UV Written Buried Waveguide on P-B Codoped Silica on Silicon Layer

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Introduction

Several years ago much attention has been devoted to processing of the UV induced refractive index change in silicate glasses [1] and its application, especially for Fiber Bragg Gratings (FBGs) fabrication. UV writing can strongly simplify the fabrication process of thin film photonics devices, because several complicated processing steps like photolithography and reactive ion etching may be bypassed. In recent years directly UV written planar waveguides were demonstrated in photosensitive germanium doped silica thin films [2], followed by UV written waveguide devices such power splitters and directional couplers. In this paper we demonstrate the UV photoinduction of singlemode buried waveguides through the metallic mask and UV excimer laser beam on Boron-Phosphorous codoped silica on silicon. Refractive index profiles of the written waveguides have been deduced from the measure of the near-field intensity field distribution of guided modes.

Low insertion loss (<0.5 dB/cm, including the propagation loss and the coupling loss) waveguides have been obtained.

Experiment

The samples used for UV writing consist of three layers buffer/core/uppercladding grown by Low Pressure Chemical Vapour Deposition (LPCVD) for the buffer and core layers, Plasma Enhanced Chemical Vapour Deposition (PECVD) for the uppercladding, on silicon 6 inches wafers. The buffer layer is a 15 μm of undoped silica, the core layer is a 6.5 μm of a codoped Boron-Phosphorous silica, Boron has been added to have an index matched layer with the buffer and the uppercladding that is a 10 μm of undoped silica. Prism coupling technique has been chosen to measure @ 1.55 μm the refractive index of three layers that are respectively 1.4444, 1.4434, 1.4396.

Straight waveguides have been written into the photosensitive core layer covering the sample with a mask fabricated by an aluminum deposition (~500 nm) on a UV transparent silica bulk and wet etching to discover the desired geometry. The width of the stripes on the aluminum layer is around 5.5 μm. The UV beam (dim=15×30 mm^2) of a pulsed excimer laser @ 193 nm (fluence=20 mJ/cm^2/pulse, rate=50 Hz) has been used to irradiate the sample through the mask (Fig.1). Before the UV exposure the samples were hydrogen loaded at room temperature, 100 atm, 20 days to enhance the photosensitivity. After UV writing, the samples were annealed at 80 °C for around 20 hours to increase the hydrogen outdiffusion.

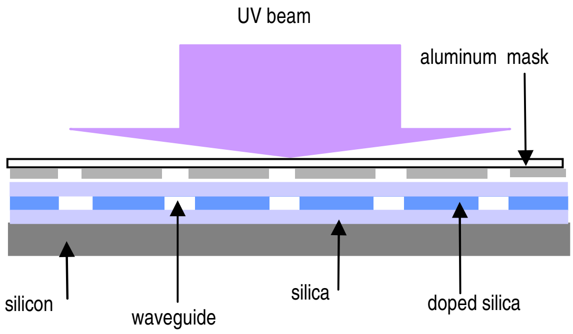


Fig.1: Scheme of waveguide fabrication technique

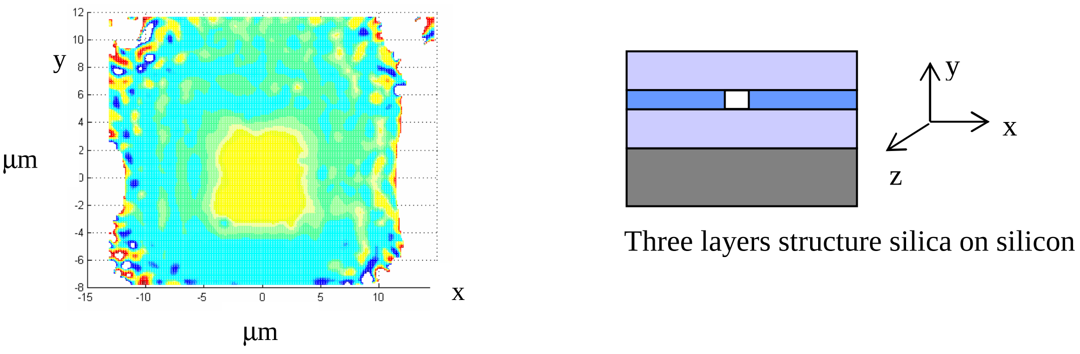
To measure the refractive index profile of the UV induced waveguide an optical bench, using the near field pattern (NFP) method has been set up. This is a well-known technique [3][4], which calculates the bidimensional refractive index profile from simplified Helmoltz equation if the transverse waveguide power distribution is known.

$$\Delta n(x,y) - \frac{n_{eff}^2 - n_s^2}{2n_s} = -\frac{1}{2n_s k_0^2}\frac{\nabla_t^2\sqrt{I(x,y)}}{\sqrt{I(x,y)}} \qquad (1)$$

n_{eff} is the waveguide effective index, k_0 the wavenumber, $n(x,y)=\Delta n(x,y)+n_s$ the local refractive index , n_s the substrate index and $I(x,y)$ the intensity distribution (NFP). Device (CCD) array infrared camera has been used to have high linearity, uniformity and low levels of dark current and noise. The refractive index measurement has been done @ 1.55 um.
Insertion loss measurements have been performed coupling light from a 1.55 um diode laser to the polished waveguide facet using a cleaved standard singlemode silica fibre (SMF). On the output waveguide polished facet, light has been coupled on a second cleaved silica fibre.

