Electron spin decoherence in disordered graphitic nanospheres

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Graphitic materials are highly promising for spintronic applications due to their low spin-orbit coupling and minimal presence of spin-active nuclei [1]. Among these, carbon nanospheres (CNS), composed of nested concentric graphitic layers, present an attractive system for such applications [2]. However, spin decoherence, primarily driven by hyperfine interactions, remains a key challenge for practical implementation. In this work, we investigate spin decoherence in large, disordered CNS, focusing on predicting and enhancing the electron spin decoherence time (T_2). We develop and experimentally validate a simplified analytical model that accurately describes hyperfine interactions and T_2 in systems with various edge types and point defects, such as B/N substitutions, chemisorbed hydrogen, and carbon vacancies. Our model identifies the dominant decoherence mechanisms and reveals the critical role of structural disorder and isotopic distribution in determining spin coherence. By addressing key decoherence pathways, this study establishes a robust theoretical framework for optimizing spin properties in carbon-based materials, emphasizing the importance of defect minimization through controlled annealing. By comparing our theoretical predictions with experimental data, we demonstrate that spin polarization in CNS extends over a characteristic region of approximately 5 nm when T_2~175 ns. Additionally, we propose a refined annealing process that successfully extends T_2 to 362 ns. These findings provide crucial insights into improving spin properties in CNS, offering a pathway toward enhanced performance in quantum computing and spintronic applications.

References

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