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NANODIAMONDS – A VERSATILE DRUG DELIVERY SYSTEM: A REVIEW

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ABSTRACT

In nano-science and nanotechnology basically more no of nano material has been synthesized and discovered rapidly. Nanodiamonds are most disparate origin. Nanodiamonds are other forms of carbon nano-materials with new properties and application these nano-diamonds are found in crude oil at very low concentration like 1000 ppm. The Meteorites, interstellar dust and proto planetary nebulae as well as in certain sediment layers on earth. It can also be produced in the laboratory by using various method chemical vapor deposition or by detonating high explosive materials. Nano diamonds have excellent mechanical and optical properties, also high surface areas and tunable surface structures. Nanodiamonds are prepared by various methods like Detonation method Ultrasonic, Cavitations method and Pulse-laser Irradiation. Here we review the synthesis, structure, properties, and applications of individual Nano diamonds and clusters of Nano diamonds and their useful applications in medical and biological applications.

KEYWORDS: Nanotechnology, Nano particles, Nanodiamonds, Detonation.

INTRODUCTION

After 25 years of intensive research for new nano-carbon species fullerene C60 and carbon nano-tubes, a consensus is gradually being form among researchers working in the field that nano-diamond and graphene would be the final choices. Nanodiamonds are one of the most advanced carbon materials in the world. Nanodiamonds have mechanical and optical properties, high surface areas and tunable surface structures. Nano-diamond is the nano-particle of diamond with a size below 1 micrometer (A diamond particle with dimensions of only few nano particles). They can be produce by impact events such as detonation or meteoritic impact. Because of their inexpensive, large-scale synthesis, potential for surface fictionalization, and high biocompatibility, nano-diamonds are widely investigated as potential material in biological and electronic application and quantum engineering.[1] Diamonds are renowned for their superlative physical qualities such as the highest hardness on earth, superior thermal conductivity to any bulk material, and the high refractive index and V-number or constringency of transparent material. Nanodiamonds are not only small-sized diamonds with the above features but they also could generate other functions owing to their nano size, various functional groups, high dispensability, ζ potential, and amorphous carbon. Nanodiamonds are produced by a detonation method and the diamonds synthesized are extremely tiny particles with average diameter between 4~6nm. Nanodiamonds has unique applications compared to other nano materials such as nano-silica, graphene, carbon nanotubes, fullerenes, and carbon nanohorns,etc.[2]

History of nanodiamond

Studying the history of Nano- material is essential because it allows researchers to understand their origin and earlier contribution to civilization, which is turn do not applicable to further development and innovation. Currently the development and utilization of nanodiamond have been performed. In this manner fundamental data on historical aspects and advancement of dyanamic technique of Nanodiamond given in table no 1.

Table 1: Brief and systematic pre-historical information about nanodiamond research Structure of Nanodiamond.

Year	Remark
1956	Ineffective efforts at dynamic synthesis
1960	The revolution of the prospects for diamond synthesis by means of shock compression of graphite; initial stages of experimental study
1961	Diamond preparation with the maintenance of shock-compressed graphite
1962	Diamond preparation with the maintenance of shock-compressed graphite and diamond produced ~2%
1963	Diamond preparation via by compression method, and it produced ~20% diamond yield (by the scientists, K.V. Volkov, Vyacheslav Danilenko, and V.I. Elins.)
1963	Detonation diamond preparation with diamond yield 8–12%
1965	Diamond preparation from graphite
1976	Commercial production of diamond micro powder by means of the compression method
1982	Ultrafine -dispersed diamonds production
1983	Pilot-scale production of diamond micro powders
1984	Industrial production of ultrafine-dispersed diamonds
1994	Beginning of studies on ultrafine-dispersed diamonds sintering under static circumstances as well as high-density ultrafine-dispersed diamonds grains by the explosion, production of diamond single crystals
1986-1992	Research on ultrafine-dispersed diamonds synthesis by an explosion at mass level charges
Present	Application of Nanodiamonds in various filed such as composites, Biomedical, Tribology, and Electronics and so on.

Nanodiamonds are allotropic form of carbon. NDs are carbon- based materials approximately 2 to 8 nanometers in diameter. Each nanodiamonds surface possesses functional groups that allow a wide spectrum of compounds to be attached to it, including chemotherapy agents. The crystal structure of nanodiamonds consists of two close packed interpret ending face centered cubic lattices; one lattice is shifted with respect to the other along the element al cube space diagonal by one- quarter (1/4) of its length .NDs is often described as a crystalline diamond core with a perfect diamond lattice structure surrounded by an amorphous shell with a combination of sp2/sp3 bonds' a number of diamonds are carbon atoms with both graphitic (sp2) and diamond void (sp3) bonds. The two types of bonds are interconvertible, for example, the stretched face of diamond is a graphene plane. In reverse, the graphene may become a diamond.

