Available online at www.pelagiaresearchlibrary.com

Pelagia Research Library

Advances in Applied Science Research, 2011, 2 (5): 110-114

Pelagia Research Library
ISSN: 0976-8610
CODEN (USA): AASRFC

Optical Waveguides on Polymer Substrates for chemical sensing applications

Vishnu Prasad V J*, Ramanand A and Sagayaraj P

Department of Physics, Loyola College, Chennai, India

ABSTRACT

We demonstrate the inscription of optical waveguides on a polymer substrate using an excimer laser. The fabricated waveguides are imaged using phase contrast microscopy. The suitability of PMMA for fluorescence sensing applications, the Experimental procedures and characterization techniques used in our work is presented.

Keywords: Waveguide fabrication, Excimer Laser, PMMA, Fluorescence.

INTRODUCTION

The use of a UltraViolet [UV] laser beam to write directly, structures such as waveguides into polymers has attracted much attention in the recent years. This technique exploits the ability of changing locally[1] and permanently the refractive index in a photosensitive material under light irradiation. Compared to other fabrication techniques, for example involving photolithography, it offers the advantages of a fast (single-step process) and a low-cost way for engineering complex core/clad channel structures for integrated optic devices. PMMA[polymethyl methacrylate] when irradiated by UV–laser light with a wavelength of 248 nm undergoes photo induced chemical reactions[2-4] , have been investigated by Phase contrast microscopy. It was been shown that depending on the experimental conditions, an increase in the refractive index of the modified zones could be achieved. Raman Microscopy was used to confirm the purity of synthesized PMMA thin films.

MATERIALS AND METHODS

A. Excimer laser based waveguide fabrication

The PMMA was first exposed to UV radiation at 248 nm to examine the index modification of the polymer. The samples were irradiated for 1000, 2000,3000,5000 and 7000 pulses at 100,150 and 200 Hz. The incident energy on the substrate was varied from 0.15 to 6 mJ to inscribe waveguides with the least physical ablation of its surface. The direct UV writing apparatus consists of an Excimer laser with pulsed wave output at 248 nm and a incidental beam of 6mmx3mm. The samples consist of PMMA and Nile blue doped PMMA thin film spin coated on a PMMA . The thickness of the spin coated thin films was approximately 120µm estimated using a surface profiler . The substrate was positioned on a sample holder connected to a

computer controlled translation stage, which shifted vertically to the incident UV laser beam at different speeds. Various fluences were used by varying the power and the writing speed to evaluate the behavior of the PMMA wafer under different conditions.

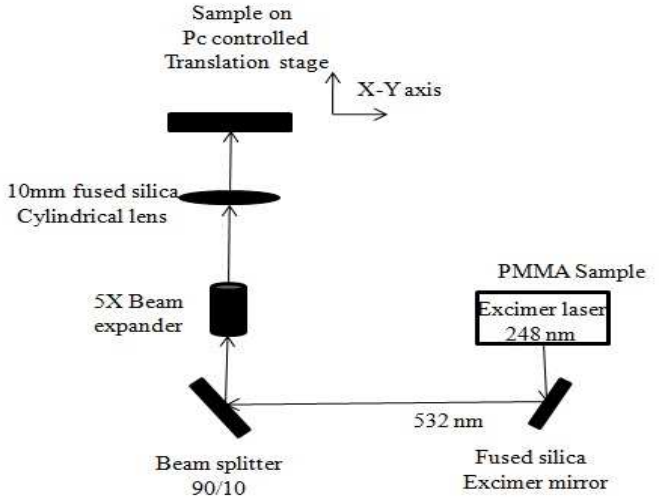

Fig 1: Schematic of Excimer laser waveguide inscription setup

B. Femtosecond laser based waveguide fabrication

Poly (methyl methacrylate) (PMMA) samples with a thickness of ~3 mm, and an area of 2.5 cm×2.5 cm were used in our experiments. Before irradiating with fs pulses[6,7], these samples were sonicated for 20 minutes in dilute NaOh and for 20 minutes in deionised water to remove dust particles. The writing system is schematically shown in Fig. 2. In our experiments, waveguides were fabricated using a Ti: sapphire oscillator amplifier system. operating at a wavelength of 800 nm, delivering 300 fs pulses and ~7 nJ output energy with a repetition rate of 82 MHz. We have used 40X (Numerical Aperture (NA) of 0.65) microscope objective in our experiments for focusing . The theoretical spot sizes were estimated using the formula $D = 1.22 \lambda /NA$ where D is the spot size, λ is the wavelength used. The spot size was estimated to be 1.5 μm. The sample was translated using a computer controlled Newport ESP300 motion controller.

