Potential Spin Qubits Using Transition-Metal-Ion Doped Halide Double Perovskites

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Solid-state spin qubits are a cornerstone of scalable quantum networks, traditionally requiring nuclear-spin-free hosts to maintain coherence. In this work, we present the first demonstration of halide double perovskites (HDPs) as a viable platform for solid-state spin qubits, establishing a new material library for quantum information technology. Utilizing transition-metal (TM) centers—Cr^{3+} and Fe^{3+} ions—doped into a $Cs_2In(Na,Ag)Cl_6$ host[1], we demonstrate that these centers exhibit long-lived electron spin coherence despite the nuclear-spin-rich environment of the perovskite lattice. We report benchmark coherence times T_2 of 29.5 μs for Cr^{3+} and 21.2 μs for Fe^{3+} at 4 K. Our findings reveal that strong spin localization at the TM sites facilitates deterministic electron-nuclear (e-N) spin rotations with neighboring $^{35,37}Cl$ and ^{133}Cs spin, limiting the number of e-N interaction and resulting in long spin coherrence in the Nuclear spin-rich hosts. Furthermore, by probing spin-resolved optical transition at high magnetic field, we show that Cr^{3+} centers are optically addressable through spin-selective intra-d-shell transitions, enabling clear protocols for high-fidelity optical initialization and readout. These results highlight the potential of halide perovskites to provide a chemically tunable "sandbox" for engineering advanced quantum states, such as qudits, using inexpensive and scalable solution-based synthesis. By combining superior optoelectronic properties with robust spin coherence, this platform opens new avenues for integrating quantum nodes with existing semiconductor technologies.

Reference

1. Khamkaeo, S. et al. Spin Qubits Candidate in Transition-Metal-Ion doped Halide Double Perovskites. Nat Commun 17, 415 (2026).