Tellurite Glass on Polymer Planar Waveguides

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***Abstract*-Tellurite glass thin films were deposited by excimer laser ablation onto silica and polymer covered silica. The transmittance, fluorescence and refractive index of the films have been studied. The films on both substrates were fabricated using identical process parameters and the results show promise and indicate that further optimization is required for producing high quality glass films on polymer suitable for integrated optical device fabrication. Furthermore, the films deposited on silica were etched using CHF_3 based reactive ion etching, and an etch rate of 68nm/min in preparation for integrated device patterning.**

Key words: tellurite glass; thin film; polymer; PLD; planar waveguide; reactive ion etching

I. INTRODUCTION

The ever increasing demand for bandwidth in many data communication and imaging systems is the motivation for forming optical interconnects in backplane systems [1]. A terabit capacity passive polymer optical backplane architecture has recently, been demonstrated [2], which shows that polymer waveguides offer a cost effective way to build optical interconnects due to straightforward patterning techniques and the capability to integrate these with printed circuit boards. Several polymer materials possess adjustable physical properties and low propagation losses, making them desirable for applications in light transmission devices [3]. Specifically, siloxane polymers are regarded as one of the most promising materials for optical waveguiding due to their high transparency and low Rayleigh scattering in addition to the excellent thermal and mechanical properties [4]. Adding active functionality to a polymer integrated device has been demonstrated by doping the polymer with fluorescent dye molecules [5]. In this paper, we propose the alternative approach of using a rare earth doped glass film as the “active” or gain element in a glass-polymer integrated structure. We used an erbium doped tellurite glass having high dopant solubility and broad emission bandwidth for potential amplification in the C and L bands of optical communication networks. The pulsed laser deposition (PLD) of the glass was first optimized for silica glass substrates and its suitability for patterning and integration is studied using reactive ion etching (RIE) experiments. The glass was then deposited using PLD on a polymer film pre-deposited by spin coating on a silica substrate. The fabrication procedure, light propagation characteristics, and photoluminescence properties of the fabricated thin films are also reported.

II. EXPERIMENTS

The molar composition of the glass target used for pulsed laser deposition was $72TeO_2.17WO_3.11La_2O_3$ and was doped with 1wt% Er_2O_3 (TWL). The glass was prepared by conventional melting and quenching processes. Commercial high quality silica substrates were used for a series of experiments to optimize the deposition condition for the TWL glass. The Dow Corning PDMS polymer films on silica substrate have an approximate thickness of 25 µm and a refractive index of 1.507 at 633 nm. The pulsed laser deposition was carried out in a Dual-PLD system (PVD Products, USA) under controlled atmosphere. The chamber was first pumped down to below 10^{-5} mTorr, and the substrate was rotated at the speed of 20 rpm and at a distance of 50 mm from the target, during the deposition. The substrate temperature was maintained at 100°C during the deposition process and the output from an ArF laser (193nm, 10Hz) was incident on the target at the angle of 60°, whilst the target was rotated at 40 rpm. The ablation was carried out with laser fluence of 1.3 mJ/cm^2 and under a partial pressure of oxygen of 135 mTorr. The deposition time for the film on silica was 3 hrs while that for the film on polymer was 6 hrs. The films on silica were used for reactive ion etching (RIE) to assess their suitability for patterning. The RIE was carried out at a pressure of 36 mTorr and RF power of 200 W for 10 min, with a CHF_3 gas flow rate of 2 sccm. The refractive index and propagation loss of the films were measured using a Metricon Model 2010 prism coupler using He-Ne laser (633nm), and an ultraviolet-visible-NIR spectrometer (Lambda 19, Perkin Elmer), was used to measure the transmittance of the thin films. The fluorescence spectrum of the thin film was measured using a Spectrofluorimeter (Model FS 920, Edinburgh Instruments, UK), and the thickness and image of the etched channels were obtained using Alfa-IQ surface profiler and optical microscope respectively.

III. RESULTS AND DISCUSSION

A. Glass films on silica and patterning

A series of thin films of the TWL glass was deposited on silica glass substrates of refractive index 1.46 (at 633nm) to optimize the PLD process parameters prior to selecting the parameters listed in the experimental section. The surface morphology of films was studied using high resolution SEM and the image shown in Fig. 1 corresponds to the film fabricated under those conditions. The refractive index of the glass film is 1.8, which is lower than that of the target glass refractive index of 2.10. This may be due to the defects at nanoscale in the films shown in the inset of the figure and is currently under investigation. The loss of the film on silica is about 0.2 dB/cm at 633 nm and the thickness was 1.07 µm. An optical micrograph of a portion of two etched channels is shown in Fig. 2a. The height of the channel is 0.68µm after 10 minutes etching as shown in Fig. 2b.

