Thin film engineering in Er-doped CeO_2 for quantum memory

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Developing a commercially available quantum memory device is essential for building wide-area ground-based quantum networks, which will yield applications like guaranteed cryptographic security that uses existing telecommunication infrastructure. However, a functional quantum memory requires the discovery of the optimal materials for these devices, and the optimization of their processing parameters. Researchers have investigated a multitude of materials that could be useful, especially diamond nitrogen-vacancy centers, silicon carbide, and rare-earth doped oxides. A particularly promising candidate for quantum memory is erbium-doped ceria (Er:CeO_2), which theoretically could yield long quantum coherence times of up to 47 ms [1]. Er:CeO_2 is also favorable due to erbium's $^4I_{15/2}$ to $^4I_{13/2}$ optical transition in the telecom-C band (~1.5 μm), which would allow for direct incorporation of Er:CeO_2 quantum memory into already-existing telecom optical fiber infrastructure with minimal signal attenuation. Recent research on MBE-grown Er:CeO_2 on Si(111) suggests that the emission lifetime of Er:CeO_2 can be further improved through thin film engineering and the reduction of Er^{3+} concentration below 1% [2].

We build on this research by doping CeO_2(111) with low Er^{3+} concentrations (<1%). We use Raman spectroscopy, atomic force microscopy (AFM), and photoluminescence excitation (PLE) spectroscopy to investigate the effects of MBE growth parameters, grown host material quality, and low Er^{3+} concentrations on Er:CeO_2 optical linewidths and emission lifetime. We expand this investigation from Si(111) to two additional substrates, GaAs(111)A and yttria-stabilized zirconia(111) (YSZ), to identify the effects of different substrates and compressive/tensile strain on PLE spectra.

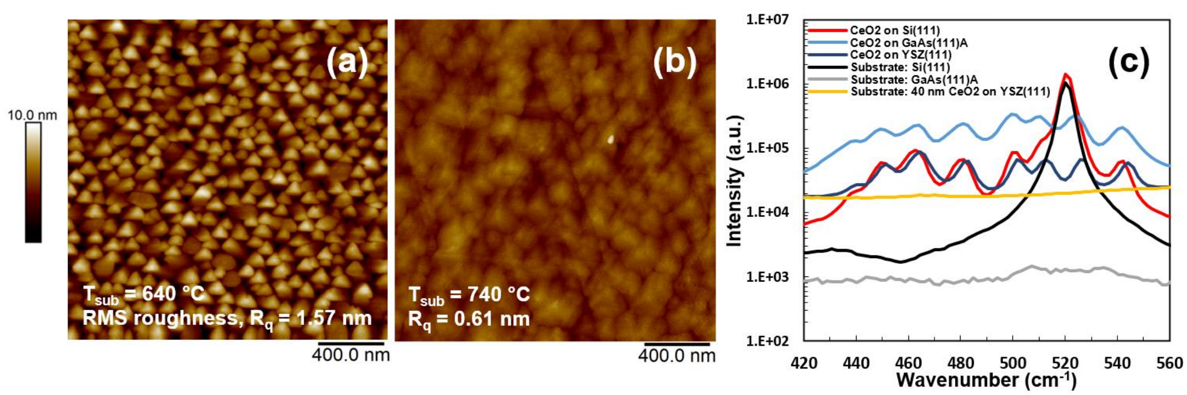

Figure: (a),(b) 2 × 2 μm^2 AFM images of Er-doped CeO_2 grown at different substrate temperatures (T_{sub}): (a) T_{sub} = 640 °C, (b) T_{sub} = 640 °C. (c) Raman spectra for Er-doped CeO_2 grown on Si(111), GaAs(111)A, and YSZ(111), with each substrate included for reference.

[1] Kanai *et al.*, arXiv:2102.02986 [quant-ph], (2021).

[2] Inaba et al., Opt. Mater. Express, **8**(9), (2018).

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