

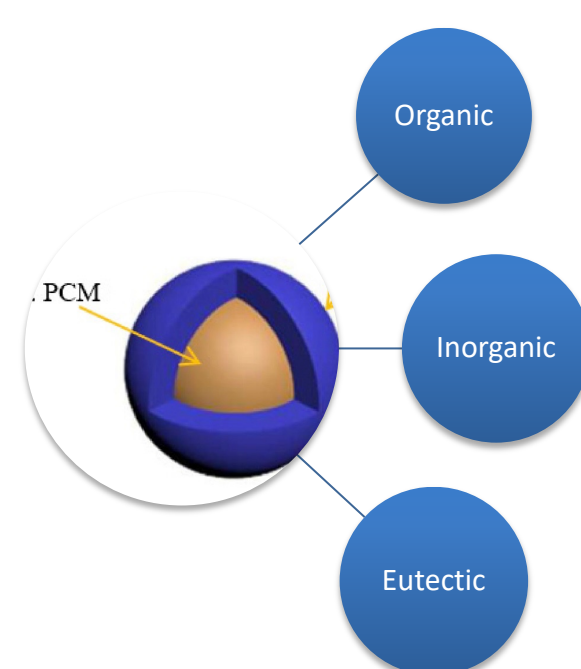
NePCM doped with Carbon Allotropes for Thermal Energy Storage: a Patent Landscape Analysis

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INTRODUCTION & AIM

Nano-enhanced phase change materials (NePCM) are composites made of an organic or inorganic PCM and nanoparticles (metal, metal oxide, carbon nanotube, graphite, graphene) capable of increasing their thermal capacity or conductivity. [1,2]



This study focuses on the patent analysis of organic NePCM doped with carbon allotropes for thermal energy storage.

METHOD

Patent searches were carried out using two databases (**Espacenet** - provided free of charge by the European Patent Office and **Orbit**, a paid-for system provided by Questel), using precise and controlled keywords in the title/abstract/claims search fields with Boolean and proximity operators and classification codes.

Classification symbols were retrieved by means of the Espacenet classification search tool and the WIPO ICCAT system.

A summary of the IPC (International Patent Classification) and CPC (Cooperative Patent Classification) codes used in the search is shown in the table below.

Classification code	System	Definition
C09K5/06	IPC/CPC	Materials undergoing a change of physical state when used • the change of state being from liquid to vapour or vice versa
C09K5/02	IPC/CPC	Materials undergoing a change of physical state when used
C01B32/158	IPC/CPC	Carbon nanotubes
C01B32/182	IPC/CPC	Graphene
C01B32/198	IPC/CPC	Graphene oxide
C01B32/152	IPC/CPC	Fullerenes
C01B32/18	IPC/CPC	Nanoonions; Nanoscrolls; Nanohorns; Nanocones; Nanowalls
C08K3/041	CPC	Use of Carbon as compounding ingredient - Carbon nanotubes
C08K3/042	CPC	Use of Carbon as compounding ingredient - Graphene or derivatives
C08K3/043	CPC	Use of Carbon as compounding ingredient - Carbon nanocoils
C08K3/044	CPC	Use of Carbon as compounding ingredient - Carbon nanohorns or nanobells
C08K3/045	CPC	Use of Carbon as compounding ingredient - Fullerenes
C08K3/046	CPC	Use of Carbon as compounding ingredient - Carbon nanorods, nanowires nanoplatelets or nanofibers

An example of search query used in Espacenet is reported below.

Graphene or derivatives

(ctxt=("phase change" prox/distance<3 "material?") OR ctxt all "Ne-PCM" OR cl all "C09K5/06" OR cl all "C09K5/02" OR ctxt=("nano-enhanced" prox/distance<2 "PCM")) AND (cl all "C08K3/042" OR ctxt all "graphene" OR cl =/low "C01B32/182" OR ctxt=("graphene" prox/ordered "oxide") OR ctxt all "r-GO") AND (ctxt any "thermal" OR ctxt any "energy" OR ctxt=("energy " prox/distance<3 "storage"))

Carbon nanotubes

(ctxt=("phase change" prox/distance<3 "material?") OR ctxt all "Ne-PCM" OR cl all "C09K5/06" OR cl all "C09K5/02" OR ctxt=("nano-enhanced" prox/distance<2 "PCM")) AND (cl all "C08K3/041" OR ctxt=("carbon" prox/ordered "nanotube?") OR cl =/low "C01B32/158") AND (ctxt any "thermal" OR ctxt any "energy" OR ctxt=("energy " prox/distance<3 "storage"))

