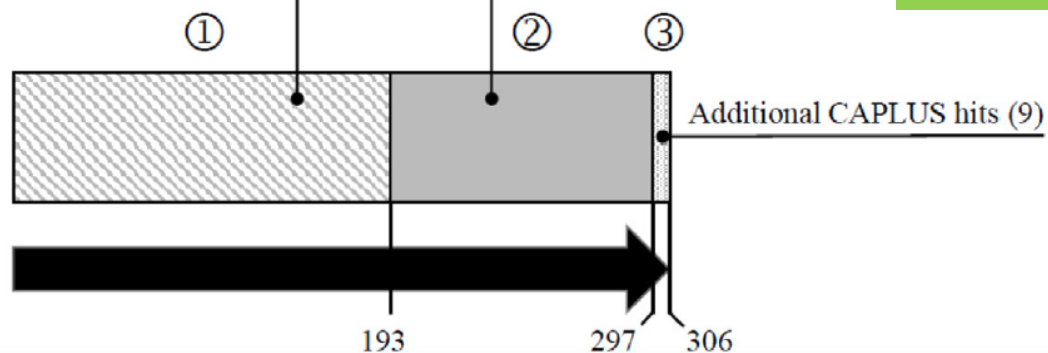
- ✓ Orbit Intelligence, Octimine, Patsnap, Ambercite AI, etc...

Are patent databases complete? (1)



Combined SciWalker, Patentscope,
SureChEMBL hits (193)

Additional FullPat hits (104)



10 patent families were not found in FullPat

Most unique hits were found in FullPat (102). In contrast, CAPLUS (9), SureChEMBL (2), and SciWalker (1) retrieved much less.

World Patent Information 66 (2021) 102055



Contents lists available at ScienceDirect

World Patent Information

journal homepage: www.elsevier.com/locate/worpatin



Current methodologies for chemical compound searching in patents: A case study

Joerg Ohms

Wissinfo GmbH, 79106 Freiburg, Germany

Are patent databases complete? (2)

Use of **AI and semantic engines** in prior art searching

EP patent applications published from **2019 to 2021** in the field of chemistry → 47 documents were selected in which only “A” rated prior art documents were listed in the ISR, and of these 47 cases, **16 were included in the study**.

Each case had previously been the subject of **opposition proceedings**, which introduced new patent citations not present in the original International Search Report (ISR).

All tools successfully located at least some opposition citations.



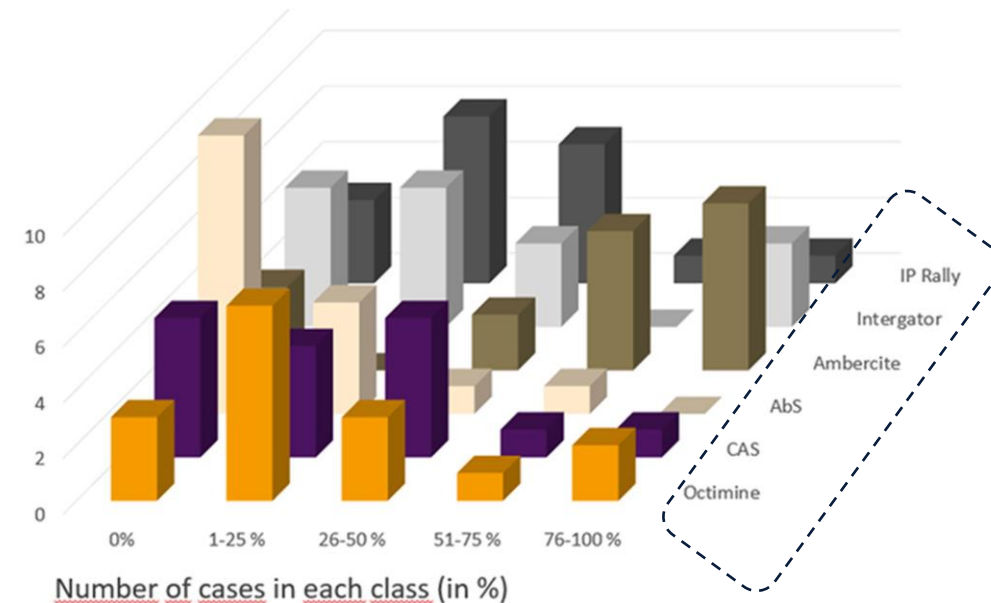
World Patent Information

Volume 82, September 2025, 102358



Evaluating the effectiveness of ranking-based patent search engines for identifying relevant prior art: A comparative study in the area of chemistry

David Rees , Manuel Wirz





Method

02

Method - 1

1. **Database:** Espacenet (offers free access to **more than 150 million patent documents worldwide**, containing information about inventions and technical developments from 1782 to today - <https://www.epo.org/en/searching-for-patents/data/coverage/weekly>)

2. **KWs + Classification symbols**

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.

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

3. Search fields: **Title/Abstract/Claims + Full text**

Method – 2 (2D nanomaterials)

Non-metallic 2D materials

- Graphene, Hexagonal Boron Nitride, Phosphorene and Graphitic Carbon Nitrides

Transition metal compounds

- MXenes, Layered Double Hydroxides and Transition Metal Dichalcogenides

Metallenes

- pure metal atoms with unsaturated coordination (stanene, bismuthene, ...)

Method – 3 (Query strategy for «graphene»)

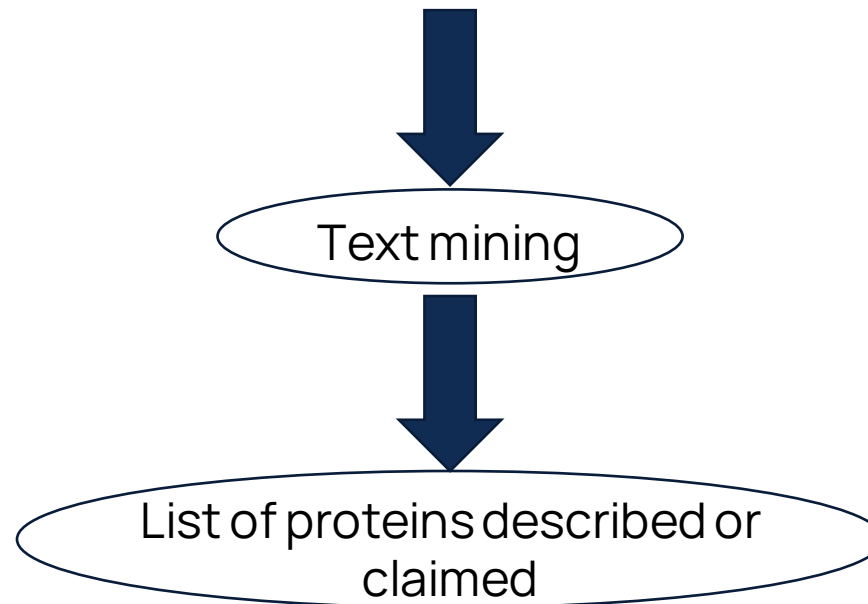
ctxt=("protein" prox/distance<3/ordered "graphene")

