n-Type Phosphorus Doped Ultra-Nanocrystalline Diamond Thin Films With Enhanced Conductivity and Metallicity and Method of Producing the same

IITM Technology Available for Licensing

Problem Statement

- The problem statement discussed in the present invention is ***how to implement the n-type Phosphorus Doped Ultra-Nanocrystalline Diamond Thin Films with increased conductivity*** which has potential applications in diamond-based electronic devices.
- Hence, present invention provides the solution in efficient manner.

Technology Category/ Market

Technology: *n*-Type Phosphorus Doped Ultra-Nanocrystalline Diamond Thin Films;
Industry: Wide bandgap Semiconductor, High-Power Electronics, High-Frequency Devices, Optoelectronics and Photonics, Energy Sector, Aerospace & Defense, & etc.
Application: Diamond Detector, Optical Systems, Power Electronics,& others.
Market: The global diamond semiconductor market is projected to grow at a **CAGR** of **12.3%** during the forecast period **(2024-30).**

Technology

- Present patent describes a method of synthesizing **a *n*-type phosphorus doped ultra-nanocrystalline diamond (UNCD) thin film *via* chemical vapor deposition and doping phosphorus** into diamond lattice by a technique called **ion implantation** that exhibits **enhanced conductivity**.
- The present invention further elaborates that by **varying the phosphorus ion's fluence/dose** at a given incident energy, **UNCDs of different transport properties** can be **achieved**.
- The ***n*-type diamond** thin films are grown by **hot filament chemical vapor deposition** and **implanted by phosphorus ions.**
- With necessary optimized annealing conditions post implantation, it is established that **optimal concentration of phosphorus dopants can balance increased conductivity without significantly compromising the structural integrity of the diamond film**.

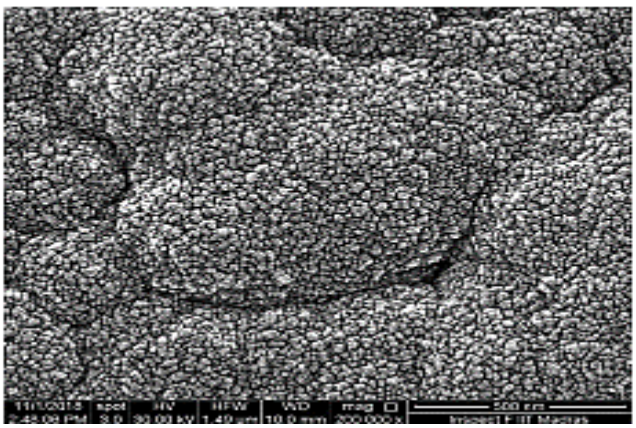

FIG. 1 illustrates the microstructure of the grown ultra-nanocrystalline diamond thin film on Si substrate with film thickness of ~1 µm.

Intellectual Property

IITM IDF Ref. 1887;
IN Patent No. 383546 (Granted)

TRL (Technology Readiness Level)

TRL-4, Proof of Concept ready, tested and validated in Laboratory

Research Lab

Prof. Ramachandra Rao M S;
Dept. of Physics,

CONTACT US
Dr. Dara Ajay, Head TTO
Technology Transfer Office,
IPM Cell- IC&SR, IIT Madras

IITM TTO Website:
https://ipm.icsr.in/ipm/

Email: smipm-icsr@icsrpis.iitm.ac.in
sm-marketing@imail.iitm.ac.in
Phone: +91-44-2257 9756/ 9719