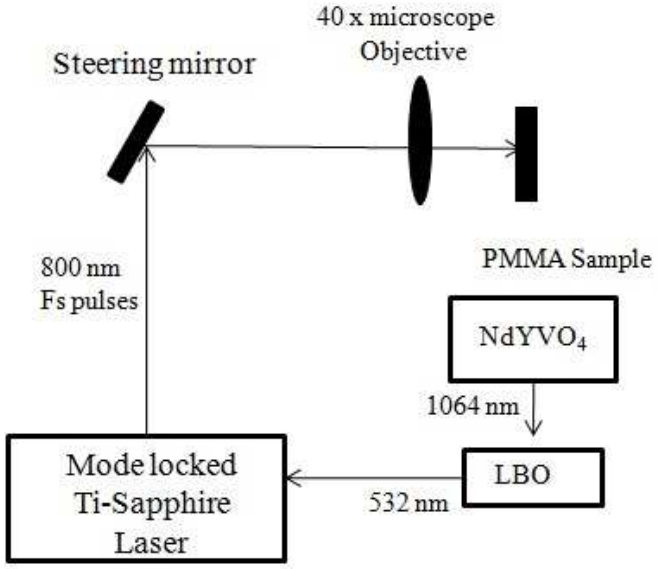

Fig 2: Schematic of Fs laser setup used in waveguide fabrication

C. Phase Contrast Microscopy

The phase contrast apparatus consists of an Vaiseshika zoom stereoscopic microscope (type-

7004) with a trinocular head capable of magnification from 7X to 60X continuously and a working distance of 80mm from the objective (20 X).The microscope was adapted with a pair of 50mm linear glass polarizers from Edmund optics (NT43-787) functioning as an analyzer and polarizer, enabling it to view phase changes . The microscope is combined with a Yoko CCD camera providing images with a magnification of 160X.

RESULTS AND DISCUSSION

In this paper, phase contrast microscopy images of Excimer laser induced bulk modifications in PMMA is reported.Exposure of the PMMA film to the UV laser leads to waveguide formation . For high fluences, physical damage and ablation of the polymer thin film was observed, but at low fluences the physical ablation was not observed and only a refractive index modulation was observed as seen from the phase contrast microscopy image. Efforts are underway in polishing the substrate and at coupling excitation light into the waveguides.

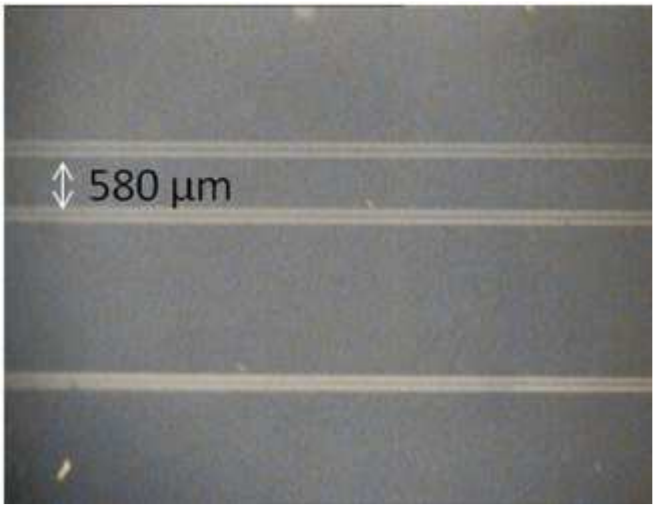

Fig 3: Phase contrast image of Excimer laser written waveguides on PMMA thin films

TABLE I Excimer laser parameters used for waveguide inscription

Laser energy	No of pulses	Reprate (Hz)	Scan velocity (mm/s)	Observation
6 mJ	1000	10	1	Ablation observed
5 mJ	1000	10	1	Ablation observed
4 mJ	1000	10	1	Ablation observed
1mJ	1000	10	0.5	Ablation observed
500 µJ	1000	100	0.5	Ablation observed
100 µJ	1000	100	0.3	Ablation observed
40 µJ	1000	200	0.400	No ablation
26 µJ	3000	200	0.133	No ablation
20 µJ	4000	200	0.100	No ablation

First, the influence of the input energy, the importance of the incubation effects, and of physical changes caused by laser pulses were studied. Then, experimental observations about waveguiding structures and discussion about the optimal writing conditions are also presented . Fig 4 shows the waveguiding structures written using the Excimer laser and Table I shows the systematic approach adopted to inscribe waveguide in PMMA wafers.