Results and discussion

The results of the NFP measurement on UV written planar waveguides are described below. Figure 2 shows the reconstructed index maps of a buried waveguide; it is easy to see the waveguide square shape around 8×8 μm^2. A strong and symmetrical index variation (around 6×10^{-3}) is shown in the horizontal cut (x) (see fig. 3). On the vertical cut (y) is shown the depth of the UV photoinduction and the different index value of the uppercladding and buffer intrinsic to the growth process.



Three layers structure silica on silicon

Fig. 2: Refractive index mapview of a buried waveguide

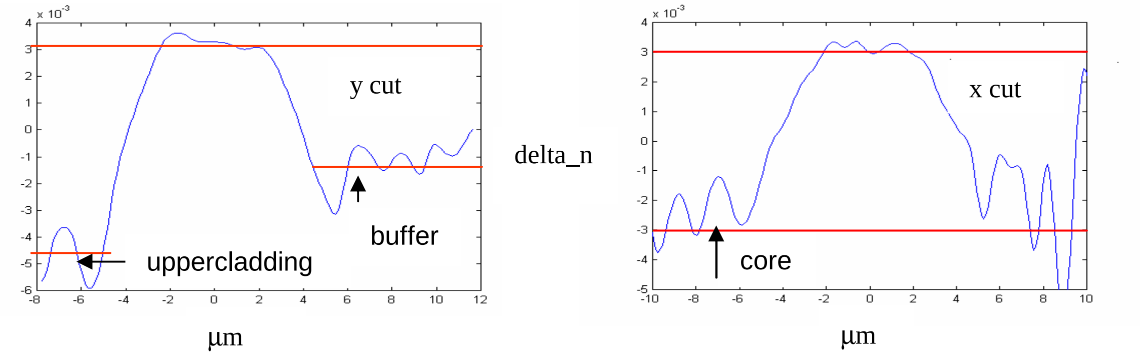
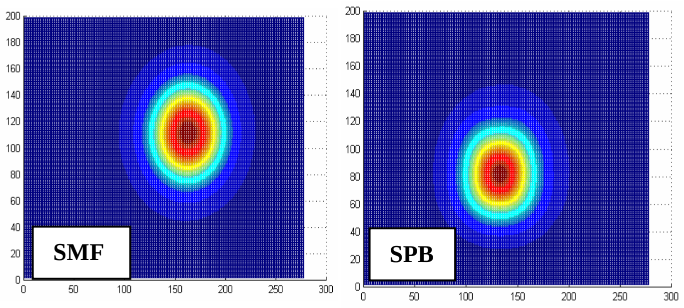


Fig. 3: Two main cuts of the refractive index profile

In figure 4, the effect of the index matching on waveguide intensity mode profiles is shown. The profile of a single mode standard fibre (SMF) is shown for reference (a).



(a) (b)

Fig. 4: Guided mode intensity distribution: mapview (a) single mode fiber (SMF), (b) waveguide silica P-B doped (SPB)

By using the measured mode profiles (Tab.1) of the fiber and of the waveguide the overlap integrals have been calculated to estimate the fiber-waveguide coupling loss due to the mismatch. The calculated value is 0.05 dB for each coupling.

	W_x	W_y
SMF	10 µm	10 µm
SPB	9.0 µm	9.8 µm

Table 1

w = mode profile width @$1/e^2$

So the total coupling losses could be estimated around 0.1 dB and the propagation losses around 0.4 dB/cm.

Conclusion

UV photoinduction of singlemode buried waveguides through the metallic mask and UV excimer laser beam on Boron-Phosphorous codoped silica on silicon have been demonstrated. Refractive index profiles of the written waveguides have been deduced from the measure of the near-field intensity field distribution of guided modes. The reconstructed index of the buried waveguide shows a square shape around 8x8 μm^2 and a strong index variation (around 6×10^{-3}). Low insertion loss (<0.5 dB/cm, including the propagation loss and the coupling loss) waveguides have been obtained. By using the measured mode profiles of the fiber and of the waveguide the overlap integrals have been calculated. The value is 0.05 dB for each coupling, so the total coupling losses could be estimated around 0.1 dB and the propagation losses around 0.4 dB/cm.

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References

[1] M. Douay et al., “Densification involved in the UV-based photosensitivity of silica glasses and optical fibers”, *Journal of Lightwave Techn.*, vol. 15, no. 8, pp. 1329-1342, 1997.

[2] M. Svalgaard, C.V. Poulsen, A.Bjarklev, O. Poulsen, “Direct UV writing of buried singlemode channel waveguides in Ge-doped silica films”, *Electronics Letters*, vol. 30, no.17, pp. 1401-1403, 1994.

[3] L. McCaughan, E. E. Bergmann, “Index distribution of optical waveguides from their mode profile”, *J. Lightwave Techn.*, vol. LT 1, no. 1, pp. 241-243, 1993.

[4] D. Brooks, S. Ruschin, “Improved near field method for refractive index measurement of optical waveguides”, *Photonics Technology Letters*, vol. 8, no. 2, pp. 254-256, 1996.