

Engineering Erbium-Doped Rare-Earth Oxide Thin Films For Quantum Networks

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Telecom spin qubits in semiconductors are of considerable interest for quantum memories and repeaters for quantum communication networks. Among the candidate systems, erbium ions (Er^{3+}) are especially promising because they provide a telecom C-band optical transition together with long-lived spin states, making them attractive for spin-photon interfaces. The development of CMOS-compatible erbium doped thin films is therefore an important step towards scalable Er^{3+} -based quantum devices. In this talk, we present a comparative study of two complementary approaches to this goal: (1) molecular beam epitaxy (MBE) of Er^{3+} doped oxide thin film on silicon [1-4] and (2) controlled spalling [5] of thin film from high-quality bulk Er^{3+} -doped crystal onto CMOS-compatible platforms. Specifically, we compare Er^{3+} doped CeO_2 thin film and spalled Er^{3+} doped CaWO_4 film to elucidate competing spin decoherence dynamics and the influence of surfaces/interfaces. The MBE grown $\text{Er}^{3+}:\text{CeO}_2$ exhibits a promising narrow optical homogeneous linewidth (~ 440 kHz) [2], a spin relaxation time of ~ 120 ms and a spin coherence of 38.8 μs at 77mK [3]. We identify spectral diffusion driven by Er–Er spin flips as the dominant decoherence mechanism, with the large and symmetric g-tensor of this host playing a critical role in inducing strong Er–Er magnetic dipolar interactions. For comparison, we further explore an asymmetric host, CaWO_4 . By optimizing the spalling conditions for this medium-hard material, we obtain $\text{Er}^{3+}:\text{CaWO}_4$ films with thicknesses of ~ 1 microns. The spalled film shows a spin coherence of 347 μs , only 20% lower than that of bulk crystal (438 μs) [6]. In this host, the Er–Er interaction is governed by the much weaker $g \sim 1.2$ tensor component, significantly suppressing Er bath spin flip induced spectral diffusion. The modest reduction in coherence between spalled and bulk samples may be attributed to additional decoherence from dangling bonds and charges at the spalled surface. Finally, we discuss the trade-offs between epitaxial growth and crystal spalling as routes to scalable erbium-based quantum-network platforms, and outline mitigation strategies for reaching millisecond-scale spin coherence in integrated devices.

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