NV Center Diamond Imaging

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NV (Nitrogen-Vacancy) Diamond Sensor

- NV Center: defect in diamond where a nitrogen sits next to a missing (vacant) carbon atom
- Makes a quantum system sensitive to magnetic fields
- Enables subcellular **spatial resolution** (400 nanometres) imaging of magnetic fields
  - compared to existing techniques such as MRI and SQUID (difference in spatial resolution or application to living samples)
- Maintains long (stable) NV electronic spin **coherence times** even when in close proximity to magnetic field sources, though nearby magnetic forces may cause slight but manageable reductions in coherence times
- Can detect and image electron spins within the diamond crystal and materials 20 nm beneath the diamond's surface
- Imaging Magnetosomes (magnetic-field-sensing organelles) on the diamond surface

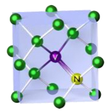

Figure 1. Nitrogen-Vacancy Center Model (Source 3)

How Magnetic Imaging Works/Setup

- The green laser light (532 nm) excites the NV centers to a higher energy state
- These NV centers emit red light (637 - 800 nm) when returning to ground state
- Microwaves are applied to induce **spin state transitions**
- Magnetic fields shift the microwave frequencies, affecting the red fluorescence intensities read
- Using different crystal axes and microwave frequencies, vector magnetic field maps can be made, showing bacteria location and orientation

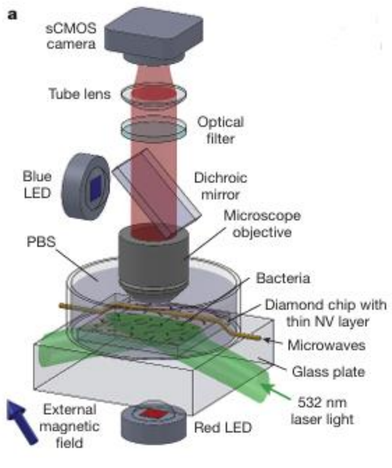

Figure 2. Wide-Field Magnetic Imaging Microscope (Source 1)

Verification & Applications

- Match magnetic field images with normal images taken in the same place and time to verify accuracy of NV imaging
- Construct images of the magnetic field created by magnetosomes produced in magnetotactic bacteria
- Optical and magnetic imaging of multiple cells to characterize and identify bio-magnetic structures
  - Mapping and simulation of magnetic fields

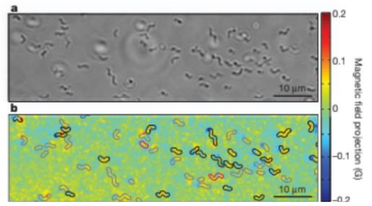

Figure 3. Wide-Field Optical (a) & Magnetic Images (b) of magnetotactic bacteria (Source 1)

Conclusion

- NV diamond sensors best suited for imaging spins and magnetic nanoparticles of a target located within 20-30 nm from diamond's surface
- Laser power must be controlled to maintain conditions in which the biological samples stay alive
  - About 44% of bacteria remain viable after NV center imaging
- This method is not useful in detecting non-magnetotactic organisms with a weaker magnetic field, but can be used to study magnetic nanoparticle formation, which may affect magnetic navigation and neurodegenerative diseases. It could also be used for tagging molecules, identifying neuron activity, and detecting free radicals from the immune system.

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