Study of Tm-doped Aluminosilicate films for Integration of Lasers on a SOI Silicon Photonics Platform

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Thulium-doped glass has recently been highlighted as a potential candidate for amplifiers in a new telecommunications window, due to its potential for strong gain across a broad bandwidth in the 2-micron regime [1]. However, the use of such technology in a silicon or planar platform has received much less attention [2,3]. Lack of on-chip lasers is an obstacle to progress in silicon photonics with much research focused on mounting processed III-V lasers, bonding gain material, or the deposition of gain material onto SOI wafers.

Here we report the preparation and study of Tm-doped aluminosilicate glass, which has been demonstrated as an efficient laser/amplifier in fibre-technology covering a 1.7-2.1 µm window. To achieve efficient operation the Tm^{3+} doping concentration is typically optimised for enhancing cross relaxation energy exchange between the $^3H_4$ and $^3F_4$ energy levels allowing an efficient "two-for-one" pumping approach [4]. Fluorescent emission and gain can then be achieved by pumping with readily available ~795 nm sources diode-lasers. As such we have started preliminary investigations of higher concentrations to attempt to obtain enhanced gain per unit length devices.

Waveguide films were fabricated by sputtering in an Ar-O_2 atmosphere from powder-pressed aluminosilicate targets with three different compositions of Tm_2O_3 (3, 7, 10 wt% Tm_2O_3), and with a 1:10 ratio of Tm to Al atoms. This level of Al composition was observed to reduce clustering of the Tm^{3+} in Tm-doped fibres [4]. The films were deposited on silicon substrates with thermal silica grown as a lower cladding. After deposition samples were cleaved into segments and annealed at different temperatures. The films were characterised for thickness, surface roughness, refractive index, fluorescence emission spectra (Fig.1a) and excited-state lifetime (Fig.1b) when pumped at 792 nm. Fluorescence was collected via a 1.5 mm diameter fibre, filtering out the pump signal with an RG1000 long-pass filter. Channel waveguides were fabricated by ion beam milling to allow measurement of the absorption cross section at the pump wavelength (792 nm), achieving a value of ~5 x 10^{-21} cm^2.

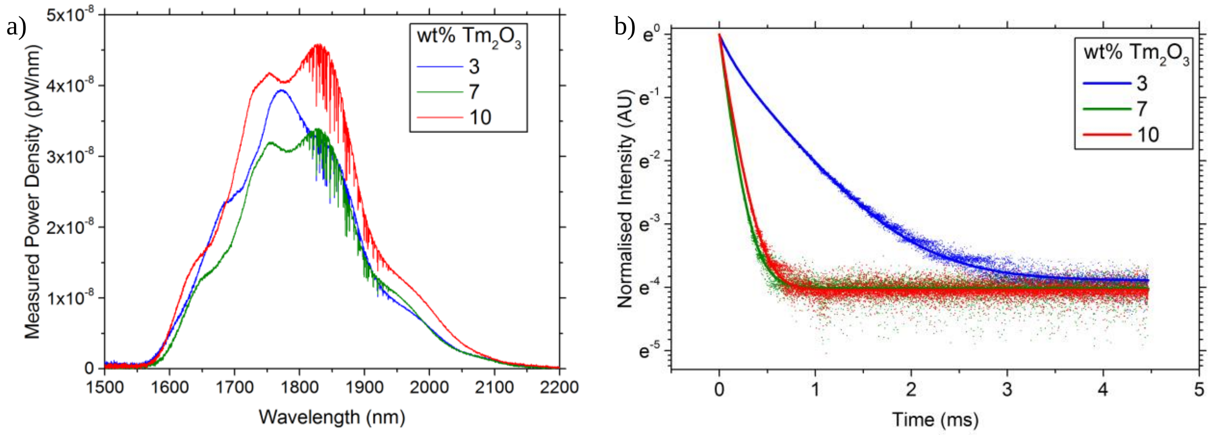

Fig. 1 a) Fluorescence spectra for varying Tm compositions, and, b) corresponding lifetime measurements

The longest lifetime was observed for the 3 wt% Tm_2O_3 film, which had an intermediate fluorescence intensity compared to the other compositions. The longer lifetime compares favourably with published work [4] indicating that the Tm^{3+} ions are activated correctly in the ligand. A reduction in lifetime with increased composition is potentially a result of ion-ion interaction and will be the focus of future investigations. However, the 10 wt% Tm_2O_3 films provide the highest intensity indicating that there is scope for higher gains with an optimised Al composition. Varying annealing conditions and composition has shown longer lifetimes can be reached at these higher concentrations. These results, and others to be presented, demonstrate the potential for the development of a 2 µm SOI integrated laser based on further developments of the Tm-doped aluminosilicate system.

References

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