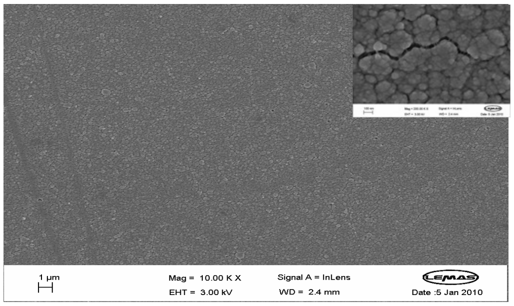

Figure 1. SEM image of the TWL film on silica. Inset showing image at higher magnification.

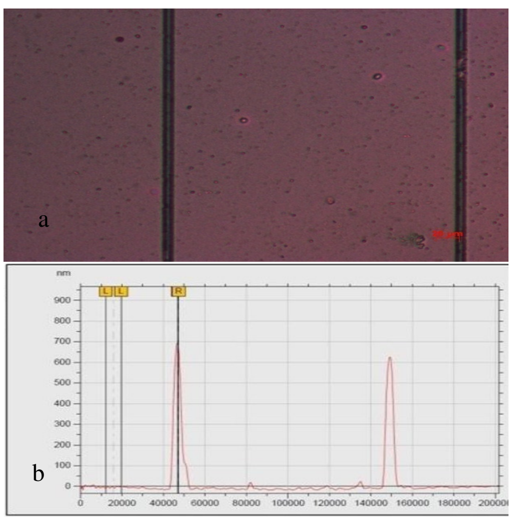

Figure 2. a. Microscopy image, b. height measurement of etched channels.

B. Glass films on polymer

The thin films on polymer substrates were deposited under the same conditions as used for those deposited directly on silica substrates. In Fig. 3 the transmittance spectra of the glass thin films on silica and on polymer are compared. The transmittances of both films are higher than 90% in the wavelength range from 900nm to 2500nm. However, the apparent reduction in the transmittance for the film on polymer is evident. This implies that further optimization of the PLD process is necessary to obtain improved optical quality glass thin films on polymer. The thickness of the glass film on polymer is 1.87 µm. The photoluminescence spectrum of the film is reported in Fig. 4 and the FWHM of this spectrum is 88 nm. Propagation loss in the film and waveguide patterning and transmission experiments using glass on polymer waveguides, are currently under progress and the results of these experiments will be reported at the conference.

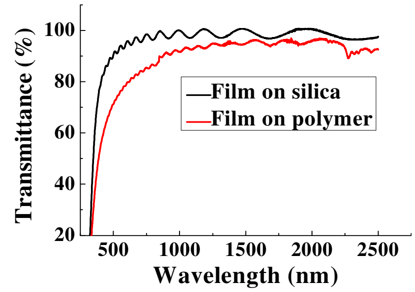

Figure 3. Transmittance of the glass film on silica and polymer substrates.

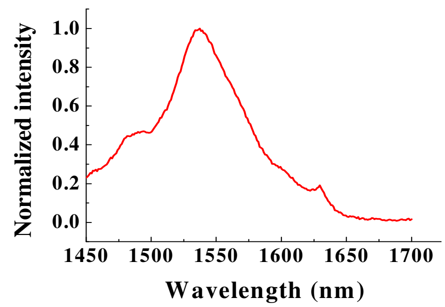

Figure 4. Normalized PL spectrum of the thin film on polymer.

IV. Conclusion

Tellurite glass thin films were fabricated on silica and polymer substrates using pulsed laser deposition technique. The glass films were patterned using RIE technique in CHF_3 gas and a good etching rate of 68 nm/min was obtained. The propagation loss of the film on silica is as low as 0.21 dB/cm. Optical properties of pulsed laser deposited films on polymers need further improvement. The FWHM of the PL of the Er^{3+}-ion doped tellurite glass film on polymer is 88 nm. These preliminary results show excellent prospect for integration of glass based active devices on polymer platform using pulsed laser deposition and RIE.

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