

Spin center defects for quantum information science

Denis R. Candido, University of Iowa, USA

February 10, 2026

Defects with spins in solids – also known as spin centers – have been shown as promising long-lived qubits with the ability to be optically initialized and interrogated. Interestingly, they have also been demonstrated to be noninvasive quantum sensors with high sensitivity to both magnetic and electric fields and temperature. Nevertheless, to unlock the full potential of defect-based technologies, challenges such as the suppression of noise and the creation of spin-spin entanglement need to be tackled. In this talk, I will discuss recent developments we developed on these two main points. In the first part of my talk, I will discuss our recent theoretical results demonstrating magnons as mediators of coupling and entanglement between Nitrogen-Vacancy (NV) centers [1,2]. Next, I will show how to experimentally determine the NV-NV coupling mediated by magnons for a diamond slab on top of a YIG bar [3]. This is obtained through the magnon-induced self-energy of the NV center, obtained by combining both room-temperature longitudinal T1 relaxometry and the fluctuation-dissipation and Kramers-Kronig relations [3]. Further, we will discuss interfacing NV centers to different magnetic topological excitations. These include the use of magnon modes for entangling quantum skyrmions [4,5], the use of spin centers to study both gyrotropic modes in magnetic topological vortex states [6] and topological magnons [7]. Finally, I will also discuss how to implement quantum simulation of the spin-chains and Dicke Hamiltonian using spin centers [8,9].

In the second part, we study the electric noise in spin defects due to both fluctuations of the surface charged density and the electrostatic potential at the surface of our crystal [10,11]. We show that the depth-dependence of the surface charge noise is strongly influenced by the two-point correlation function of the charged particles' positions, rather than solely by the character of the charge fluctuators, e.g., monopole or dipole [11]. We then show that spin defects can be used for sensing of diffusion phenomena (and other surface electric dynamics), via their fingerprints and signatures within the spin defect's T1 and T2 [11]. Furthermore, we provide the first complete theory for dephasing and relaxation processes of NV-centers that takes into account all the Lindblad dissipators allowed by NV symmetry [8]. We also study the corresponding interplay of magnetic and charge noise (surface and bulk) on NVs [10]. By contrasting these findings with our experimental data, we show that surface-charge noise is the dominant source of noise in bare diamonds, while silica and TiO₂-coated diamonds show a dominant bulk source [12,13]. This demonstrates suppression of the surface noise via coating processes, with a corresponding 3.5-fold increase in NV-coherence times [12,13]. We demonstrate that the implantation of silica-coated nanodiamonds in cells allows for probing cellular activity via the unaccounted transverse dipole term, which induces systematic shifts in the zero-field splitting [14]. Finally, we also show an alternative method for the suppression of both bulk and surface charge noise based on embedding spin-centers in p-n diodes [15].

References:

- [1] D. R. Candido, G. D. Fuchs, E. Johnston-Halperin, and M. E. Flatte, *Materials for Quantum Technology* 1, 011001 (2021).
- [2] M. Fukami, D. R. Candido, D. D. Awschalom, and M. E. Flatte, *PRX Quantum* 2, 040314 (2021).
- [3] M. Fukami, J. C. Marcks, D. R. Candido, L. R. Weiss, B. Soloway, S. E. Sullivan, N. Deegan, F. J. Heremans, M. E. Flatté and D. D. Awschalom, *PNAS* 121 (2024).
- [4] C. Psaroudaki and C. Panagopoulos, *Phys. Rev. Lett.* 127, 067201 (2021).
- [5] D. R. Candido and C. Psaroudaki, in preparation
- [6] C. Patrickson, E. Gomes da Silva, P. Keatley, D. R. Candido, I. Luxmoore, in preparation.
- [7] J. Leiberton, N. W., Eudes Gomes and D. R. Candido, in preparation.
- [8] T. Losey, D. R. Candido, J. Zhang, Y. Meurice, M.E. Flatté, S.W. Tsai, *Physical Review B* 110 (1), 014413 (2024)
- [9] A. C. Lourenço, D. R. Candido, E. I. Duzzioni, *Annals of Physics* 482, 170196, (2025)
- [10] D. R. Candido, M. E. Flatté, *PRB* 110 (2), 024419 (2024)
- [11] D. R. Candido, M. E. Flatté, *PRB* 110 (17), 174450 (2024)
- [12] U. Zvi, D. R. Candido, et al, *PNAS* 122, 21 (2025)
- [13] X Yu, ..., D. R. Candido, A. Esser-Kahn, P. C. Maurer, *Physical Review Applied* (2026), in press
- [14] U. Zvi, ..., D. R. Candido, A. Esser-Kahn, P. C. Maurer, *Advanced Materials*, e05107, (2026)
- [15] D. R. Candido and M. E. Flatté, *PRX Quantum* 2 (4), 040310 (2021)

Bio:

Prof. Candido earned his Ph.D. from the University of São Paulo under the supervision of J. Carlos Egues where he studied band structure and transport properties in topological quantum systems. After completing his Ph.D., Prof. Candido was a postdoctoral researcher in David Awschalom's group at the University of Chicago in 2019 and in Michael E. Flatté's group at the University of Iowa from 2019 to 2021 – where he primarily conducted studies on spin defect centers in semiconductors. Since 2022, Prof. Candido has been an Assistant Professor at the University of Iowa in Iowa City, where he conducts research in quantum information science and condensed-matter systems.