Query language: en / de / fr Filters: Earliest priority date: 2004-01-01 — 2024-12-31 ✕

131 results

ctxt=("protein" prox/distance<3/ordered "graphene") OR (cl all "C08L89/00" AND (ctxt all "graphene" OR cl all "C08K3/042" OR cl all "C01B32/182"))

449 results



Broaden the search using proteins' names instead of generic term "protein"

Method - 4 (classification symbols used in the “graphene query”)

C08L 89/00 **Compositions of proteins; Compositions of derivatives thereof (foodstuff preparations A23J 3/00)**

▲ ☐ **C01B 32/00** **Carbon; Compounds thereof (C01B 21/00, C01B 23/00 take precedence; percarbonates C01B 15/10; carbon black C09C 1/48)**

- ☐ **C01B 32/15** • Nano-sized carbon materials
- ☐ **C01B 32/182** •• Graphene
- ☐ **C01B 32/184** ••• Preparation
- ☐ **C01B 32/188** •••• by epitaxial growth

▲ ☐ **C08K 3/00** **Use of inorganic substances as compounding ingredients**

- ☐ **C08K 3/02** • Elements
- ☐ **C08K 3/04** •• Carbon
- ☐ **C08K 3/041** ••• {Carbon nanotubes}
- ☐ **C08K 3/042** ••• {Graphene or derivatives, e.g. graphene oxides}
- ☐ **C08K 3/043** ••• {Carbon nanocoils}
- ☐ **C08K 3/044** ••• {Carbon nanohorns or nanobells}
- ☐ **C08K 3/045** ••• {Fullerenes}
- ☐ **C08K 3/046** ••• {Carbon nanorods, nanowires, nanoplatelets or nanofibres}

Method - 5 (Query strategy for «graphene»)

Objective: to obtain a complete dataset for each 2D nanomaterial

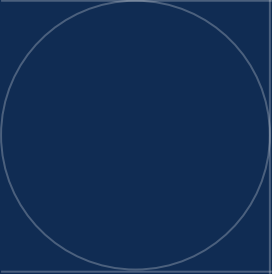
~~ctxt=("protein" prox/distance<3/ordered "graphene")~~

ctxt=("gelatin" prox/distance<3/ordered "graphene") OR ("albumin" prox/distance<3/ordered "graphene ...

Use the filter (cl any "B82Y" OR ftxt all "nanocomposite?" OR ftxt all "bionanocomposite?" OR ftxt=("nano" prox/unit=sentence "composite?"))" to obtain a very comprehensive and specific dataset (to be used if the number of results is greater than 20)

Method - 6 (Final query for graphene)

