Quantum Sensing for Energy Applications

The application of rapidly evolving quantum technologies to real-world systems is providing new opportunities for quantum-sensing technologies, including optically detected magnetic resonance (ODMR) in sensing and identifying potential energy system problems that could benefit from quantum sensing. The quantum system can be enhanced for high sensitivity and high dynamic range in the data collection process. Sensitivity can make a quantum sensor useful for various applications, such as atomic impurities (N, Si, Sn, etc.) and carbon vacancy on a diamond lattice.

Hybrid Quantum-Classical Sensing: Advantages and Scopes

Traditional Sensors
- Provide wide bandwidth and range
- High update rate and high dynamic range in the data collection
- Sensitivity: $1 \text{nm}^3/\text{cm}^3$ (0.1 mT/m)
- Spin noise: $10^{11}$ at $1$ Hz
- Low update rate but highly accurate for the measurement of a given point
- Ultrahigh sensitivity
- May not be simple but low cost
- Extremely fast (ms)

Quantum Sensors
- Provide extra accuracy without error or noise
- Typically bandwidth is $10$ [one year second] $< 8 \text{ mT/m}$
- $\sim 300 \text{ K}$
- $(\Delta \nu) < 370-700 \text{ K}$
- Spin relaxation time and pt sensing
- Zero-photon line emission (thermometry)
- Room temperature operation

Disclaimers:

- Atomic impurity (N, Sn, etc.) and carbon vacancy in a diamond lattice: spin pubs
- Information stored in spin states are optically readable
- Optically detected magnetic resonance (magnetometry, thermometry, electrometry)
- Spin relaxation (con and pt sensing)
- Zero-photon line emission (thermometry)
- Room temperature operation

Modelling of Diamond with NV center for field and pressure sensing

- Changes in the electronic and optical properties of bulk diamond with N impurities and/or N with a carbon (C) vacancy defect on sensing-related applications.
- Sensitivity at the nanoscale can be achieved using NV centers in diamond. NV center-based sensor shows almost zero function of magnitude improvement over the traditional sensors.
- Shifting of band gap and splitting of bond edge under (up to $2\%$) changes in the lattice parameters.
- The split is up to $40\%$ due to a tensile strain under $2\%$

Comparison with traditional optical sensors
- Quantitatively this is about $4\%$ of magnitude improvement over traditional optical sensor!
- This shows a superiority of stress sensitivity behavior that could be achieved by manipulating the ground state spin levels in NV center nanodiamond over the traditional optical sensor based on the band edge or band gap shift application.

Disclaimer:

This project was funded by the U.S. Department of Energy, National Energy Technology Laboratory, in part, through a site support contract. Neither the United States Government nor any agency thereof, nor any of their employees, nor the support contractor, nor any of their employees, makes any warranty, express or implied, or assumes any liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, or otherwise, does not necessarily constitute its endorsement, recommendation, or favoring by the United States Government or any agency thereof. Views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.