Comparative study of rare-earth doped sesquioxides grown by pulsed laser deposition and their performance as planar waveguide lasers

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The sesquioxides yttria, scandia and lutetia have been identified as promising host materials for high power lasers due to their excellent thermal properties, their ability to incorporate RE-ions and their resulting spectroscopic properties [1]. However, the melting points of these materials exceed 2400°C and are therefore problematic to grow from the melt. Pulsed laser deposition (PLD) is an alternative method of growing thin crystalline films of these materials, avoiding the requirement for such high temperature growth.

Samples of doped yttria, scandia and lutetia have been deposited onto 1 cm^2, 1 mm thick YAG substrates that are heated from the rear by a CO_2 laser beam, shaped by a ZnSe tetraprism to match the square surface profile of the substrate. A KrF excimer laser operating at 248 nm and delivering 20 ns pulses at a repetition rate of 20 Hz is used to ablate doped sintered ceramic targets of the respective sesquioxides in a controlled low pressure oxygen atmosphere. Subsequent sample analysis is focussed on crystallinity, surface quality, spectroscopic characteristics and propagation loss for the end application as optical waveguides. In this study, we focus on correlations between the substrate temperature during crystal growth and the results from the characterisation of the crystallinity and laser performance with the aim of determining optimum conditions for realising high quality crystalline waveguides with lower propagation losses and greater potential for higher power lasers.

Sesquioxides grow preferentially in the (222) crystal orientation on YAG substrates as there is a near lattice match and it is energetically favourable even when deposited on amorphous substrates [2]. In fig. 1 (a) the (222) peak heights of Y_2O_3 for Yb:Y_2O_3 samples deposited at a selection of temperatures indicates that there is an optimum temperature for yttria growth by PLD that corresponds to around 75% of the full 30 W of CO_2 power available incident on the substrate, which we estimate from calibration experiments to be ~900^{o}C. The resulting waveguide samples were end facet-polished plane parallel for loss measurements and laser experiments.

Yb:Y_2O_3 has been deposited on both YAG <100> and <111> oriented substrates to investigate the effect on crystal growth and, more importantly, subsequent lasing performance from end-pumped quasi-monolithic cavities, with a 5% transmission (T) output coupler (OC) used for each sample in the results displayed below. Fig. 1 (b) shows little change in slope efficiency with growth temperature for samples deposited on YAG <111>. The most notable point we have taken from these lasing experiments is that the slope efficiencies achieved with the Yb:Y_2O_3 on YAG <100> are significantly better than those achieved with growth on YAG <111>.

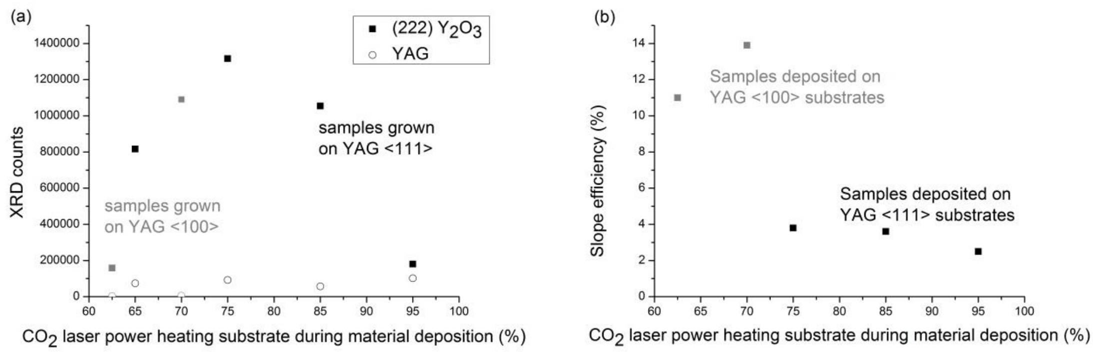

Fig. 1 (a) Variation in XRD peak counts observed in Yb:Y_2O_3 deposited on YAG substrates at different temperatures, (b) slope efficiencies of lased samples correlated with growth temperature.

Our highest output power to date from a PLD-grown Yb:Y_2O_3 planar waveguide laser is 1.2 W, with a slope efficiency of 20% using a 70%T OC and limited by available pump power [3]. Recent experiments demonstrated a slope efficiency of 46% with a 19.5%T OC for an Yb:Y_2O_3 sample on YAG <100> substrate. Further experiments are underway with additional Yb:Y_2O_3 samples as well as Yb:Lu_2O_3, so laser performance between the two materials can be compared. Experiments with Nd-doped Lu_2O_3 and Y_2O_3 are also underway.

References

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