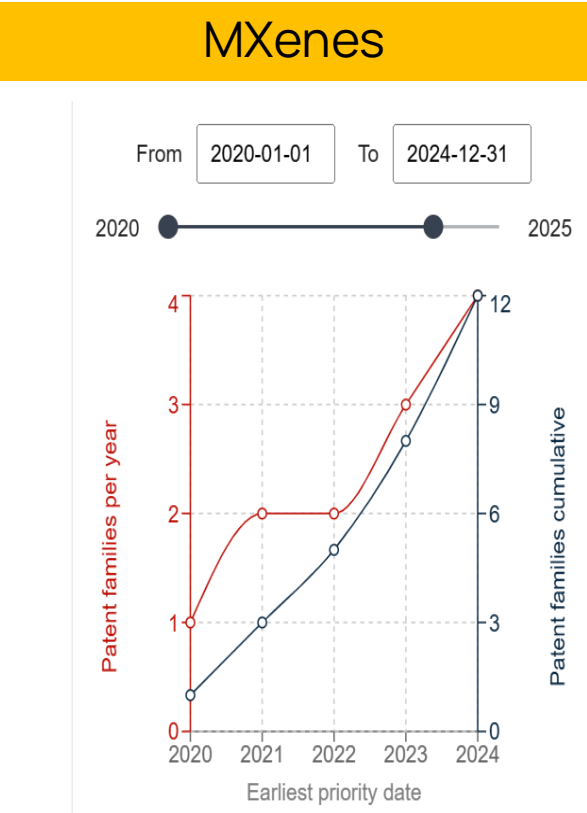
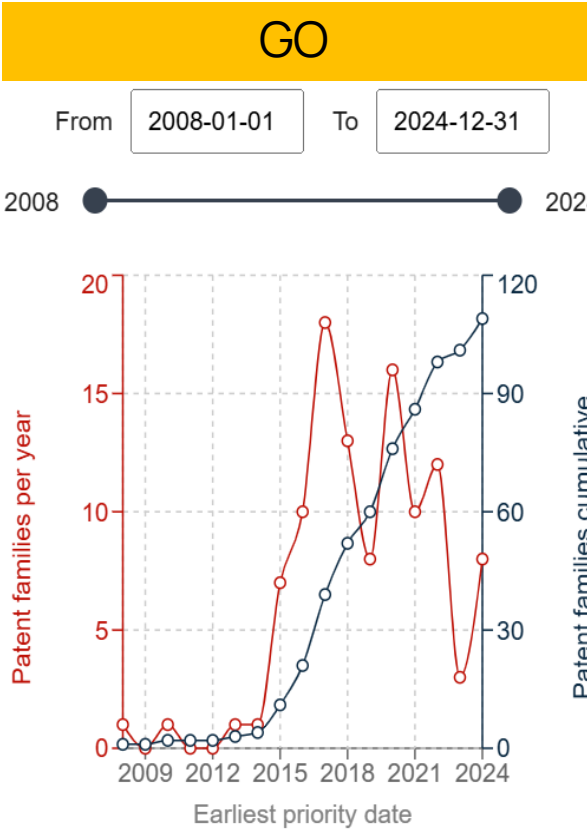
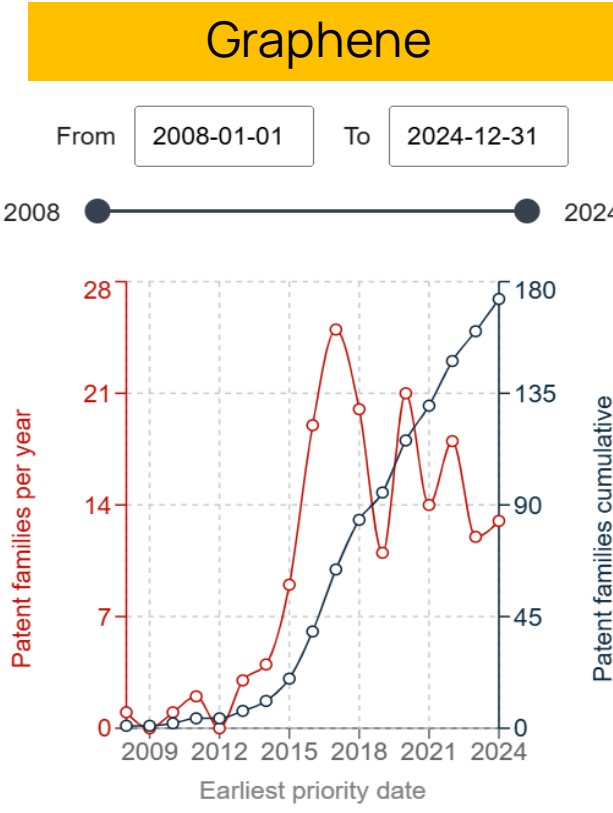
(ctxt= ("albumin" prox/distance<3/ordered "graphene") OR ctxt= ("gluten" prox/distance<3/ordered "graphene") OR ctxt= ("zein" prox/distance<3/ordered "graphene") OR ctxt= ("soybean" prox/distance<3/ordered "graphene") OR ctxt= ("whey" prox/distance<3/ordered "graphene") OR ctxt= ("resilin" prox/distance<3/ordered "graphene") OR ctxt= ("lysozyme" prox/distance<3/ordered "graphene") OR ctxt= ("lactalbumin" prox/distance<3/ordered "graphene") OR ctxt= ("casein" prox/distance<3/ordered "graphene") OR ctxt= ("silk" prox/distance<3/ordered "graphene") OR ctxt= ("gelatin" prox/distance<3/ordered "graphene") OR ctxt= ("collagen" prox/distance<3/ordered "graphene") OR ctxt= ("keratin" prox/distance<3/ordered "graphene") OR ctxt= ("BSA" prox/distance<3/ordered "graphene") OR ctxt= ("actin" prox/distance<3/ordered "graphene") OR ctxt= ("hemoglobin" prox/distance<3/ordered "graphene") OR ctxt= ("lactoglobulin" prox/distance<3/ordered "graphene") OR ctxt= ("insulin" prox/distance<3/ordered "graphene") OR ctxt= ("hydrophobin" prox/distance<3/ordered "graphene") OR ctxt= ("myosin" prox/distance<3/ordered "graphene") OR (cl all "C08L89/00" AND (ctxt all "graphene" OR cl all "C08K3/042" OR cl all "C01B32/182")))) AND (cl any "B82Y" OR ftxt all "nanocomposite?" OR ftxt all "Bionanocomposite?" OR ftxt= ("nano" prox/unit=sentence "composite?")) → 173 results



