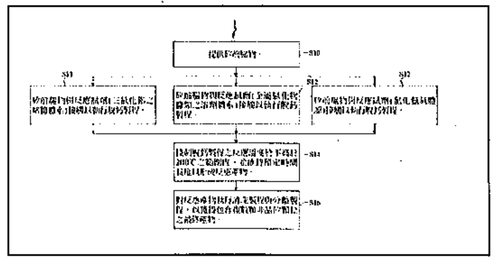
附件四、技術說明表

製造非晶矽顆粒之方法



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市場及需求:

全球鋰離子動力電池正由傳統石墨負極轉向高能量密度負極，矽基材料被視為取代石墨以提升續航力的關鍵技術 。台灣廠商目前在鋰電池產業鏈中，上游材料（如正極、電解液）研發相對緩慢，極需具備高門檻、差異化的技術來突破專利壁壘與提升毛利。現有矽負極技術存在「體積膨脹（約 400%）導致結構粉化」與「庫倫效率低下」等問題 。本專利提出的「二維非晶矽奈米片」與「Sn 摻雜提升熱穩定性至 800℃」技術，能有效解決這些痛點，市場需求強烈。

技術摘要(含成果):

本專利提供一種低溫、安全且具備高工業放大潛力的非晶矽奈米片製造方法。該方法以二矽化鈣 ($CaSi_2$) 為前驅物，在不高於 200℃ 的無氧環境中，透過選定的反應試劑體系（$AlCl_3$ 熔鹽、金屬氯化物溶劑或 PVC 熱裂解產生的 HCl 氣體）進行選擇性脫鈣。透過原位錫 (Sn) 摻雜技術，本發明成功將非晶矽的再結晶溫度提升至 800℃ 以上，克服了現有非晶矽在高溫下易結晶化失效的技術瓶頸，所得產物呈現二維 (2D) 層狀奈米片形貌，且在鋰離子電池負極應用中展現卓越的首次庫倫效率 (ICE > 79%) 與長循環壽命。

優勢:

高安全性與製程環保：反應溫度低於 200℃，並避免使用 SiH_4 等自燃氣體或有機鋰等高危險試劑；且製程可整合 PVC 廢料處理，兼具減碳效益 。
製造成本優勢：前驅物 $CaSi_2$ 價格低廉，反應路徑多樣且製程簡單，透過機械化學球磨法可將反應時間大幅縮短，適合工業規模化生產。
優異的熱穩定性與性能：獨特的 Sn 摻雜改性策略將再結晶門檻提升至 800℃，擴大了負極製程的窗口，產物 2D 片狀結構有效緩解充放電體積膨脹，大幅提升電池的循環穩定性。

競爭產品:

類別	代表技術	本專利競爭劣勢/缺點
氣相沉積法	SiH_4 / Si_2H_6 熱裂解製程	原料成本高昂，且矽烷氣體具極高自燃風險，安全設備要求嚴苛。
化學還原法	矽鹵化物加還原劑（如丁基鋰）	製程繁瑣，試劑極具危險性，且廢液處理成本高，難以大規模生產。
傳統鹼金屬矽化物法	NaSi 等鹼金屬矽化物脫鹼	脫鹼過程中與空氣或水接觸反應極度劇烈，安全風險高，廢液處理困難。

專利現況:

無

聯絡方式(請不用填):

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METHOD OF MANUFACTURING AMORPHOUS SILICON PARTICLES

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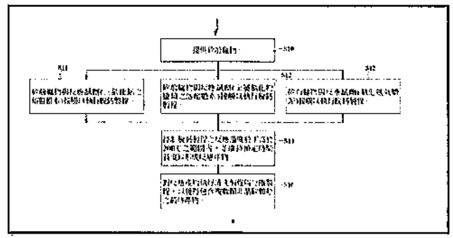

Experience:

Please visit https://che.ntu.edu.tw/che/cwlan.html

Market Needs:

The lithium-ion industry is shifting toward high-energy-density silicon anodes to extend battery range. Taiwan's supply chain requires such high-barrier, differentiated technologies to enhance competitiveness and margins. This patent's 2D amorphous silicon nanosheets and Sn-doping strategy effectively resolve critical industry pain points—specifically volume expansion and low Coulombic efficiency—addressing significant market demand.

Our Technology:

This patent presents a low-temperature, scalable method for producing 2D amorphous silicon nanosheets by selective decalcification of $CaSi_2$ at < 200˚C. By employing in-situ Sn-doping to raise the recrystallization threshold above 800°C, the process overcomes the thermal stability limitations of traditional amorphous silicon. The resulting nanosheets significantly enhance the initial coulombic efficiency (> 79%) and cycling stability of lithium-ion battery anodes.

Strength:

1. High Safety & Sustainability: The < 200°C process eliminates hazardous reagents (SiH_4, organolithium) and enables PVC waste integration, offering a safe, carbon-reducing solution.
2. Cost Efficiency: Using inexpensive $CaSi_2$ precursors and rapid mechanochemical ball milling, the simplified process is highly scalable for industrial production.
3. Superior Stability & Performance: Unique Sn-doping raises the recrystallization threshold to 800°C, while the 2D flake structure mitigates volume expansion, significantly improving cycle life.

Competing Products:

Category	Representative Technology	Competitive Disadvantages / Weaknesses of Existing Technologies
Vapor Deposition	SiH_4 / Si_2H_6 thermal cracking process	High raw material costs, extreme self-ignition risks of silane gases, and stringent safety equipment requirements
Chemical Reduction	Silicon halide + reducing agent (e.g., Butyllithium)	Complex processes, high-risk reagents, and high waste treatment costs, making large-scale production difficult
Traditional Alkali Silicide Method	Decalcification of alkali silicides (e.g., NaSi)	Extremely violent reactions upon contact with air or water during decalcification, high safety risks, and difficult waste treatment

Intellectual Properties:

None

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