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High-index overlay gratings on K^+-exchanged waveguides in BK-7 glass using excimer laser ablation

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Abstract: Sub-micron relief gratings have been ablated on InO_x thin films overlaid on K^+ ion-exchanged waveguide channels, using 248nm excimer laser interferometry. Strong Bragg reflection has been demonstrated.

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Bragg relief gratings overlaid on optical waveguides may be used as high-extinction ratio wavelength filters with applications in integrated optics and optical communications. Bragg gratings have been written using electron beam lithography and etching on a complex waveguide structure consisting of a thin silicon overlay on ion diffused waveguides in $LiNbO_3$ [1]. This configuration enhances the guided field closer to the surface resulting in strong interaction with the film region.

A new waveguide grating design process which relies on a novel grating patterning method and new materials will be presented in this paper (Fig. 1). This design consists of the combination of a potassium ion-exchanged single-mode channel waveguide with a high-index film (InO_x) overlaid on its upper surface. The high-index overlayer is deposited over a part of the waveguide length (see Fig.1). An input fibre efficiently excites the diffused waveguide mode that in turn excites predominantly the fundamental mode of the composite (diffused + overlayer) waveguide. A relief grating is patterned on the InO_x layer using 248nm interferometric excimer laser ablation [2]. The above method is single-step and can reproduce high quality grating structures over a variety of periods.

Ion-exchanged waveguides were fabricated in BK-7 glass using conditions that are described elsewhere [3]. A thin film of InO_x ($n \approx 1.8$) [4] of 2.5cm length was sputtered on the top of 4cm long waveguides using DC magnetron sputtering. The InO_x was sputtered in 100% O_2 atmosphere resulting in a polycrystalline film of average grain size of 50nm. The transmission losses as well as the grating spectra of the composite structure were measured by coupling the ASE spectrum of an Er-doped amplifier into the waveguide using a single-mode fibre. The waveguide output was collected by a lens system of two 10x objectives and an intermediate IR-polarizer. Finally, the signal was injected into a multi-mode fibre and directed into an optical spectrum analyser. The above setup allows polarisation-resolved measurements.

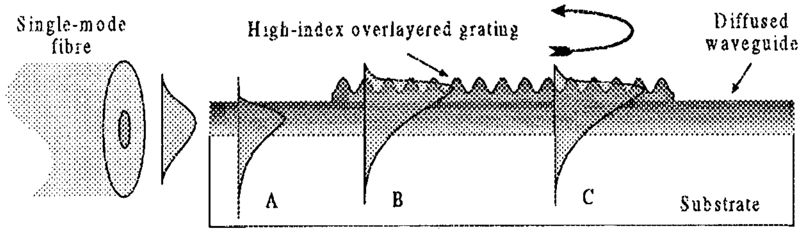

Fig. 1. 1 High-index grating overlayer on diffused waveguide. A: Field profile in unperturbed region. B: Field profile in high-index superstructure. C: Back-reflection operation.

The excimer laser interferometer is described in detail in reference [2]. Gratings with a period of 514nm were ablated on waveguide chips that had InO_x overlayers of various thickness. The excimer laser beam was homogenised during recording in order to minimise any spatial irregularities that may insert phase errors, degrading the grating operation. Gratings of 1.6cm length were produced using energy densities of $60mJ/cm^2$ and 5 to 100 pulses. A grating that has been ablated using a fluence of 60mJ/cm2 and 5 pulses is presented in Fig. 2.

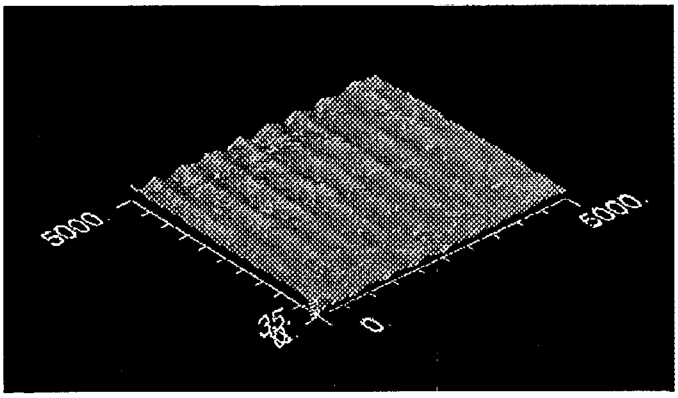

Fig. 2. AFM microscan of an ablated grating in a 135nm InOx film. All scales are in nanometers.

The TE transmission and reflection spectra of an ablated grating on a 135nm film fabricated using 5 pulses of energy density of 60mJ/cm^2, which has been overlaid on a 8μm wide waveguide, is presented in Fig.3. Due to poor overlap with the overlayer, no detectable grating response was observed for TM polarisation.

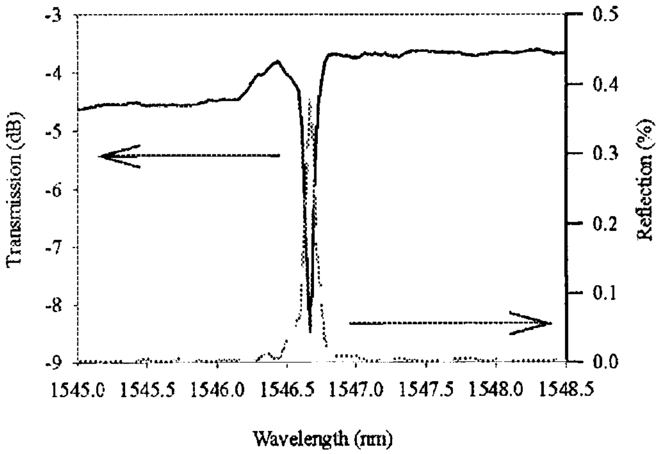

Fig. 3. Transmission and reflection spectra of an ablated grating in a 135nm overlayer sputtered onto a 8μm wide waveguide. Solid line: Transmission spectrum. Dashed line: Reflection spectrum. The reflection spectrum has been corrected for propagation losses.

The example grating in Fig.3 has a maximum strength of about 4.7dB and a bandwidth $\Delta\lambda_{FWHM} \approx 0.08$nm. A wide and shallow spectral step is observed at shorter wavelengths, which is attributed to coupling to radiation modes. The additional losses of the waveguide grating (including coupling losses) remained low even after UV exposure of the film. However, longer exposures or higher energy densities resulted in significantly greater absorption losses and weaker grating strengths. Annealing of the waveguide chip up to 250°C for two hours in O_2 atmosphere reduced the losses by almost 1dB. Additionally, there is a near-linear dependence of the grating reflection wavelength on the waveguide width, exhibiting a slope of 0.248nm/micron width change over a range of 3 μm to 8μm. Grating strengths up to 20dB, accompanied by higher transmission losses, have also been observed in Ta_2O_5 overlaid devices. Detailed results for multiple gratings will be presented.

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