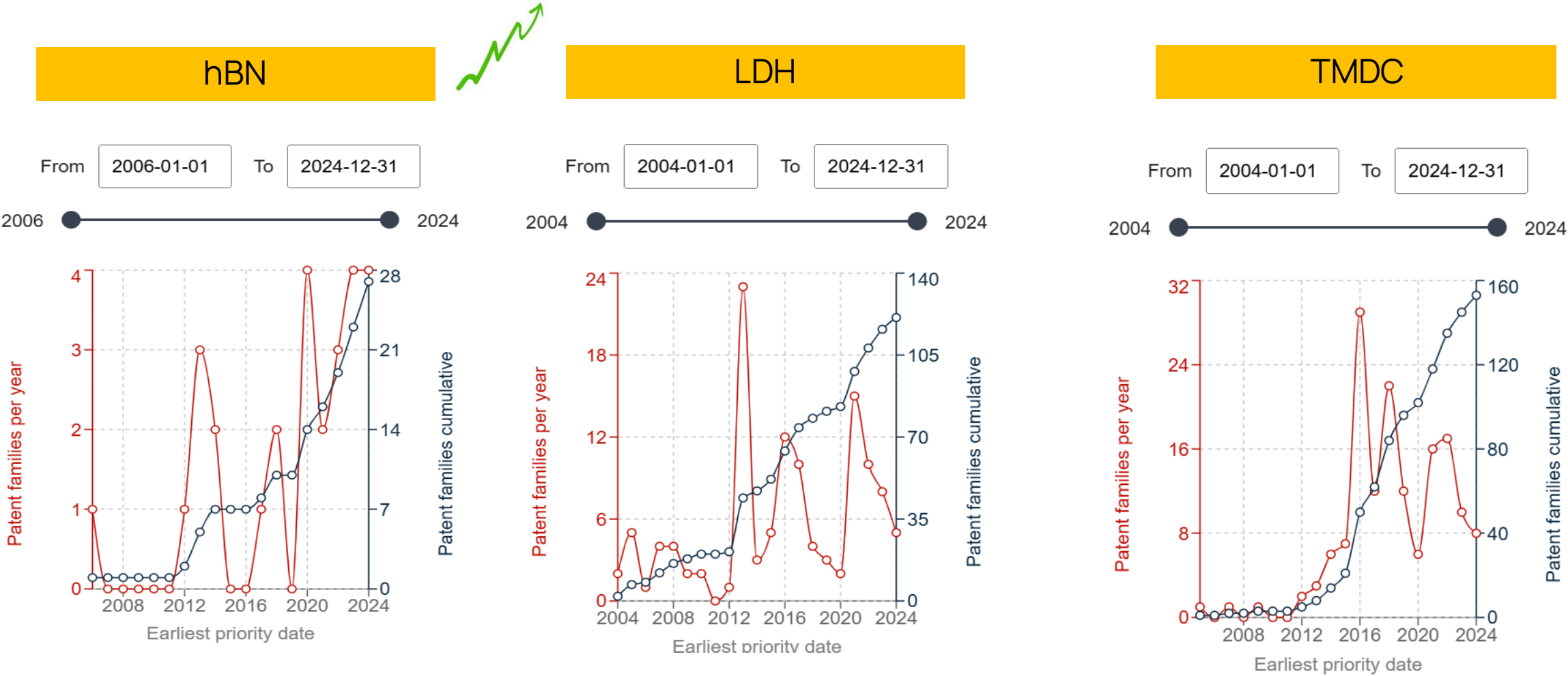
Results

03

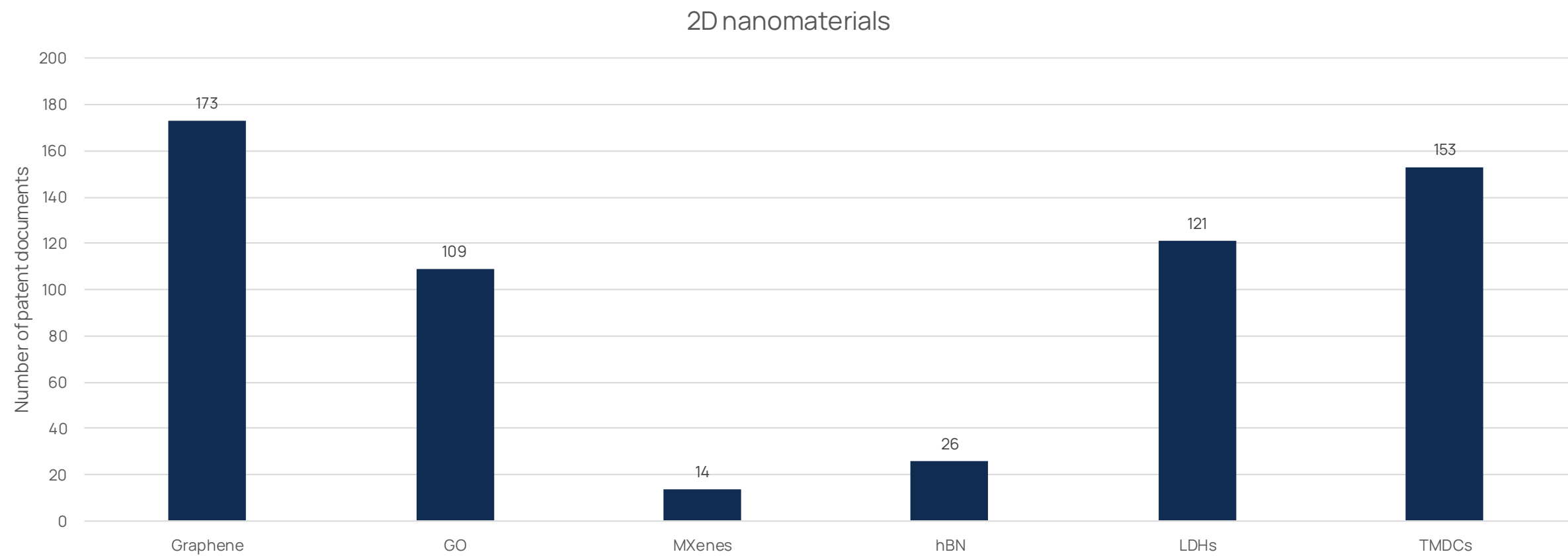
Results – (Filing trends – 1)



Filing trends - 2



Results – (Type of claimed 2D nanomaterials)



Results – (g-C₃N₄)

CN108102391A g-C₃N₄ composite edible antibacterial film and preparation method thereof