Under intense femtosecond laser irradiation, optical properties of PMMA polymer can be permanently modified. When a femtosecond laser pulse is tightly focused in the bulk of a transparent material, structural modifications are photoinduced as a result of a strong electronic excitation[5-6]. We draw attention on a phase contrast picture showing the morphology of the Fs laser interaction on the PMMA wafer(fig 4) and the observation from different laser scan velocities on the PMMA wafer (Table II). It is worth noticing that the modification threshold depends on the exposure time of the PMMA wafer to Fs irradiation.

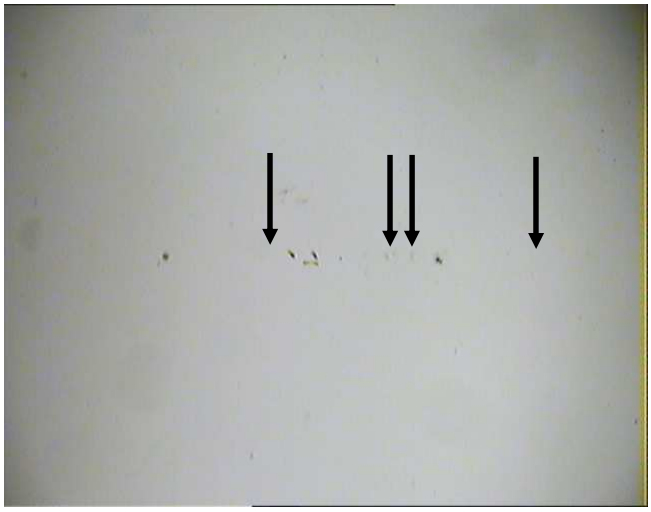

Fig 4: Phase contrast image Fs laser induced ablation on PMMA thin films.

TABLE III Femto Second laser parameters used for waveguide inscription

Sample no	Scan speed	No of scans	Observation
1	0.1mm/s	2	Ablation observed
2	0.5mm/s	2	Ablation observed
3	1mm/s	2	Ablation observed
4	2mm/s	4	No ablation observed
5	3mm/s	4	No ablation observed
6	4mm/s	6	No ablation observed
7	5mm/s	6	No ablation observed
8	6mm/s	8	No ablation observed
9	7mm/s	8	No ablation observed
10	8mm/s	8	No ablation observed

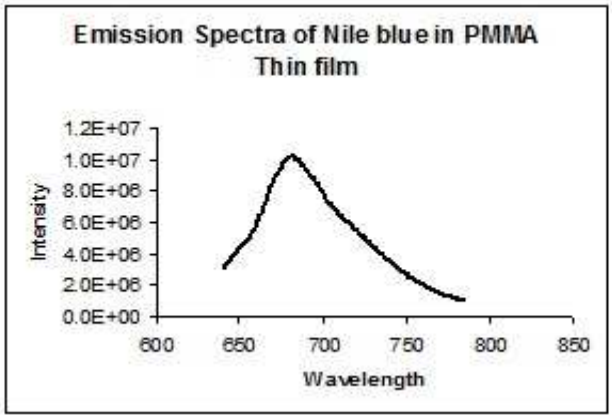

Fig 5: Emission spectra of Nile Blue Doped thin film

In order to use the PMMA waveguides for fluorescence sensing applications we need to dope the PMMA wafer with the fluorophore (Nile Blue) and observe the fluorescence spectrum. The emission spectra of Nile blue doped PMMA hin film excited at 620 nm gives an emission centered at 670 nm which establishes the suitability of Nile Blue doped PMMA thin film to be excited using a 635nm laser diode .

CONCLUSION

In this paper, it is shown that the UV–laser-assisted and femtosecond photochemical modification of the polymer structure of Polymethyl methacrylate. PMMA can be used to define optical waveguides. The fabricated waveguides have been characterized for fluorescence and purity.

Acknowledgment
The authors would like to acknowledge the Department of Science and Technology for funding this study**.**

REFERENCES

[1] C. Wochnowskia, M.A. Shams Eldinb and S. Meteva *Polymer Degradation and Stability* Volume 89, Issue 2, August **2005**, Pages 252-264
[2] R. M. Silverstien , F. X. Webster, Spectrometric Identification of Organic Compounds,John Wiley & Sons, Inc, New York, 6th Ed., **1998**.
[3] C. Contardi, E.R. Taylor, A. Fu, *J. Non-Cryst. Solids* 291 (**2001**)113.
[4] A.K. Mairaj, C. Riziotis, A.M. Chardon, P.G.R. Smith, D.P. Shepherd, D.W. Hewak, *Appl. Phys. Lett.* 81 (20) (**2002**)
[5] R.N. Nurmukhametov, L.V. Volkova, S.P. Kabanov, *J. Appl. Spectrosc*. 73 (**2006**).
[6] H.Y. Kaptan, O. Guven, *J. Appl. Polymer Sci*. 64 (**1997**) 1291.

.