Reactively Co-Sputtered Al_2O_3:Er^{3+} for Active Photonic Devices

J.D.B. Bradley, L. Agazzi, D. Geskus, F. Ay, K. Wörhoff, and M. Pollnau

Integrated Optical MicroSystems Group, MESA+ Institute for Nanotechnology, University of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands

Reactive co-sputtering has been applied as a low-cost method for deposition of Al_2O_3:Er^{3+} layers. Channel waveguide fabrication has been optimized and results in waveguides with low background losses (0.21 dB/cm), demonstrating the feasibility of realizing active photonic devices. A net optical gain of 0.84 dB/cm for a 1533-nm signal has been obtained in a 700-nm-thick Er^{3+}-doped Al_2O_3 waveguide pumped at 980 nm, which is the highest gain demonstrated thus far in this material.

Introduction

Er^{3+}-doped aluminum oxide (Al_2O_3:Er^{3+}) has previously been investigated as a potential material for active integrated optical devices [1]. Relatively high erbium concentrations (~10^{20} cm^{-3}) without clustering and a wide emission spectrum around the C-band (1535-1565 nm) make this material interesting for many applications, including telecom devices. Reactive co-sputtering offers an alternative, low-cost method for deposition of such layers. However, in previous studies the co-sputtering process was unreliable and the channel waveguide fabrication resulted in very high optical losses, limiting the net optical gain [2]. Both issues have been addressed, and we report here reliable co-sputtering and channel waveguide fabrication methods, resulting in Al_2O_3:Er^{3+} channel waveguides with background losses as low as 0.21 dB/cm. To investigate the potential for integrated active devices such as amplifiers and lasers using this technology, Er^{3+}-doped channel waveguides with varying concentration have been fabricated and the gain has been measured. A net gain of up to 0.84 dB/cm has been demonstrated at the emission peak of 1533 nm.

Al_2O_3:Er^{3+} Waveguide Fabrication

Deposition of planar Al_2O_3:Er^{3+} waveguides on thermally oxidized Si substrates has been optimized by use of an AJA ATC 1500 system equiped with rf sputtering guns, resulting in reliable, low-background-loss layers (0.11 dB/cm at 1550 nm). A reactive ion etching (RIE) method for fabricating high-resolution, low-propagation-loss channel waveguides in Al_2O_3 layers has also been developed [3]. The optical losses of uncladded 2.5-μm-wide ridge waveguides, etched to a depth of 220 nm in an optimized 700-nm-thick Al_2O_3 layer, were determined by the cut-back method to be 0.21 ± 0.05 dB/cm. This indicates that only very small additional losses on the order of 0.1 dB/cm are introduced by the dry-etching process. Even more promisingly, Al_2O_3:Er^{3+} channel waveguides etched through to the SiO_2 layer and with a 5-μm PECVD SiO_2 cladding deposited on top showed no measurable increase in background losses. This waveguide configuration allows bend radii below 300 μm without increasing the propagation loss at 1550 nm. Figure 1 shows a cross-section of a PECVD-SiO_2-cladded Al_2O_3 waveguide and the Er^{3+} concentration as a function of sputter gun power applied to the Er target.

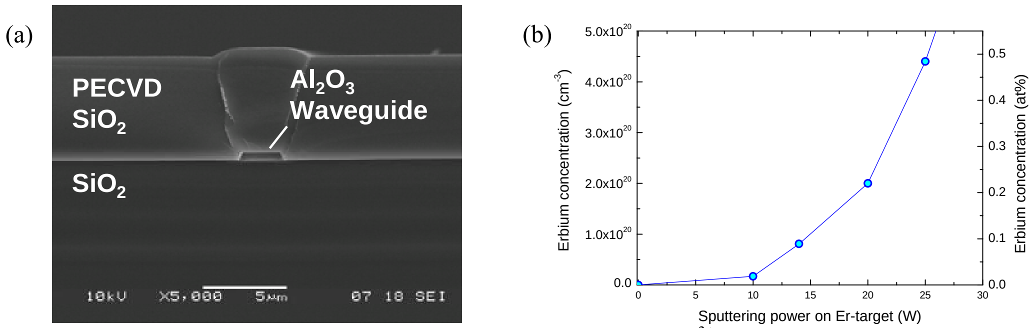

Fig. 1. (a) SEM image of a cladded Al_2O_3 channel waveguide (b) Er^{3+}-ion concentration as a function of sputtering power.

Optical Gain

Al_2O_3:Er^{3+} channel waveguides with three different Er^{3+} concentrations (0.8-, 1.0-, and 2.0x10^{20} cm^{-3}), thicknesses between 700-950 nm, and waveguide widths of 4.0-8.0 µm were fabricated. The loss spectra were measured using a tunable laser source (1480-1600 nm) and fiber coupling setup and the small signal enhancement was measured using the same tunable laser with a 980-nm Ti:Sapphire pump source and a lens coupling setup with lock-in detection. A maximum net gain of up to 0.84 dB/cm for 93 mW of input pump power was measured for the sample with lowest Er^{3+} concentration. Net gain was demonstrated over a wavlength range of approximately 40 nm. The net gain as a function of wavelength and as a function of pump power is shown in Fig. 2.

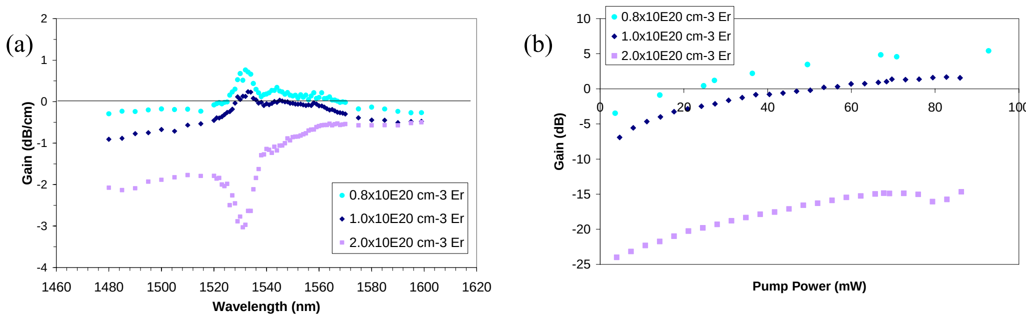

Fig. 2. (a) Gain (dB/cm) as a function of wavelength at 70 mW pump power and (b) gain (dB) at 1533 nm as a function of pump power in the waveguide for Al_2O_3:Er^{3+} samples with varying Er^{3+} concentration.

Summary

Straightforward fabrication, low background losses, and high gain have been demonstrated with reactively co-sputtered Al_2O_3:Er^{3+} waveguides. Further enhancement of gain and various integrated devices are currently being investigated in this material.

References

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