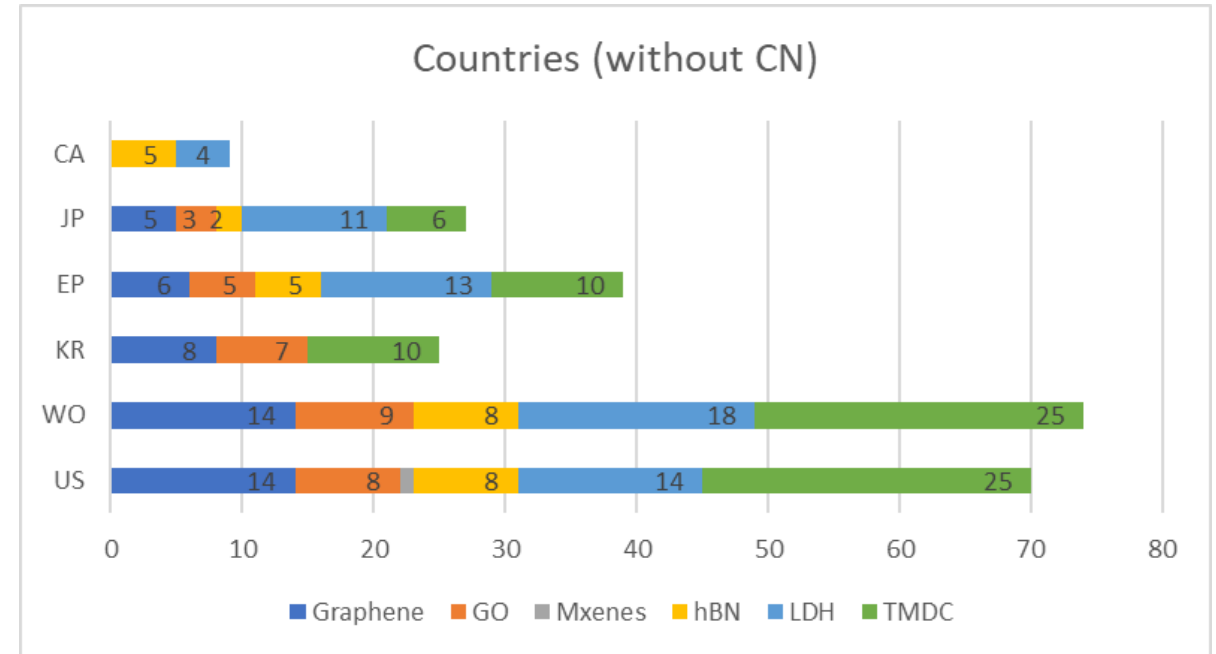
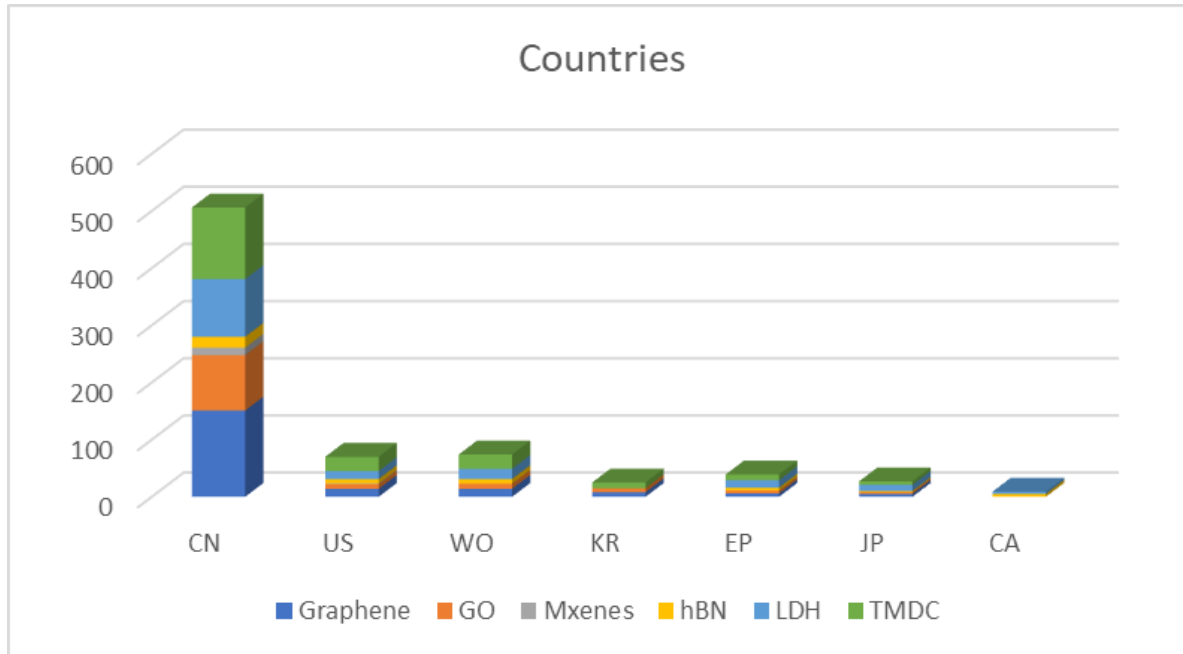
1. A solid edible film comprising an ink phase carbon nitride.
2. The edible film according to claim 1, wherein the content of the ink phase carbonitride is 7.7 to 20% by weight of the film.
3. The edible film of claim 1, further comprising at least one water soluble polymer.
4. The edible film according to claim 3, wherein the water-soluble polymer is selected from the group consisting of starches, celluloses, seaweeds, plant gums, animal gums, microbial gums, synthetic macromolecules, edible proteins; further selected from straight Amylose, high amylose, hydroxypropylated high amylose, amylopectin, dextrin, hydroxypropylmethylcellulose, hydroxyethylcellulose, hydroxypropylcellulose, carboxymethylcellulose, sodium alginate, Xanthan gum, guar gum, gum arabic, pectin, chitin, fructan, chitosan, pullulan, collagen, gelatin, polyacrylic acid, polyvinylpyrrolidone, polyvinyl alcohol, Polyethylene glycol, zein, wheat gliadin, soy protein.

Results – (Metallenes)

CN116948114A Dielectric layer, preparation method, chip three-dimensional packaging method and application

1. A bismuthene-PEDOT:PSS-silk protein composite hydrogel, which is mainly composed of bismuthene, PEDOT:PSS, regenerated silk protein, and water; in the composite hydrogel, bismuthene and π interact through hydrogen bonds - π electron interaction is combined with the amino acid residue R on the surface of silk protein; at the same time, a hydrogen bond is formed between the negatively charged group in PEDOT:PSS and the amino acid residue R in silk protein, and PEDOT is embedded into the protein through hydrogen bonding. In the silk protein network, it combines with the atoms in the amino acid residues R of the silk protein to form a core. In addition, the β -sheet structure of silk protein is connected to each other through anti-parallel strong hydrogen bonds, and is stacked alternately into a parallel multi-layer structure to form a strong but not stretched fiber, and cooperates with the α -helical structure to increase the complex water content. The overall mechanical properties of the gel.

Results - Priority countries

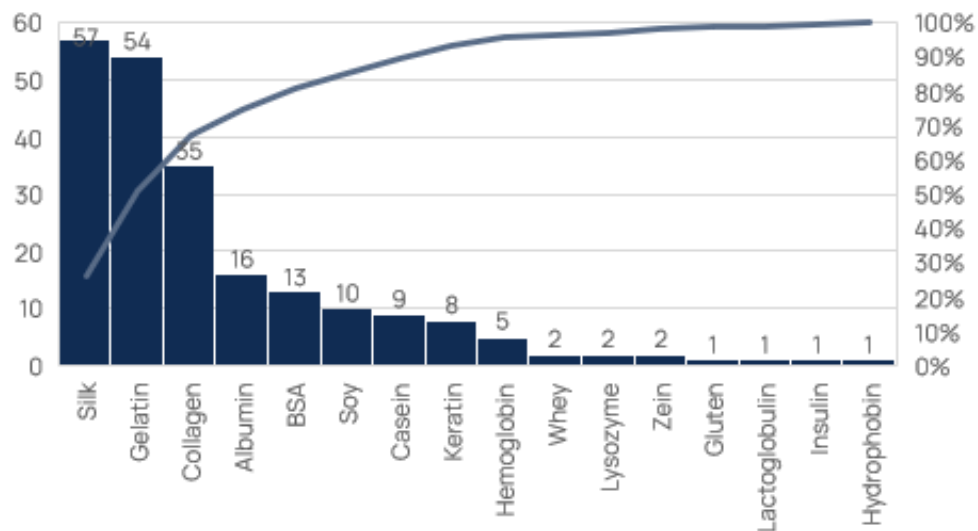


Chinese patents are not extended abroad! (FTO)