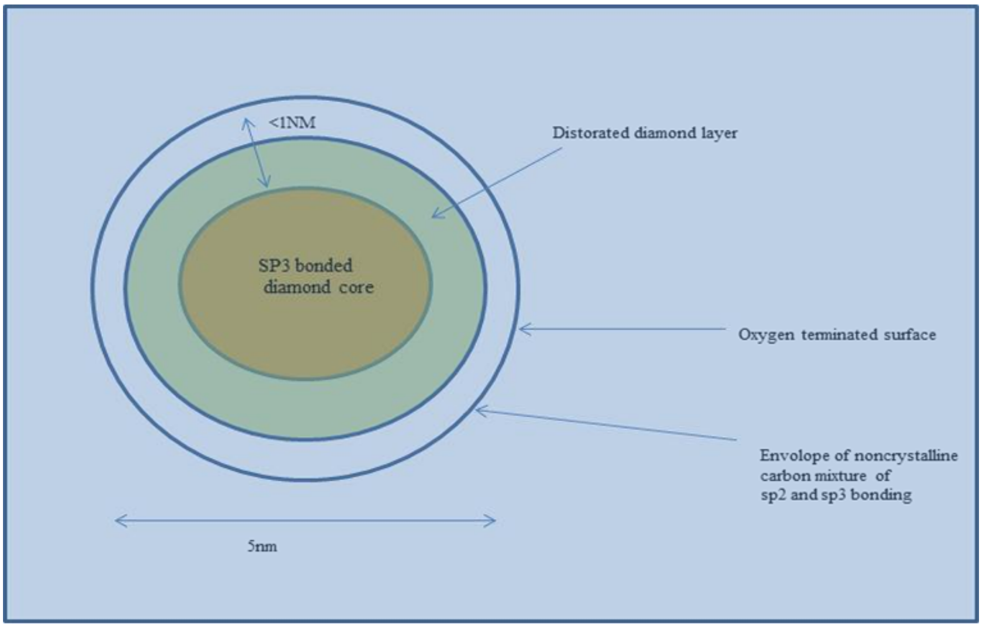

Fig 1: schematic representation of possible hybridization in nanodiamond.

There are three main aspects in the structure of diamond nanoparticles to be considered: the overall shape, the core, and the surface. With the help of multiple diffraction experiments, it has been determining d clearly that the overall shape of diamond nanoparticles is either spherical or elliptical. At the core of diamond nanoparticles lies a diamond cage, which is composed mainly of carbons. While the core closely resembles the structure of a diamond, the surface of diamond nanoparticles resembles the structure of graphite. A recent research and study shows that the surface consists mainly of carbons, with high amounts of phenols, pyrones, and sulfonic acid, as well as carboxylic acid groups, hydroxyl groups, and epoxide groups, though in lesser amounts. Occasionally, defects such as nitrogen-vacancy centers can be found in the structure of diamond nano particles. 15N NMR research confirms presence of such defects. A recent study shows that the frequency of nitrogen- vacancy centers decrease with the size of diamond.

