IIT MADRAS
Indian Institute of Technology Madras

Technology Transfer Office
TTO – IPM Cell

Industrial Consultancy & Sponsored Research (IC&SR)

METHOD OF SYNTHESIZING GRAPHENE QUANTUM DOT

IITM Technology Available for Licensing

Problem Statement

- Conventional methods to synthesize graphene quantum dots (GQDs) involves **complex processes, the use of strong acids, organic solvents etc**.
- Further there is requirement **of post treatment to purify or modify the surface functionalization and improve the performance of the quantum dots.**

Technology Category/ Market

Category – Advanced materials
Applications-Semiconductors, Supercapacitors, electronics, energy storage, sensors, coatings, composites, drug delivery systems, biomedical devices
Industry – Semiconductors, Biomedical
Market -**The global quantum dots market size** reached US$ 6.5 Billion in 2022 and expected reach **US$ 25.4 Billion by 2028, exhibiting a growth rate (CAGR) of 23.4% during 2023-2028.**

Key Features / Value Proposition

❖ ***Technical Perspective:***

❑ The present invention discloses **a facile and single step process** to synthesize **pristine and heteroatom doped GQDs.**

❑ Capable of producing a pristine graphene quantum dots (GQD) electrode material with **cycling efficiencies** for the GQD is in the range of **75-80% at 0.05 A/g at 160 cycles for lithium anode and 40-60% at 500 cycles for sodium ion battery anode.**

❖ ***User Perspective:***

❑ **The purity of GOD better than 99%**

❑ **Cost- effective, simple and large-scale method**

TRL (Technology Readiness Level)

TRL 4- Technology Validated in Lab

Research Lab

Prof. Ramaprabhu S
Dept. of Physics

Intellectual Property

- **IITM IDF Ref. 1735**
- **IN445132-Granted**

Technology

Method for synthesizing pristine graphene quantum dots (GQD):

- **Providing a catalyst loaded substrate in a reactor**
- **Maintaining the reactor (1000 to 1200°C and inert atmosphere)**
- **Passing a hydrocarbon carrier gas**
- **Precipitation of carbon and formation of GQD**

❑ The said catalyst comprises a transition metal nanoparticle, a transition metal oxide, a metal alloy, or a metal hydroxide; viz. **$MmNi_3$ and the substrate is stainless steel.**

❑ The carrier gas is selected from the group of methane, ethane, liquefied petroleum gas, ethylene, acetylene, hexane, benzene, and xylene, thereby **causing the atoms from the carrier gas on the catalyst surface to form the GQD.**

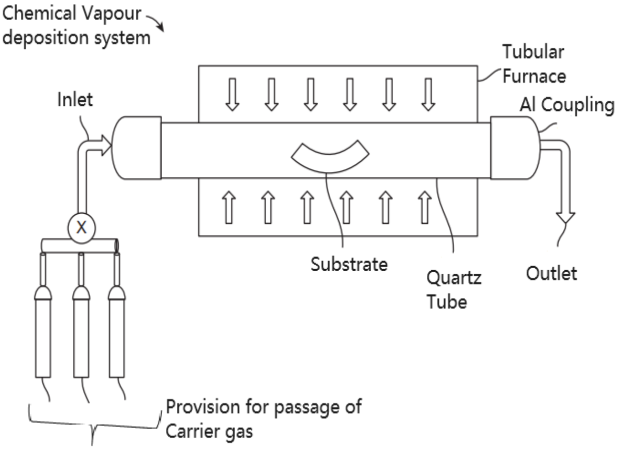

FIG. 1 illustrates a schematic diagram of a reactor useful for catalytically synthesizing GQDs.

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Method for synthesizing heteroatom doped graphene quantum dots (GQD):

Providing a mixture comprising graphite oxide (GO) and a heteroatom precursor in a reactor

Flushing the reactor with an inert gas

Introducing hydrogen gas (H_2) in the reactor at a flow rate (40 to 60 SCCM)

Annealing the mixture at a temperature (200 - 500°C) in the presence of H_2 gas

Formation of heteroatom doped GQD.

