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Author: Mr. Jaroslav Hruby
Institute for Material Research (IMO), IMOMEC, IMEC , Belgium

Ms. Goele Magchiels
Institute for Material Research (IMO), IMOMEC, IMEC , Belgium
Mr. Tom Mladenov
Hasselt University, Belgium
Mr. Dylan Gybels
Institute for Material Research (IMO), IMOMEC, IMEC , Belgium
Mr. Kirian Winter
Institute for Material Research (IMO), IMOMEC, IMEC , Belgium
Mr. Jelle Vodnik
Institute for Material Research (IMO), IMOMEC, IMEC , Belgium
Dr. Emilie Bourgeois
Hasselt University, Belgium
Prof. Milos Nesladek
Hasselt University, Belgium

DIAMOND AS A QUANTUM SENSOR FOR SPACE EXPLORATION

Abstract

Classical sensors used nowadays in space industry rely on the statistical behaviour of measured entities (eg. electron flux, charge, resistance) as response to external fields. In contrast, quantum sensors detect the interaction of coherent individual quantum objects or spin ensembles with the measured fields. This provides a direct access to the quantum nature of physical quantities such as magnetic field, electric field or pressure, resulting in a more efficient way of measuring. Despite their benefits, quantum based technologies often require large instruments and a specific operational environment, as the cryogenic temperatures to achieve superconductivity in SQUIDs, for example. Resulting bulkiness and complexity are severe limitations for their wider employability in real-life applications.

Diamond is known as the hardest natural material, can withstand large pressures, and exhibits a high radiation hardness due to its wide band gap. These properties make diamond-based sensors excellent to be used in harsh (aero)space conditions. An opto-magnetic defect, known as Nitrogen-Vacancy (NV) center, located in the diamond crystalline lattice, can be exploited as a solid-state qubit. By reading out the electronic spin state of negatively charged Nitrogen-Vacancy centers (NV-), the magnetic field, electric field, and temperature can be measured, relying on the fine (spin-spin) interactions. Due to its physical qualities, diamond-based sensors can operate in a wide range of temperatures (0K to 500K).

The working principle of electric readout NV-based magnetometry in diamond was proven in laboratory conditions[1]. In order to demonstrate the technical realization of a miniaturized sensor and the utilization of quantum sensors in real conditions, we are developing a matchbox sized (50x30x20 mm) prototype of a diamond quantum magnetometer. By exploiting the properties of NV centers, a sensitivity of sub-pT[2] and a wide dynamic range up to mT can be achieved. During this development, we aim to

observe the Earth's magnetic field with a nT sensitivity. The prototype devices test flight is scheduled for October 2018, in the framework of the OSCAR-QLITE project, on board of a stratospheric balloon flight during the 11th cycle REXUS/BEXUS program, organised by SNSB, DLR and ESA.

By enabling novel ways of sensitive measurements of physical quantities, diamond-based sensors can be employed in a widely for both space and terrestrial applications such as biosignal measurement, space weather monitoring, navigation, magnetometry, mineral exploration, or onboard sample analysis.

[1] Bourgeois, E. et al., Nat. Comm. (2015);6, 8577.
[2] Wolf, T. et al., Phys Rev X. 2015;5(4):041001.