Unique Fingerprinting Using Strain in Nanodiamonds

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Overview

Fluorescent nanodiamonds are nanoparticles (less than 100 nanometers) made of diamonds that have been engineered to emit fluorescent light. They are used in various applications, including biological imaging and sensing. However, they cannot be distinguished one from the other as the number of photons emitted per second from one nanodiamond is similar to that of another. Here we provide a new method of quantum-enhanced sensing by dispersing nanodiamonds, that comprise atom-sized defects, on a substrate and extracting the strain parameters of these particles to distinguish between them, thus providing their unique fingerprint.

Background and Unmet Need

Fluorescent markers are site-labeled markers in nanotechnology that provides a distinct signature or signal from a sample. Nanoparticles known as fluorescent nanodiamonds (FND) constitute an established technique of marking specific locations by a tailored functionalization of the nanodiamondsâ€™ surface groups. Due to their robust and inert nature, FNDs are considered highly stable emitters with a wide range of functional groups applicable to many systems. However, the fluorescence of each nanodiamond is indistinguishable from its neighbors as they have the same number of photons emitted per second. This calls for a class of markers that would allow one to tell them apart.

The Solution

Dr. Amit Finkler and his team invented a novel method that enables to distinguish between nanodiamonds using specific color defects in them called nitrogen-vacancy (NV) centers and their spin-strain interaction with their host diamond matrix.

Technology Essence

Nitrogen-vacancy (NV) centers have a characteristic photoluminescence spectrum. More importantly, the intensity of red fluorescence emitted by them is highly dependent on the surrounding magnetic field. Since this is an atomic, spin-1 defect, we can relate the magnetic field the defect experiences, to a specific microwave frequency via the Zeeman effect. Hence, it is possible to gauge the magnetic field by observing a pronounced dip in the intensity of emission as we scan the frequency of a microwave synthesizer. A large variance in axial and transverse strain can be encoded to an individual radio-frequency resonance for a cluster of NDs. The nanodiamonds (each nanodiamond hosts a few NV centers) are usually created by ball milling, and as a result, due to the extreme conditions during the milling process, each atomic defect or NV in a nanodiamond will have a slightly different strain field in its surrounding environment, which in turn will cause the microwave frequency to deviate from its zero-strain value of 2.87 GHz (at room temperature). For nanodiamonds of sufficient high quality of the starting material, this microwave dip or resonance will be narrow enough such that it would be possible to distinguish between the different nanodiamonds. Therefore, if one injects a very small amount of such fluorescent nanodiamonds into the device one wishes to give a unique tag, it would be possible to create a strain-induced microwave tag that can be read out optically by scanning with a small microwave source (such as a VCO).

Applications and Advantages

- High spatial resolution sensing using nanodiamonds as unique fluorescent markers.
- Serves as unique fingerprints for specific organelles in cells.
- A platform for anti-counterfeiting measures.
- Inexpensive solution using powder of nanodiamonds or nanodiamonds in solution.
- A unique identifier that will not deteriorate or deviate/change.
- Stable, reliable, and robust long-term solution.
- Bio-compatible.

Development Status

Dr. Finkler and his team invented a new method that enables identifying separate nanodiamonds based on the coupling between the strain in the nanodiamond and the spin degree-of-freedom in the nitrogen-vacancy center in the diamond. The team is currently working on a different property of fluorescent nanodiamonds having NVs in them which is related to super-resolution microscopy.

Market Opportunity

A unique fingerprint or identifier is desirable for various sorts of applications such as tracking a specific product, object or preventing forgery. Furthermore, these nanodiamonds can serve also as unique fingerprints for specific organelles in cells due to their biocompatibility, low toxicity, and unique optical properties. In addition, this unique fingerprint can be suitable to tag merchandise, clothes, etc. (as the RFID technology), be used as a QR code, and tag and monitor weapons to prevent leakage to illegal markets. The NDsâ€™ origin can also be verified as manufacturers can test the unique fingerprint of the ND batch. This has important applications in the verification of international shipping components, long-haul cargo, and electronics.

Patent Status

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