- ☐ The heteroatom precursor is selected from **a nitrogen precursor (N- GQD), a boron precursor (B-GQD), and a phosphorus precursor (P-GQD),** and wherein the weight ratio of GO to heteroatom precursor is in the range of 1: 4 to 4: 1

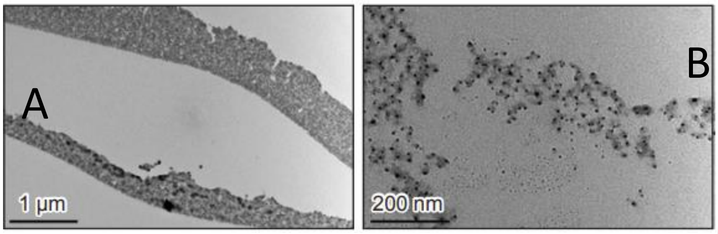

FIG. 2A depicts results of TEM image of GQDs using $MmNi_3$ as the catalyst showing aligned nature of the GQDs **FIG. 2B** depicts results of TEM image of GQDs at high resolution showing uniform distribution and morphology of the GQDs.

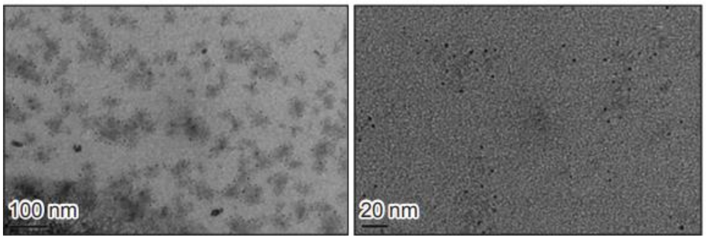

FIG. 2C and 2D depicts low- and high-resolution TEM images of B-GQDs, respectively.

For the Pristine graphene quantum dots **(GQD) electrode material,**

- ✓ The primary C(002) X-ray peak at 25.3° two theta using Cu K-alpha radiation
- ✓ Reversible specific capacity for the GQD is in a range of **400 to 500 mAh/g** in a voltage range of 0.01 to 3 V for lithium anode
- ✓ Rate capability for the GQD is 400 mAh/g at **1.5 A/g for lithium anode and 76 mAh/g at 2 A/g for sodium anode**

For the **Heteroatom doped graphene quantum dots (GQD) electrode material**,

- ✓ XRD broad peak at 26.6° and 24.8° corresponding to (002) peak for **N –GQD and B-GQD**
- ✓ The particle size of GQD is in range of **9 nm to 12 nm**
- ✓ The reversible specific capacity of GQD is in range of **800 to 1000 mAh/g at a current density of 0.05 A/g** in a voltage range of 0.01-3 V for Li anode
- ✓ **Rate capability of GQD** is in the range of 400 mAh/g at **1.5 A/g for lithium anode and 51 mAh/g at 1.5 A/g for sodium anode**

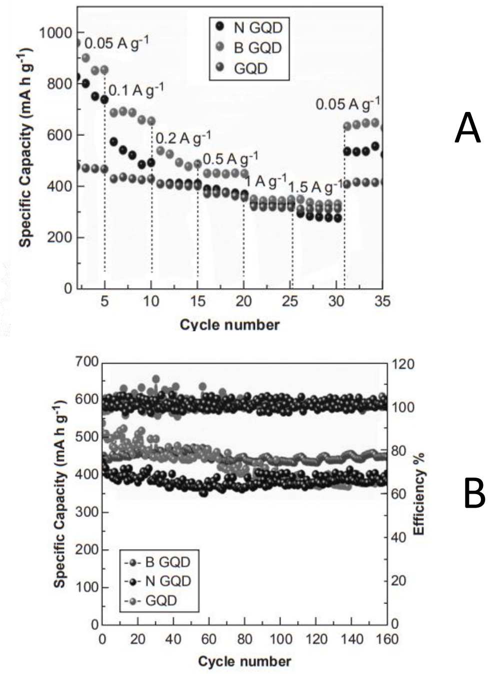

FIG. 3A depicts results of rate capability of B GQD, N GQD and GQD as anode for a lithium-ion battery and **FIG. 3B** depicts results of cyclic stability of B GQD, N GQD and GQD as anode for a lithium-ion battery

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