Submitted to ECOC ... 21-25 Sept 02

2636

DIRECT-UV WRITING OF CHANNEL WAVEGUIDES IN A BULK PHOTOSENSITIVE TIN DOPED SODIUM SILICATE GLASS

Daniel Milanese (1), Monica Ferraris (1), Massimo Olivero (1), Guido Perrone (1),
Corin B.E. Gawith (2), Peter G.R. Smith (2) and Gilberto Brambilla (2)
1 : Politecnico di Torino, C.so Duca degli Abruzzi 24, I-10129 Torino, Italy
Email: daniel.milanese@polito.it
2 : Optoelectronics Research Centre, University of Southampton, Southampton SO17 1BJ, UK
Email: cbeg@orc.soton.ac.uk

Abstract *Strong channel waveguides have been fabricated in a photosensitive bulk tin-doped sodium silicate glass by direct writing technique. The estimated maximum index variation and propagation loss were* $1.5 \cdot 10^{-3}$ *and below 1.3 dB/cm, respectively.*

Introduction

A rising demand for low cost planar waveguide devices has encouraged many researchers to develop new and alternative routes towards channel waveguide fabrication. One such approach to be recently developed is that of direct UV writing, a planar waveguide fabrication technique performed by scanning a focussed UV laser beam onto a photosensitive substrate in order to create a localised refractive index change. This technique was first employed on CVD deposited photosensitive thin films, where Ge doped silicate glasses were used to produce channel waveguides [1,2]. For such applications, direct UV writing removes the need for costly photolithography and reactive-ion etching processes, while providing a simpler route toward small batch rapid prototyping. More recent experiments in direct UV writing have led to the fabrication of channel waveguides in Ge doped sodium silicate bulk glass samples [3], with different results depending on the photosensitive element concentration; at lower Ge content (6% mol) vertical slab waveguides were obtained with a refractive index change all the way through the material, while at higher Ge content (20% mol) an increased absorption provides channel waveguides in the surface of the material. However, low numerical apertures (NA = 0.05) were obtained.

In this paper we present the first example, to our knowledge, of direct UV written channel waveguides in a tin sodium silicate glass. The incorporation of tin provides greater photosensitivity than the similar germanium-doped glass, as previously shown by writing fibre Bragg gratings in sodium silicate glasses containing tin [4].

Glass fabrication and direct writing

For these experiments, the tin-doped glass $85SiO_2:5SnO_2:10Na_2O$ was chosen as photosensitive substrate for laser direct writing, having a similar composition to that used in previous fibre Bragg grating writing experiments [4]. SnO_2 is responsible for the photosensitive behaviour and sodium oxide increases the solubility of tin oxide [5]. The glass was fabricated by melting batch powders in a Pt crucible in a furnace at a temperature of approximately 1500°C for 1h. After annealing, glass samples were drilled out of the crucible at room temperature, followed by precision cutting and optical quality polishing.

The source used for direct UV writing was a CW frequency doubled Argon-ion laser operating at λ = 244nm and focussed to a 7μm diameter spot. The samples were positioned on a vacuum chuck and translated relative to the incident beam from one edge to the other. By varying the sample speed, a number of straight channel waveguides with different writing parameters were defined into the photosensitive material.

A preliminary study was performed in order to identify the suitable laser powers and beam scanning speeds required for a large refractive index change in this material with no associated physical damage. The selected laser power was 95 mW (measured at the sample surface) and scan rates ranged from 10 to 1300 mm/min (see also table 1). End-facet polishing was performed after the UV writing process to remove any laser-induced damage at the sample edges.

Waveguide characterization and modelling

The channel waveguides produced in our tin-sodium-silicate material were characterized in terms of their near field intensity profile and propagation loss. Near field intensity profiles were acquired with a CCD camera and personal computer-based software. The input excitation came from a butt-coupled fibre connected to several lasers with wavelengths ranging from 633 nm to 1550 nm through a polarization controller. Channel waveguides were obtained for each scan speed. This proves that 5% molar content of SnO_2 was sufficient to obtain surface channel waveguides whereas to obtain the same results 20%

molar concentration of GeO_2 dopant should have been required, as previously reported [3].

Waveguides written with speed up to 800 mm/min (i.e. up to guide 8 in table 1) exhibited cut-off at around 1000 nm while the others guided only at the HeNe laser wavelength. A negligible dependence of the near field intensity profiles with the excitation polarization was observed.

The waveguide refractive index distributions were studied considering an equivalent model where it was assumed that the UV-induced index variation is directly proportional to the UV-writing intensity. This implies that the depth index cut can be approximated with a decreasing exponential function and the breadth cut with a Gaussian shape having the same width as the laser beam.

Table 1: List of the waveguides considered in this paper.

Guide	Writing speed mm/min	Max Δn
1-2	10	0.0015
3-4	100	0.0013
5-6	400	0.0011
7-8	800	0.0010
9-10	1300	0.0007

Then, the dependence of the maximum surface index variation (Δn) and of the depth decay rate (d) versus the UV writing speed was estimated by matching the measured near field intensity profiles with the theoretical profiles computed using this model. The recovered values for Δn and d are those that correspond to a difference between measured and computed field intensities below the incertitude in the measurement. An example for the waveguides written at 10 mm/min is shown in figure 1 where we compare the measured and computed depth cut of the near field intensity profile.

It has been found that d is about 4 μm for all the cases, while the maximum index variations are summarized in Tab.1. It should be noted that the near field intensity profiles for channel waveguides numbered above 6 included a significant amount of background noise, and as such the recovered values for the index variation are assumed to be less accurate.

To investigate the propagation loss, the difference between input and output powers in the butt-coupling setup were measured. By taking into account the modal mismatch between the launch fibres and the photo-written waveguides, a propagation loss below 1.3 dB/cm was estimated for all the waveguides.

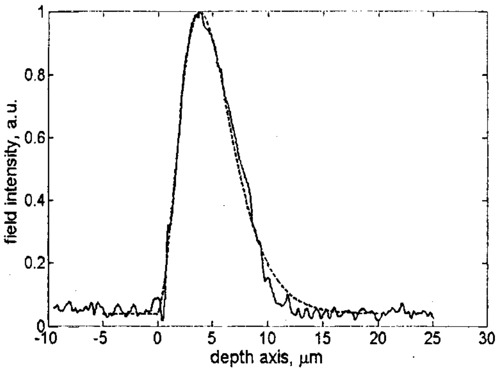

Figure 1 – Comparison of the depth cut of the measured (solid line) and computed (dash line) intensity profile for guide #1.

Conclusions

We have reported the fabrication and characterization of the first direct written channel waveguides in a bulk tin doped sodium silicate glass. Guiding at wavelength shorter than 1000 nm was obtained and a maximum index variation of $1.5 \cdot 10^{-3}$ and propagation loss below 1.3 dB/cm were estimated.

References

1 M. Svalgaard et al., Electron. Lett. 30 (1994), 1401.
2 K. Faerch et al., Phot. Techn. Lett. 14 (2002) 173.
3 D. Milanese et al., Opt. Mat 18 (2001), 295.
4 G. Brambilla et al., Opt. Lett. 25 (2000), 1153.
5 Mazurin et al., "Handbook of Glass Data", Elsevier (1985).