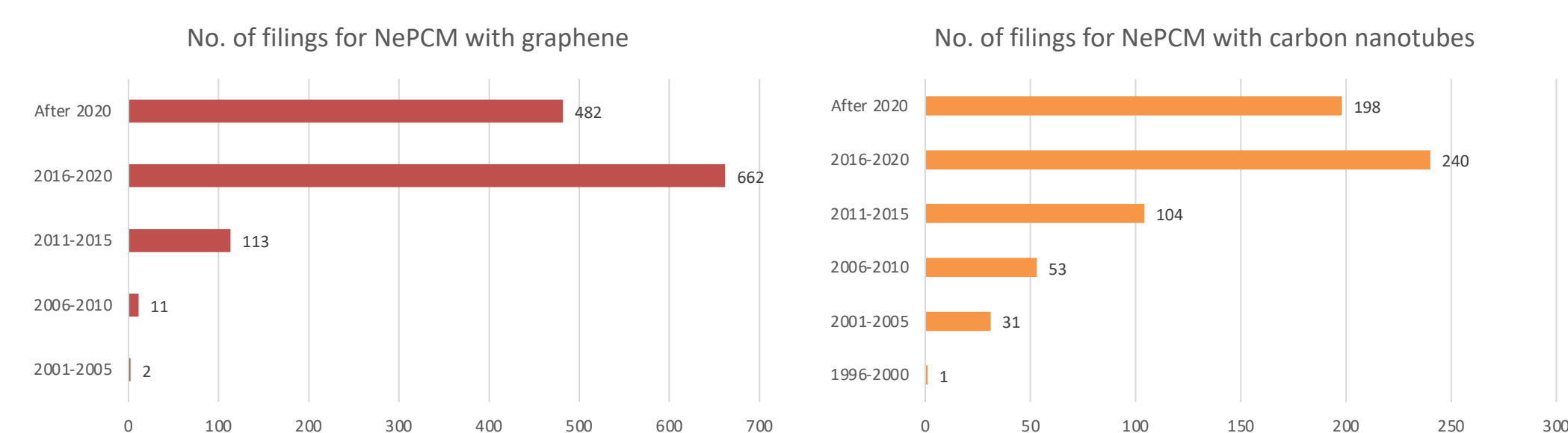
RESULTS & DISCUSSION

China is the country with the highest number of patent applications filed for NePCM with carbon allotropes, followed by the United States, Europe, and South Korea.

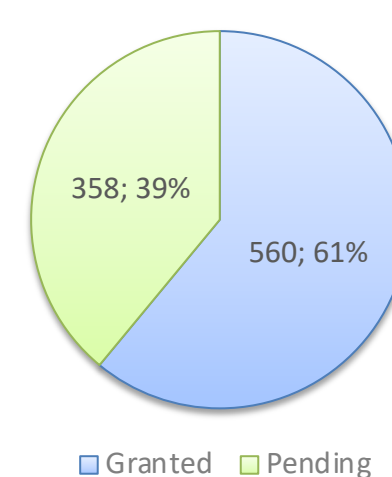
The number of patent applications filed has increased from 2016 to 2022.

However, it should be noted that the figures for later years are not reliable, as applications are kept secret for the first 18 months after filing.

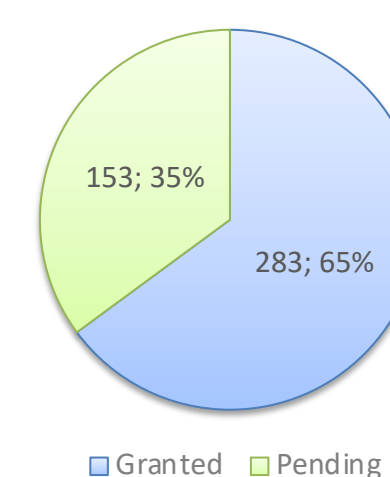
Graphene and its derivatives are the most frequently claimed compounds in applications and granted patents, followed by carbon nanotubes.



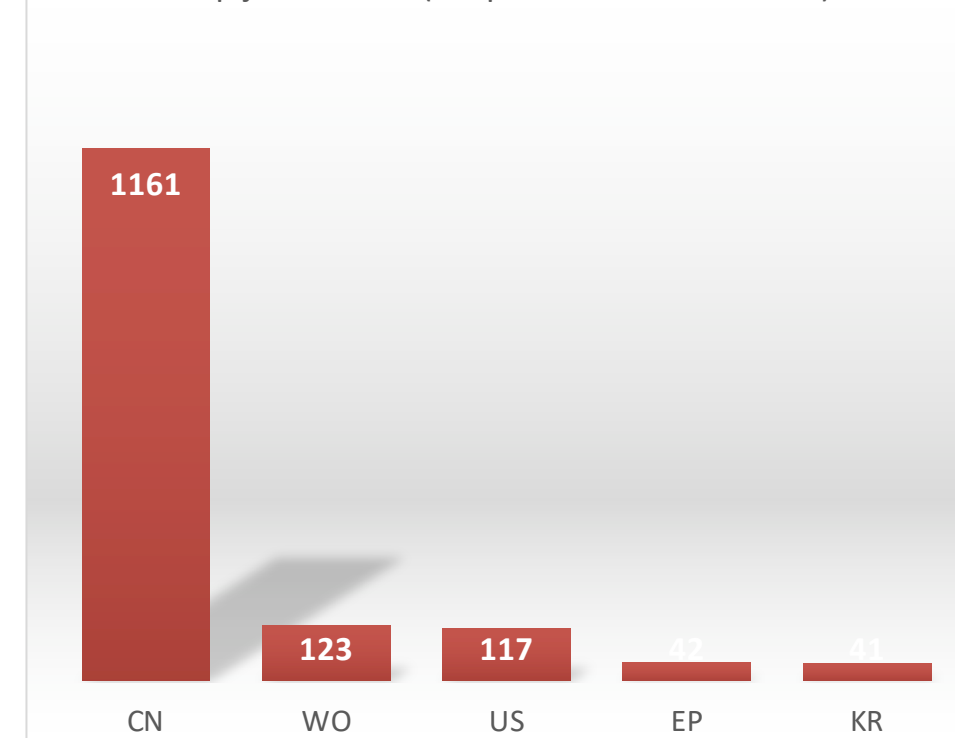
Legal status (graphene patents)



