

## NANODIAMONDS – SCIENCE & TECHNOLOGY

**NEWS:** Scientists have successfully recorded the Berry phase by the rotation of spin qubits inside the nanodiamonds at ultra-high speeds.

## WHAT'S IN THE NEWS?

## Nanodiamonds (NDs)

Nanodiamonds (NDs) are carbon nanomaterials with a size of a few nanometers to micrometres that have many potential applications.

- They are produced in a high-temperature and high-pressure process.
- They can be doped with nitrogen atoms to form nitrogen-vacancy (NV) centres, which host electron spin qubits.
- Just like a binary bit is the basic unit of information in classical (or traditional) computing, a qubit (or quantum bit) is the basic unit of information in quantum computing.

## **Properties of NDs:**

- Fluorescence and non-blinking
- Fluorescence is the property of some materials to emit light of a lower frequency when irradiated with light of a higher frequency. But unlike many other nano-scale fluorescent materials, NDs don't blink when irradiated for a long time.
- Stability
- Their fluorescence lifespan is greater than 10 nanoseconds (ns), a relatively long duration, which makes them better than quantum dots.
- They are stable under light, non-toxic, and capable of maintaining fluorescence for long periods.

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### DOPANTS/INTERNAL DEFECTS

- Color centers (fluorescence,
- phosphorescence, magneto-optics) Boron doping (electroconductivity)
- Vacancies (photoacoustics)
- <sup>3</sup>H doping (radiolabeling)
- Inherent biocompatibility Large bandgap (transparency) High refractive index ( strong UV
- scattering)

CORE

Mechanical/chemical stability

- "Quality" of color centers
- · High thermal conductivity

#### SURFACE CHEMISTRY

- Colloidal stability
- Uniformity of NDs distribution in nanocomposites
- · Formation of shells/coatings
- · Conjugation with biomolecules
- Drug adsorption
- · Electron affinity (e.g. negative)
- Catalytic properties
- Activity of subsurface color centers
- Self-assembly into photonic crystals
- Biocompatibility

#### SIZE AND SHAPE

- Size of DNDs is ~4-5nm
  Shape close to spherical
- (DND) or blocky (HPHT)
- Influence reactivity
- Interactions with cells
- · Ball rolling in nanolubricants
- Quantum confinement

#### NON-DIAMOND CARBON

- EM radiation absorption
- Fullerene-like reactivity
- Influence biocompatibility
- Influence colloidal stability

## Quantum dots

They are tiny particles or nanocrystals of a semiconducting material with diameters in the range of 2-10 nanometers (10-50 atoms).

- They are nanoparticles made from semiconducting materials. The dots show quantum effects because of their small size.
- This means that electrons inside the dot are trapped and can only occupy defined energy levels.
- They were first discovered in 1980.

## Quantum Spin

- Spin is one of the basic features of the building blocks of matter, like electrons and nuclei.
- At any given moment, its value is a combination of two states called up and down.
- If the down component is zero, the spin will be up, and vice versa.

A computer can map these values to 0s and 1s and use the electrons to encode information. Manipulating the spin forms the basis of quantum computing.

## **Berry Phase**

- The Berry phase concept was introduced by physicist Michael Berry in 1986, following earlier work by Indian physicist S. Pancharatnam.
- The Berry phase is a geometric phase acquired throughout a cycle when a system's parameters are varied and then returned to their original values.

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- Electrons exhibit both particle and wave characteristics. As waves, they possess properties such as frequency, wavelength, and phase, which can change depending on external conditions.
- The Berry phase reflects changes in an electron's wave phase when cycled through different quantum states.

Electrons can be manipulated by altering energy levels through magnetic fields. **This allows** researchers to create a cycle of states, which helps in the measurement of the Berry phase. The Berry phase generated by the rotation of the FNDs could be applied to create a gyroscope for rotation sensing.

## Applications

• NDs are stable under light and aren't toxic to living things, so they have many applications in high-resolution imaging, microscale temperature sensing, and correlative microscopy, among others.

## Progeny tracking

• In biology, scientists use NDs to track cells and their progeny over long periods.

## **Biomedicine**

• NDs are biocompatible and can be used for cell labelling and imaging, targeted drug delivery, and cancer therapy.

## **Electronic** applications

• NDs are used in thin-film electronics, photovoltaic devices, energy storage devices, and electrochemical sensors.

## Quantum engineering

• NDs are used in quantum optics and nano-magnetometry.

## Quantum optics: It is the study of the quantum properties of light.

• Nano-magnetometry: It is a technique that uses AC sensing schemes to measure magnetic fields at the nanoscale.

Source: <u>https://epaper.thehindu.com/ccidist-</u> ws/th/th\_international/issues/101913/OPS/G4DDDKS8F.1.png?cropFromPage=true