Biocompatibility of Nanodiamonds

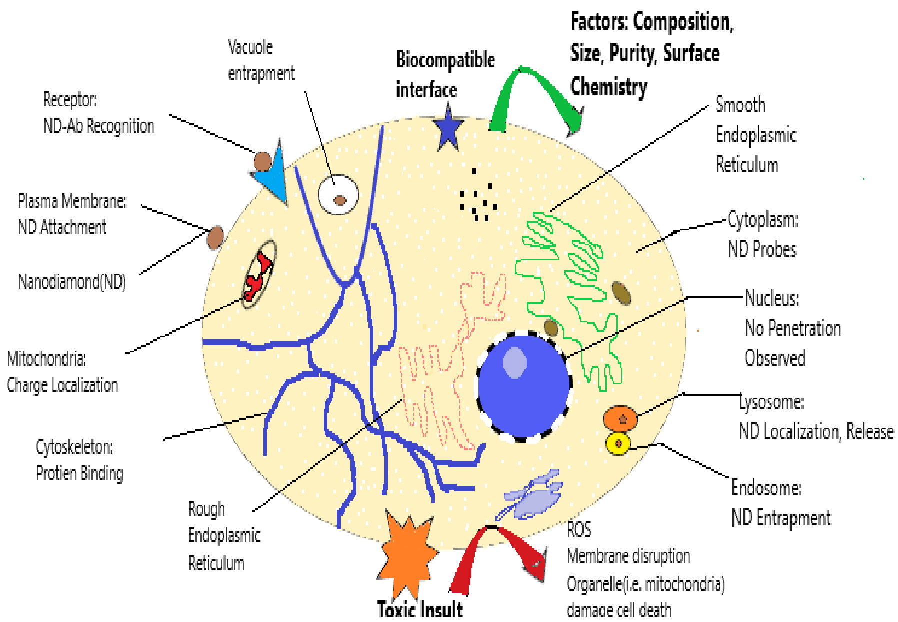

Fig 2: Interaction nanodiamond (Nanodiamond) particles including biomolecular binding.

Biocompatibility is main aspect when diamond is applied to biology. Many scientist investigated that nanodiamond with nano size of 2-10nm are not harm to a variety of cells through mitochondrial function (MIT) and luminescent ATP production assays. It was found that after the incubation of cells with nanodiamonds, cell morphology is unaffected by the presence of NDs. while nanodiamonds are seen surrounding the cell borders and attached to nitrite extensions.

Before nanoparticles are completely integrated into biomedical applications, their unique interactions with biological systems demands special consideration. Compared with other nano-sized forms of carbon, nanodiamonds show greater biocompatibility regardless of their purification method, concentration, or size For example, some researcher demonstrated differential biocompatibility between neuronal and lung cell lines after exposure to aqueous suspensions of carbon nonmaterial's (nanodiamond, MWNT, SWNT) at concentrations from 25 to 100g/mL for 24 hours with the MTT assay. The trend for biocompatibility was ND>MWNT>SWNT. The lung cells (macrophages) were more greatly affected by the presence of carbon nanomaterials generating up to five times. The amount of ROS compared with the neuro blastoma cells after exposure to either MWNTs or SWNTs. However, there was a lack of ROS generation from either cell line after incubation with the nanodiamonds as well as intact mitochondrial membranes further supporting the low toxicity of nanodiamonds.

Preparation method of Nanodiamonds

Method for synthesis of Nanodiamond is as follow.

- Precursor
- Detonation method
- Ultrasonic cavitations method
- Pulse laser irradiation

• Precursors

Nanodiamonds can be produced from a series of precursors, among which the CH4/H2 mixtures with addition of inert gases, O2 orN2 are frequently used. Thus, synthesis of NCD films by using a low amount of simultaneous O2 and N2 addition into con-ventional CH4/H2 mixtures. The NCD samples were grownin 5 kW microwave plasma CVD (MWPCVD) system on large silicon wafers. It was shown that morphologymi-cro structure, grain size, crystalline quality and growth rate of NCD films can be tailored by simply adjusting the amount of O2 and N2 addition, and with increasing the ratio of addition, the crystal quality of the NCD films is significantly increase. Additionally, carbon nanotubes were used as Nanodiamonds precursors, for instance multiwall carbon nanotubes (MWCNTs) served as a precursor to prepare diamond in a pure hydrogen microwave discharge. Also, NDs were easily formed from carbon film containing Si.) The growth of diamond and ß-Sic was controllable by adjusting the heating temperature and the proportion of Si. A method for producing a ND, in which a ND was removed from an activated carbon containing the ND, was .A ND fiber (up to 2000 nm) can also be produced by mixing a carbon source, a metal and an acid under conditions, which results in ND formation. Methods of industrial ND synthesis were generalized in a review. With attention to aspects of detonation decomposition of powerful mixed explosives with a negative oxygen balance (formation of ultrafine dispersed diamonds). The most efficient technology of chemical cleaning of diamonds with nitric acid at high temperatures and pressures for producing high-purity NDs was described (other methods see section "Purification of nanodiamonds"). Other ND precursors include fullerenes, graphite, β-Sic, carbide-organic systems, polycarbine, trotyl/hexogen, 1, 1, 1-trichloroethane, etc.

Detonation method

• Detonation Nanodiamonds (DND), also called as ultra dispersed diamond (UDD), is diamond that is synthesized from a detonation. Nanodiamonds can be created by detonating mixture of trinitrotoluene (TNT) and hexogen (RDX).[6]

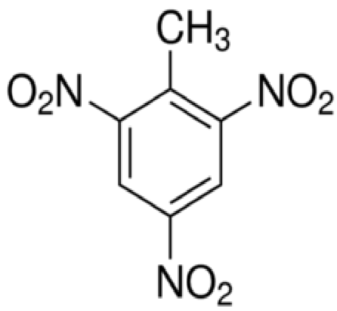

Fig.3: 2, 4, and 6 trinitrotoluene.