Images

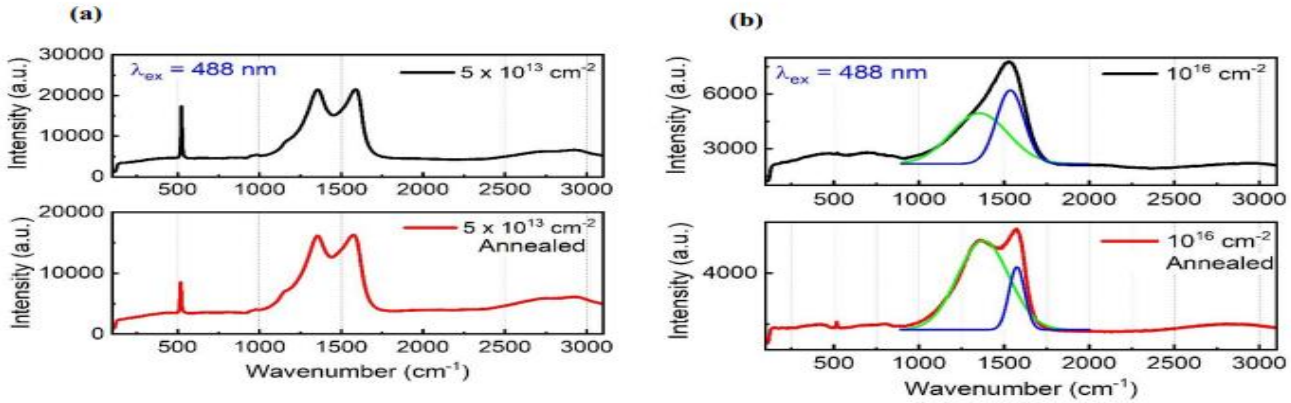

Fig.2 depicts a graphical representation of **Raman spectrum** for the **UNCD film implanted** with **fluence 5x10^{13} cm^{-2}** and **fluence 10^{16} cm^{-2}** respectively before and after **annealing post P$^-$ ion implantation.**

Key Features / Value Proposition

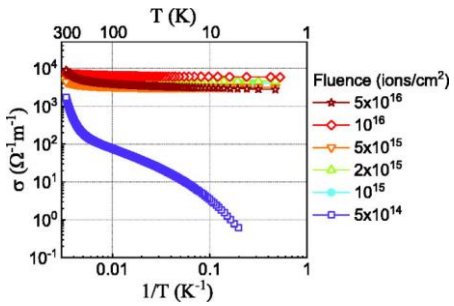

Fig.3 showing the four-point probe electrical conductivity vs inverse temperature plot varying from 300 K down to 2 K for the UNCD films implanted with various $^{31}P^-$ fluences of energy 100 keV and beam current of 1 μA.

❖ *Technical & Industrial Perspective:*

❖ Manufacturing Process:

- ❑ The **ultra-nanocrystalline diamond (UNCD) thin film** is initially deposited in **methane (CH_4) & hydrogen (H_2)** atmosphere where **CH_4/H_2 is 4.5%** in the **absence of Ar** at a pressure of **7 Torr** and substrate temperature of **800°C.**
- ❑ Post deposition, **the films** are implanted with **phosphorus ions** with **energy 100 keV** & **beam current 1 μA**. (Refer Fig.2).
- ❑ **Annealing** is performed in vacuum at **high temperature** to **ensure the mobility of vacancies/point defects** and to restore the crystallinity.
- ❑ **Annealing** helps in **recovering from amorphization** & helps in **getting rid of implantation induced defects**.
- ❑ Using a **systematic variation** of phosphorus doses implanted at **100 keV energy**, developed **UNCD films prototype** with varied **transport properties** showing insulating behavior at **low doses** with **hopping type conduction process** & semi-metallic like conduction at moderate to high doses with an almost **five times enhancement in conductivity values** *w.r.t.* undoped diamond.

❑ Utility:

Multi-functionalities with **diverse applications** including development of room temperature **quantum bits** (QUBITs) for **quantum computing, biosensing, detectors**, micro-electromechanical systems (**MEMS**), color centers, **diamond based electronic devices** & etc.

CONTACT US
Dr. Dara Ajay, Head TTO
Technology Transfer Office,
IPM Cell- IC&SR, IIT Madras

IITM TTO Website:
https://ipm.icsr.in/ipm/

Email: smipm-icsr@icsrpis.iitm.ac.in
sm-marketing@imail.iitm.ac.in
Phone: +91-44-2257 9756/ 9719