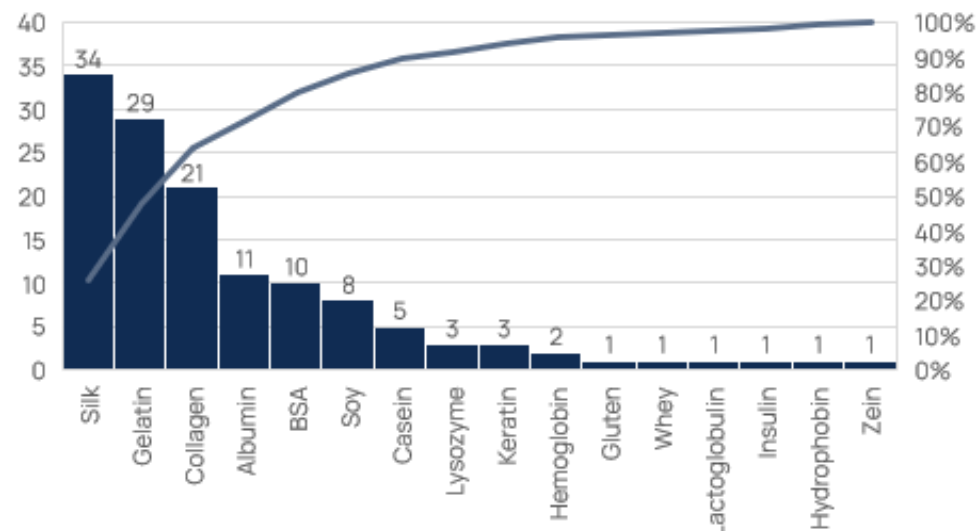
Non-Chinese applicants use PCT as first filing strategy

Results – (Type of claimed proteins – 1)