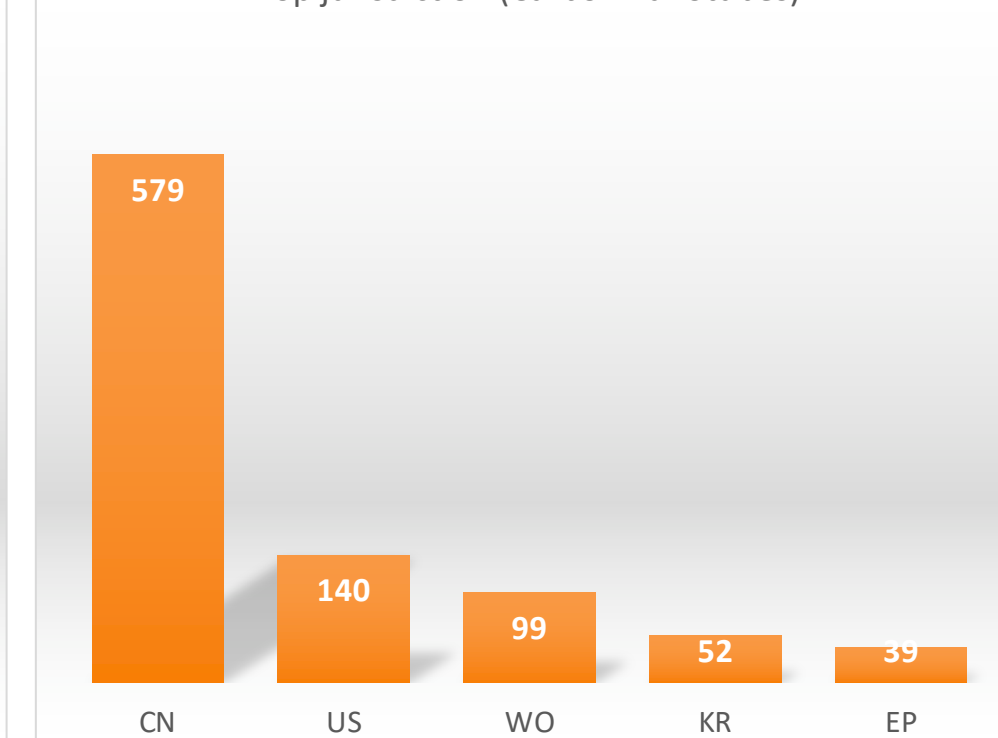
Legal status (CNT patents)



Top jurisdiction (Graphene and derivatives)



Top jurisdiction (Carbon nanotubes)



The fullerenes are rarely claimed (1.4% compared to graphene and derivatives), with an even smaller percentage claimed for other nanosized carbon materials (such as nanoonions, nanoscrolls, nanohorns, nanocones, nanowalls, and nanocoils).

Approximately 30% of the applications have been either expired, revoked, or been to be withdrawn.

Of the active patents, between 35% (for nanotubes) and 40% (for graphene) remain under examination.

The main used PCMs in combination with carbon allotropes are paraffin, stearic and lauryl acids, and lauryl alcohol.

CONCLUSION

The number of filings for NePCM doped with nano-sized carbon allotropes is on the rise. China accounts for the majority of priority patent applications. Graphene is the most frequently cited nano-sized carbon material.

REFERENCES

- [1] Aziz, A. et al. Contemporary nano enhanced phase change materials: Classification and applications in thermal energy management systems. *J. of Energy Storage* **2024**, 75, 109579
- [2] Leong, K. Y. et al. Nano-enhanced phase change materials: A review of thermos-physical properties, applications, and challenges. *J. of Energy Storage* **2019**, 21, 18-31