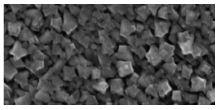

Quantum Technologies : a new platform using rare-earth oxide thin films

The development of new materials systems exhibiting remarkable quantum properties at the nanometric scale – nanoparticles, ultrathin films – is a major objective for the creation of new devices for such quantum technologies as quantum computing or quantum cryptology. Within this domain, the Nanometric Thin Films team of the INSP, in a collaboration with teams from the IRCP and the INL, has made high quality thin films of yttrium oxide doped with erbium, obtaining for the first time optical and coherence properties indicating the formation of a very promising technological platform for development of thin film quantum technologies.

Quantum Technologies are based on manipulation of the quantum states of a structure in order to build devices with performance beyond the reach of classical systems : ultra-sensitive sensors, nanometric imaging in life sciences, information processing, cryptologie ... The launching of the European Quantum Flagship and the huge international effort in this area are a measure of the stakes involved. The extreme sensitivity of quantum systems to their external environment is a quality that may be exploited, but on the other hand requires extreme control over the purity or the crystalline quality of the materials intended for producing quantum devices. Optical and spin transitions in rare-earth ions such as europium or erbium incorporated into bulk oxides are already particularly promising, with record coherence times, however engineering these materials in the form of thin films will open new paths for the fabrication, miniaturisation and the coupling of such systems to other materials or systems.

We have produced Y_2O_3 films of 200nm thickness controllably doped with Eu, employing a Chemical Vapour Deposition (CVD) technique with injection of liquid precursors. The precise and absolute determination by Rutherford Backscattering Spectroscopy (RBS), on the SAFIR platform of the INSP, allowed us to optimise growth conditions leading to finely controlled incorporation of Eu over a large concentration range, and so to reliably study the film properties as a function of the rate of replacement of Y by Eu. The films, grown on a silicon substrate, are polycrystalline, columnar, and cubic, highly structured in the [111] direction. The optical emission from the Eu ions has an inhomogeneous width of the order of 50GHz, which indicates a relatively limited level of disorder around these ions. The homogenous width of the transition responsible for the optical emission is estimated, by spectral hole burning, to be around 11 MHz. This is the first such measure for nanometric thin films, although the homogeneous width remains greater than that observed (<1MHz) in bulk material.

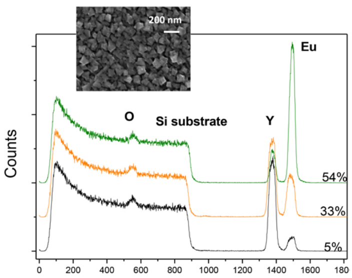

Figure 1
RBS spectra of Eu :Y_2O_3 films with different europium concentration, and (inset) the corresponding electron microscope image of a typical film.

Synthesis of these films by CVD with liquid precurseur injection is thus a promising avenue for precision engineering of new systems for quantum technology. A strong effort is now necessary to improve the crystalline properties of these films and further reduce the homogeneous width of the emitted rays. Initial tests of coupling to optical cavities are presently under way.

Reference

«Chemically Vapour Deposited Eu^{3+}:Y_2O_3 thin films: a relevant material platform for quantum technologies»
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