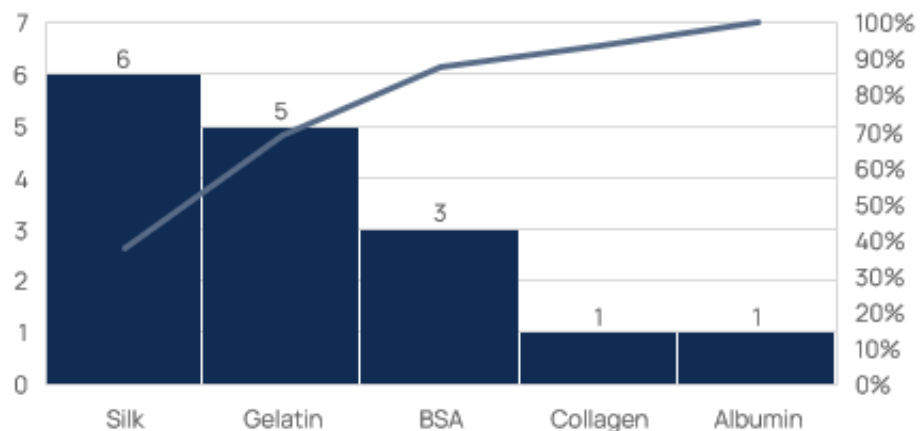
Graphene/protein nanocomposites



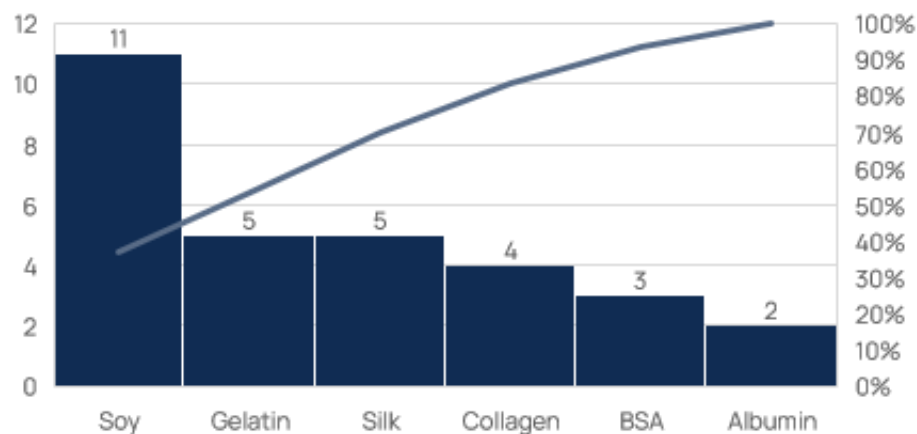
Go/protein nanocomposites



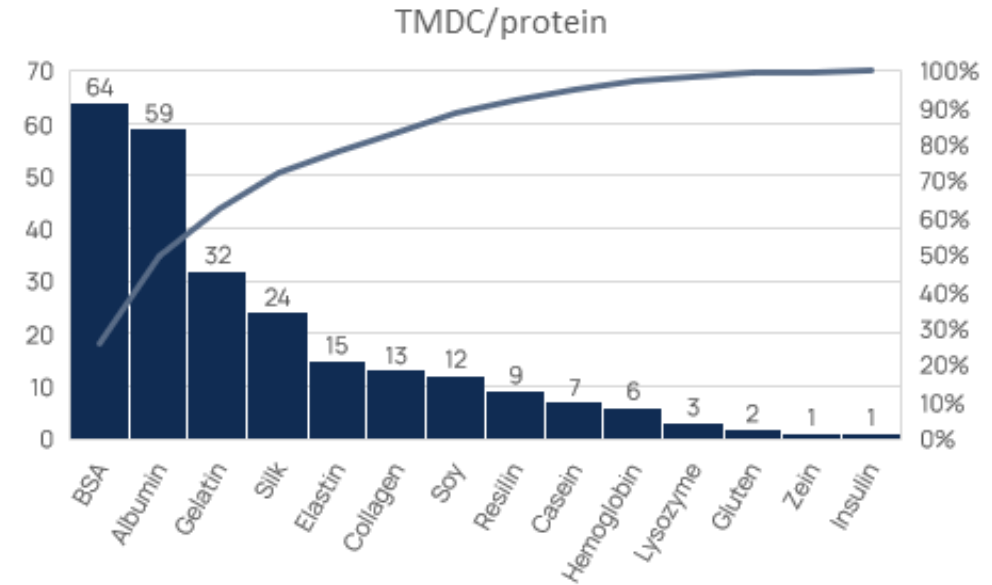
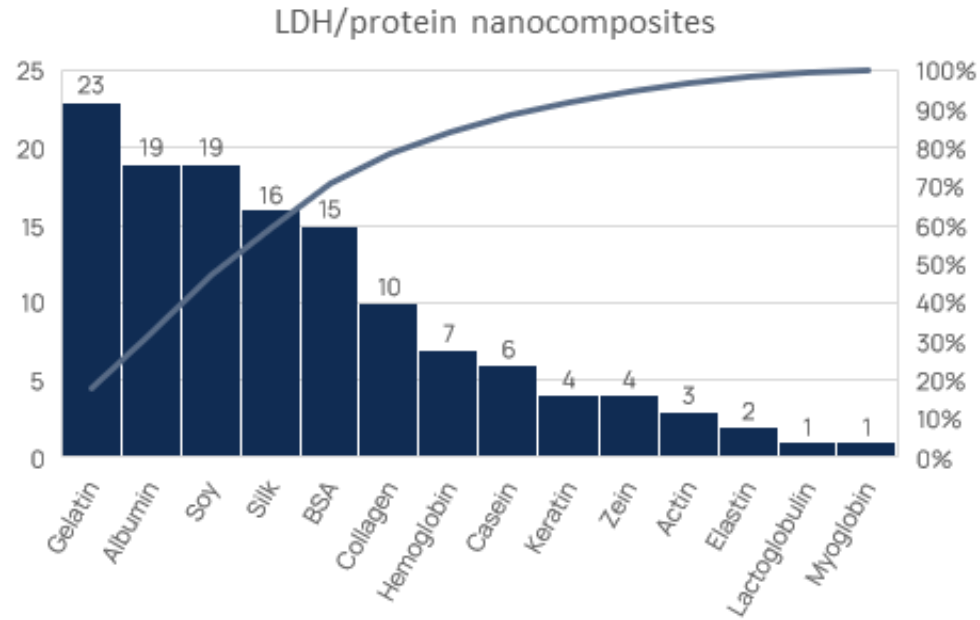
MXenes/protein nanocomposites



hBN/protein nanocomposites



Results – (Type of claimed proteins – 2)

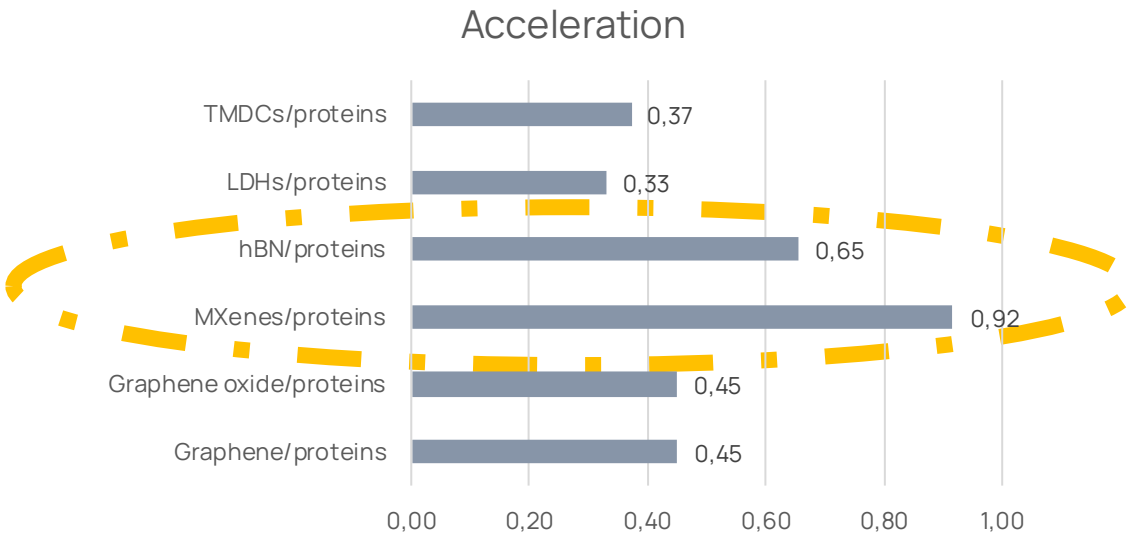




Discussion

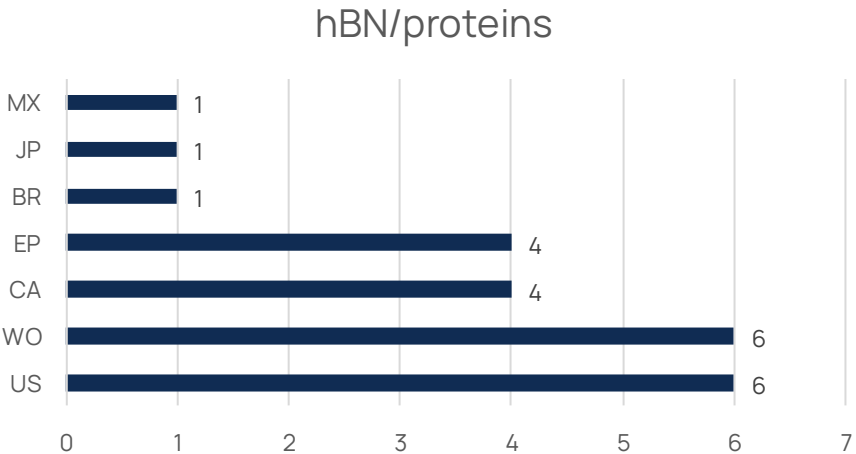
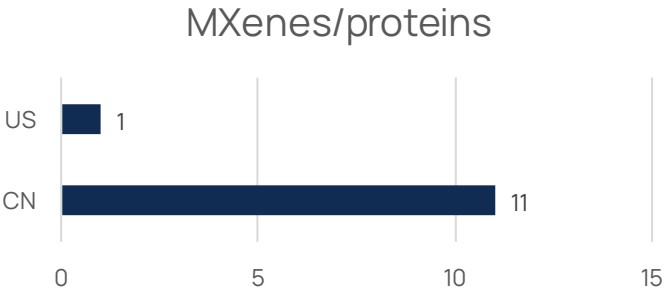
03

How to use dataset - Technology transfer



	Companies
Graphene/proteins	N
Graphene oxide/proteins	N
MXenes/proteins	N
hBN/proteins	Y
LDHs/proteins	Y
TMDs/proteins	Y

Where to patent?