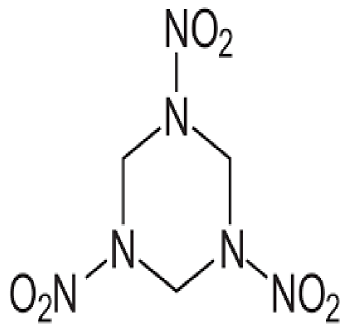

Fig.4: Hexogen.

Structural formula of two explosives commonly employed for detonation synthesis. A pure nanodiamond can be synthesized by detonation of a diamond blend and will then form by chemical purification. The soot left over basically contains tiny diamonds, which measure four nanometers (4nm) in size. However, in order for these diamonds to shine and look anything like diamonds they must be exposed to a high energy electron beam and then heated 800 degrees Celsius i.e.1073K absolute temperature. The diamond yield after detonation importantly depends on the synthesis condition and especially on the heat capacity of the cooling medium in the detonation chamber (water, air, CO2, etc.). The higher the cooling capacity, the larger the diamonds yield, which can reach 90%. After the synthesis, diamond is extracted from the soot using high-temperature high pressure boiling in acid for a long period (about 24 to 48 hrs). The boiling removes most of the metal contamination, originating from the chamber materials, and non-diamond carbon. Various measurements, including X-ray diffraction and high resolution transmission electron microscopy revealed that the size of the diamond grains in the soot is distributed around five nanometers (5 nm). The grains are unstable with respect to aggregation and spontaneously form micrometer-sized clusters the adhesion is strong and contacts between a few nano grains can hold a micrometer sized cluster attached to a substrate.

Ultrasonic cavitations method

Diamond nanocrystals can also be produced from a mixture in which particles are dispersed throughout the bulk of a fluid of graphite in organic liquid at atmospheric pressure and room temperature using ultrasonic cavitation method. The yield is about 10%. Phenomenon of cavitation can be occur when the emission ultrasonic wave into the liquid. During formation of cavitation cavities filled with gas or their mixture. During the cavitation relatively low average energy density of field is transformed into the high energy density inside and near the being begun to flap bubble. During this occurrence pressure and temp 101 Kelvin developed. The acoustic cavitation is expended on the emission of shock waves. The selection of thin carbon-containing liquids hexane C6H14 and ethanol C2H5OH is caused by the fact that acoustic cavitation energy is compared with tensile energy of the connection between the atoms C and H, and hydrogen possesses a sufficient diffusion rate from the collapse medium of cavitation bubble for obtaining the Nanodiamond(ND).

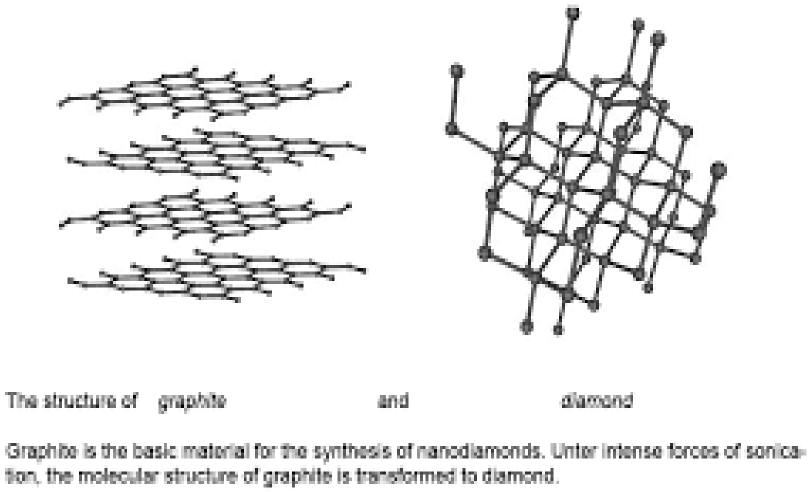

Fig.5: Ultrasonic Cavitation method[1]

Pulse-laser Irradiation
Another synthesis technique is irradiation of graphite by high-energy laser pulses. Phase modification from graphite to sp-bonded carbon chains carbine and nanodiamonds (ND) has been induced by femto second laser pulses on graphite surface. The structure and particle size of the obtained diamond is rather indistinguishable to that obtained in explosion.

