Chimie ParisTech

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IRCP Institut de Recherche de Chimie Paris

Rare-earth doped oxide thin films for on-chip optical quantum technologies

Scientific description:

Rare-earth ions (REI) present a strong interest for quantum technologies due to their ability to show long-lived quantum superposition states both in their optical and spin transitions. The perspective of using them for applications such as quantum information processing, quantum memories and indistinguishable photon sources, however, relies on developing host materials in which their outstanding quantum properties are preserved, while enabling integration into nanophotonic devices. Several proof-of-concept experiments based on rare-earth doped oxide crystals have been reported [1], [2], yet, integration into practical and scalable quantum devices has still not been stablished. In particular, specific designs compatible with both optical cavities and MW architectures are generally needed [3], [4]. In this context, the ability to host REI into thin oxide films deposited on a scalable substrate such as silicon would greatly facilitate the development of such resonators. A thin film architecture also allows flexibility in material composition or dopant spatial localization and offers integration perspectives with silicon photonic chips by standard clean room processing technologies [5], [6]. As a drawback, the obtention of high-crystalline quality oxide films on silicon is very challenging with most deposition techniques. Moreover, the optical and spin properties of REIs in thin films tend to lag behind that of their bulk counterpart, mainly due to the close proximity of surface and the presence of interfacial defects. To overcome these challenges, we have developed a hybrid thin film fabrication approach combining MBE [5] and CVD [7] deposition techniques to obtain epitaxial rare-earth oxide thin films on silicon (Fig. 1). The optical properties of europium ions embedded in this film matrix have already shown promising results with sub-MHz homogeneous linewidths measured.

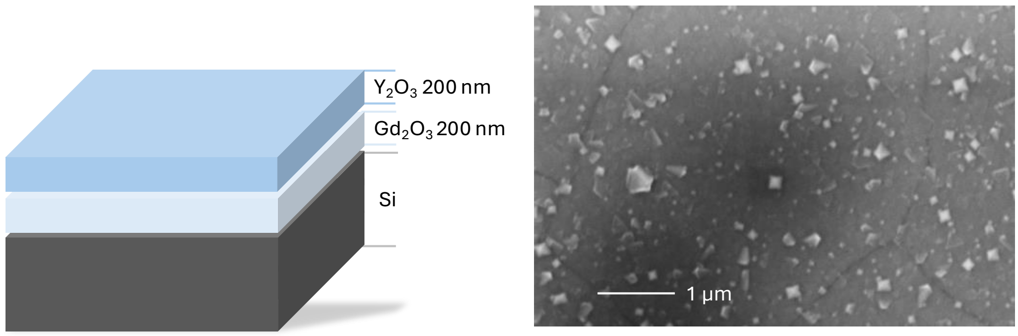

Figure 1. Left - Schematic representation of a hybrid CVD-MBE Y_2O_3/Gd_2O_3 thin film on silicon. Right – Scanning electron microscope image of the film surface showing oriented crystalline grains.

This internship will have two main objectives: (i) the optimisation of the thin-film deposition conditions towards the reproducible obtention of smooth epitaxial Y_2O_3 thin films doped with REI. (ii) the fabrication of Y_2O_3 membranes by both dry and wet chemical etching techniques. The deposited thin films, and membranes quality and eligibility for quantum technology applications will be assessed by the candidate using different morphological and optical characterizations.

Techniques/methods in use: Chemical Vapor Deposition (DPC), DRX, SEM, chemical etching, fluorescence and absorption spectroscopy.

Applicant skills: Interest on thin-film deposition and nanofabrication techniques. Basic knowledge about light-matter interactions, optics, data collection and treatment.

Internship duration - 6 months

Internship supervisor(s)

Alexandre Tallaire, alexandre.tallaire@chimieparistech.psl.eu

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Internship location: Institut de Recherche de Chimie Paris, Chimie ParisTech-PSL, 11, rue Pierre et Marie Curie, 75005 Paris

Possibility for a Doctoral thesis: Yes, by applying for a doctoral school grant.

Bibliography

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[3] B. Casabone *et al.*, “Dynamic control of Purcell enhanced emission of erbium ions in nanoparticles,” *Nat Commun*, vol. 12, no. 1, Art. no. 1, Jun. 2021, doi: 10.1038/s41467-021-23632-9.

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[5] S. Gupta *et al.*, “Dual epitaxial telecom spin-photon interfaces with correlated long-lived coherence,” Oct. 10, 2023, *arXiv*: arXiv:2310.07120. doi: 10.48550/arXiv.2310.07120.

[6] M. K. Singh *et al.*, “Epitaxial Er-doped Y_2O_3 on silicon for quantum coherent devices,” *APL Materials*, vol. 8, no. 3, p. 031111, Mar. 2020, doi: 10.1063/1.5142611.

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