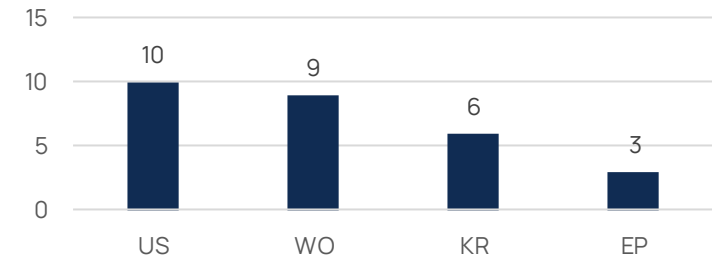
Graphene 3D Labs Inc
P&S Global Holdings LLC
Nanomech Inc

How to use dataset - Technology transfer

Graphene/protein

Priority filing or PCT → countries for national phases (except China)

Graphene extended families



Home / IP Software / Dennemeyer Octimine

Octimine — intelligent patent analysis software

Validity search using AI



Prodotto Risorse Contattaci

Inizia gratuitamente

AI per Università

Firstignite sviluppa software di intelligenza artificiale per aumentare le opportunità di partnership per le università. Trasferimento tecnologico, relazioni aziendali, avanzamento, fondazioni, sviluppo della ricerca e servizi di carriera sfruttano la nostra intelligenza artificiale per identificare e connettersi con nuove aziende, fondazioni e sovvenzioni.

How to use dataset - Prior art

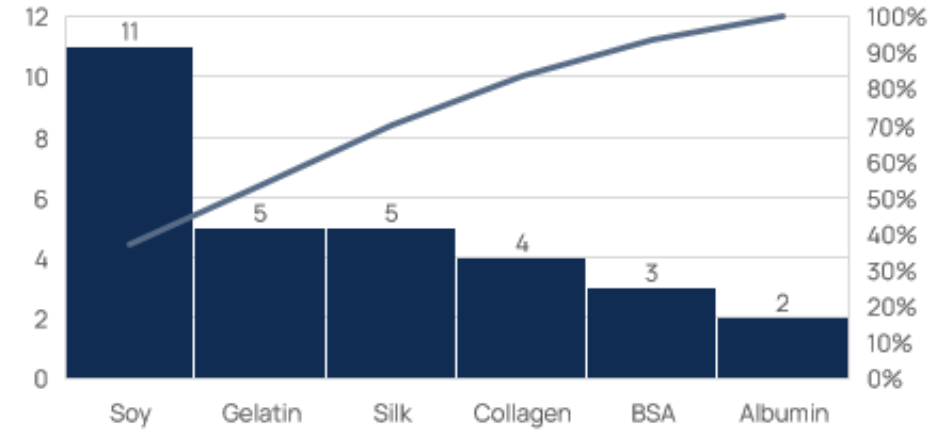
hBN

Which type of protein can I use?

Query [hBN] + elastin (claims)

Use other databases to improve the search (Octimine, Orbit, ...)

hBN/protein nanocomposites



Query language: en de fr ▼

All text fields ▼ proximity ▼

→ Group

nano

×

in the same sentence as ▼

composite?

Claims ▼ any ▼

→ Group

elastin

×

0 results found

For your query: ((ctxt all "gelatin" AND (ctxt = "hexagonal boron nitride" OR ctxt = "h-BN")) OR (ctxt all "silk" AND (ctxt = "hexagonal boron nitride" OR ctxt = "h-BN")) OR (ctxt all "collagen" AND (ctxt = "hexagonal boron nitride" OR ctxt = "h-BN")) OR (ctxt all "keratin" AND (ctxt = "hexagonal boron nitride" OR ctxt = "h-BN")) OR (ctxt all "albumin" AND (ctxt = "hexagonal boron nitride" OR ctxt = "h-BN")) OR (ctxt all "casein" AND (ctxt = "hexagonal boron nitride" OR ctxt = "h-BN")) OR (ctxt all "BSA" AND (ctxt = "hexagonal boron nitride" OR ctxt = "h-BN")) OR (ctxt all "actin" AND (ctxt = "hexagonal boron nitride" OR ctxt = "h-BN")) OR (ctxt all "soybean" AND (ctxt = "hexagonal boron nitride" OR ctxt = "h-BN")) OR (ctxt all "myosin" AND (ctxt = "hexagonal boron nitride" OR ctxt = "h-BN")) OR (cl all "C08L89/00" AND (ctxt = "hexagonal boron nitride" OR ctxt = "h-BN"))) AND (cl any "B82Y" OR ftxt all "nanocomposite?" OR ftxt all "Bionanocomposite?" OR ftxt=("nano" prox/unit=sentence "composite?")) AND claims any "elastin"

Prior art with AI (Perplexity)

US11387456B2

Energy storage device and a method of preparing the...

US9415570B2

Compositions comprising free-standing two-

US11311843B2

Precise fabrication of activated-hydrophilic-

US11427709B2

Protein-based water insoluble and bendable...

Passi dell'assistente >

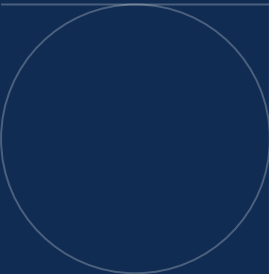
Only a small number of granted US patents explicitly claim composites that combine MXenes with proteins, with the clearest example being silk fibroin/MXene ionic-conductive materials; several other patents claim devices where MXenes interface with protein matrices (for example, gelatin electrolytes) rather than a single mixed composite phase. Below is a concise list of claimed MXene/protein composites and closely related claims identified in granted US patents.

Energy storage device and +3

Direct composite claims

- US11427709B2 (Protein-based water insoluble and bendable polymer with ionic conductivity): claims an ionic-conductive, stretchable, transparent material comprising silk fibroin, a nanomaterial, and an electrolyte, where the nanomaterial is a MXene, thereby explicitly covering silk fibroin/MXene composites as claimed embodiments. Protein-based water inso

What is claimed is: 1. An ionic conductive, stretchable, and flexible transparent material comprising **silk fibroin, a nanomaterial**, and an electrolyte, wherein the nanomaterial is present in an amount of 3 to 24 parts by weight for every 100 parts by weight of the silk fibroin, wherein the nanomaterial is a nano clay, a **MXene** or a combination hereof.



Thank you for your attention



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