Epitaxial rare-earth doped oxide thin films deposited by liquid injection CVD for quantum technologies applications

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Rare-earth (RE) ions are promising solid state qubits for quantum information technologies They indeed offer ultra-narrow optical transitions (including in the useful telecom-band wavelength for erbium) and exceptionally long spin and optical coherence time for europium at cryogenic temperatures [1]. Their 4f shells are only partially filled and are screened from their environment by outer 5p shells leading to weakly allowed yet sharp optical transitions. They thus behave as a kind of isolated ions embedded in a crystalline matrix in which a large variety of optical and spin levels can be optically addressed and manipulated to perform quantum storage or quantum processing operations. Macroscopic bulk oxide crystals (such as RE:Y_2SiO_5) have been largely studied to this aim as they can be produced with high crystallinity and purity. The development of those oxides as thin high-quality films would however offer greater prospects of scalability and ease post-processing and integration into photonic chips and optical resonators [2].

In this work, we focus on the synthesis of nanoscale Eu-doped Y_2O_3 and Y_2SiO_5 thin films on different substrates including silicon, sapphire and yttria-stabilized zirconia wafers. We used a specially developed direct liquid injection chemical vapour deposition (DLI-CVD) reactor in which liquid precursors are sprayed and flash-evaporated before being carried to the reaction area (Fig. 1a) [3]. By optimising the growth conditions, including evaporation and deposition temperatures, composition and film architecture, we produced textured polycrystalline and epitaxial thin films doped with varying amounts of europium or erbium. The optical properties of the films were then assessed by advanced spectroscopy techniques and benchmarked to optimized RE-doped bulk oxides. At low temperature, inhomogeneous linewidths of about 18 GHz were reached for the $^7F_0 \rightarrow {}^5D_0$ optical transition of Eu (Fig. 1b), while, by spectral hole burning spectroscopy, holes as narrow as 10 MHz (Fig. 1c) could be measured. These properties are still behind those observed for single crystals but are already a first step towards more integrated rare-earth doped oxide platforms for this field of application.

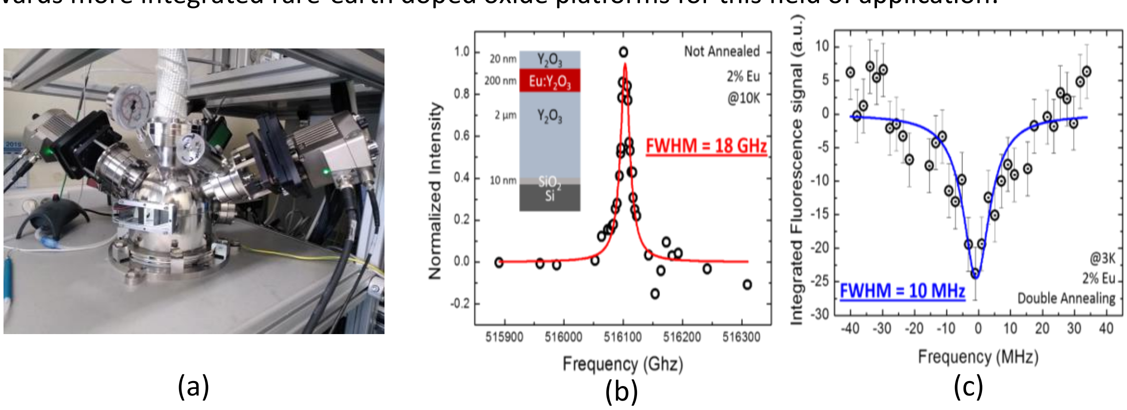

Fig. 1. (a) DLI-CVD reactor developed at IRCP, (b) inhomogeneous linewidth measured at 10K for a thin Eu-doped Y_2O_3 film on Si, (c) spectral hole burnt in the same film at 3K.

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