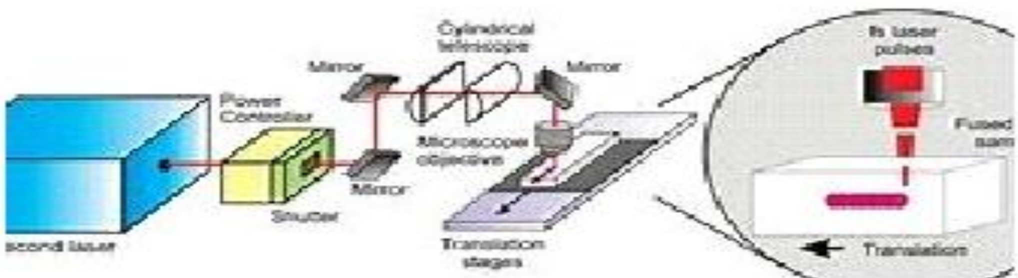

Fig 6: Setup used for pulse-laser irradiation technique

Evaluation parameters for Nanodiamonds
Fourier Transform Infrared Spectroscopy (FT-IR): FT-IR is used to confirm the carboxyl groups on ND surfaces.

X-ray Diffraction (XRD) Analysis
To determine the crystalline structure of the CS/ND nanocomposites (XRD) Analysis is used. Detailed crystallinity is determined under the assumption that the areas are proportional to the scattering intensities of crystalline and amorphous phases. Thus, the diffraction profile is separated into 2 parts: peaks are related to diffraction of crystallites, broad alone is related to scattering of amorphous, and the degree of crystalline Xc is measured as the ratio of crystalline area to total area.

Scanning Electron Microscopy (SEM)
The morphology of the composite samples was examined using Scanning Electron Microscopy.

Differential Scanning Calorimetric (DSC)
The thermal properties including glass transition, degradation and interactions of CS/ND nano composites are analyze using DSC.

APPLICATION OF NANODIAMONDS
The following are some of the application raw diamond/graphite nanomixture and pure Nanodiamonds (ND).

1) Catalyst
Some forms of nanodiamonds have a complicated structure featuring a diamond nucleus and graphite like shell with a functional cover on its surface. It is necessary to modify and activate the surface of nanodiamonds for the catalytic purposes. Nanodiamonds-based catalysts have been evaluated in the conversion of CO to CO2. Electrochemically modifying a saline-acid solution and improving the nanodiamonds powder surface with palladium holds potential to produce electrodes and catalysts of low-temperature fuel elements.[8]

2) Additives to automobile oils

For lubricants, ultra disperse diamonds can yield a new class of additives, which is exceptionally engineered to protect and restore friction units in unlike mechanisms and machines by optimizing safeguarding properties and effectual service life of lubricants.[8]

3) Galvanic coating

Nanodiamonds (ND) can be utilized as an addition to metal galvanic coatings. The production of compound coatings involves the deposition of nanodiamonds with a size of 4-6 nanometer and metals during the electrochemical and chemical recovery of metals from their salt solutions. The resultant biphasic composite electrochemical coating consists of a metal matrix with distribute particles of nanodiamonds implanted in it.[8]

4) Lapping and polishing application

a) Super hard and nanoabreasives
b) Mechanical seal lapping
c) Acrylic sheet, aircraft windows, canopies.
d) Stainless steel sheet
e) Precious stone
f) Ceramics

5) Other application of nanodiamonds

a) Medical and biological applications
b) Cold-plasma Metal-diamond and polymer-diamond coatings.
c) Floppy disks, audio/video tapes.
d) Semi-conductor products
e) Chromatographic carriers

CONCLUSION

Nanodiamond drug delivery system is one of the best examples of great evolution in drug delivery technologies and nanotechnology. It is obvious that Nanodiamond appears to be a well preferred drug delivery system over other dosage form as nanodiamond mostly stable in nature and economic. Nanodiamonds provide great opportunity for the different innovative applications, especially due to their biocompatibility and minimal cytotoxicity in biological condition. Nanodiamonds is the state-of-the-art material widely used in polishing materials, polymers, lubricants and electrolytes. There is lot of scope to encapsulate toxic anti-cancer drugs, anti-infective drugs, anti-AIDS drugs, anti-inflammatory drugs anti-viral drugs, etc.

Thus these areas require further systemic consideration and research so as to bring out commercially and valuable available Nanodiamonds preparation. The concept of incorporating the drug into or Nanodiamonds for a better targeting of the drug at appropriate tissue destination is widely accepted by researchers and academician.

Nanodiamonds are very useful in bright future for pharma industries. So far only animal experimentation of this targeted drug delivery system is reported but further clinical investigations in human volunteers, pharmacological and toxicological investigations in animals and human volunteers may help to exploit nanodiamond as prosperous drug carriers for targeting drugs more efficiently, for treating cancer, infection and AIDS etc. Thus Nanodiamond present itself as a versatile tool in therapeutics.

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