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Principles of Scanning Nitrogen-Vacancy Magnetometry Explained

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Scanning nitrogen-vacancy (NV) magnetometry is a measurement technique that combines scanned probe microscopy (SPM) with optically detected magnetic resonance (ODMR) to image magnetic field distributions with high spatial resolution (<50 nm). This technique advances our understanding of the physics of nanomagnets in condensed matter physics and cell biology.

What Scanning NV Magnetometry Can (and Cannot) Do

Scanning NV magnetometry "relies on a single, optically-readable defect spin (i.e., an NV center) embedded in a single diamond tip that is scanned over the sample of interest." While the technique has been applied to measure the temperature and electrical field, this article focuses primarily on its ability to detect very weak magnetic fields at the scale of atomic-sized.

Scanning NV magnetometry is commonly applied in two different ways. The first type of measurement, called a pulsed measurement (such as magnetometry), is extremely sensitive but very slow. It can detect the magnetic moment of nuclear spins, but the measurements can take several hours and thus are not often used for imaging.

Continuous wave (CW) scanning NV magnetometry, meanwhile, is less sensitive but is relatively fast, recording a single data point within a few seconds. CW scanning NV magnetometry is more popular for this reason and is used for a multitude of engineering and scientific applications.

For example, a researcher may wish to map the magnetic field distribution generated by current across a sheet of graphene. The experiment does not require single-molecule-level resolution; a CW measurement is capable of the 40-80 nm resolution necessary to image a single molecule. <10 nm resolution would be required. As current is applied to the graphene sheet, the magnetic field generated can be gauged using the NV center (i.e., the probe tip). In a recording, this is how field signatures can be determined. The more field a component generates, the more likely it is to encounter electrons. Lower current applied to the circuit means lower magnetic field is generated, but it remains sensitive with 40 nm resolution.

CW scanning NV magnetometry can be applied to understand how magnetism functions at various scales relevant to new materials (e.g., two-dimensional magnets, materials — ideally two atomic-

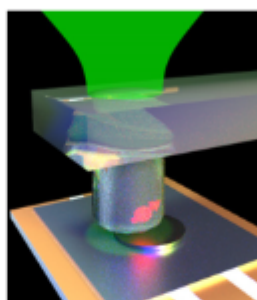


Fig. 1. The principle of scanning NV magnetometry. A diamond tip with an NV center is scanned over the sample of interest. Optical excitation and a green laser excite the scanning probe. The NV center is sensitive to the magnetic field of the sample.

layers — which are important in the field of on-chip quantum communication and magnetic memory devices. CW scanning can create a large (e.g., 500x500 pixel) image with very high spatial resolution of about 80 nm. The technique will capture technical devices, structure boundaries between the domains, and

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