An Integrated Reconfigurable Bragg Grating utilising a Photoresponsive Co-polymer

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***Abstract*— Reconfigurable Bragg grating devices are of significant interest for telecomm applications. Such devices can be fabricated by combining a UV-written silica Bragg grating with an azobenzene-based polymer – a photoresponsive material that undergoes reversible refractive index change on exposure to ultraviolet light. The preliminary 17 GHz tuning response suggests future applicability.**

Keywords- reconfigurable Bragg grating; photoresponsive polymer; direct UV written.

I. INTRODUCTION

We shall present a proof of concept for a reconfigurable Bragg grating filter using the refractive index change on photo-induced isomerism of an azobenzene functionalised methacrylate co-polymer.

Reconfigurable optical devices are of great interest for telecomm applications; such as dispersion compensation, switching, and wavelength multiplexing. Bragg gratings are important elements in such systems and, therefore, reconfigurable optical Bragg grating structures with fine wavelength control and wide tuneability are desirable. Previous approaches to this problem are to incorporate a degree of reconfiguration into existing Bragg devices through tuning of the refractive index by temperature [1], piezoelectric [2], magnetostrictive [3], or mechanically induced strain [4]. With some exceptions, these all require a continual supply of electrical power to maintain the altered wavelength.

Azobenzene-based polymers can act as photosensitive, nonlinear optical, or photorefractive materials with ever increasing fields of application, including: programmable optical interconnects, electro-optic modulation, coherent image amplification, and holographic storage [5]. The simple azobenzene motif can undergo reversible isomerism from the *trans* to the *cis*-isomer upon exposure to ultraviolet light, as shown in Fig. 1.

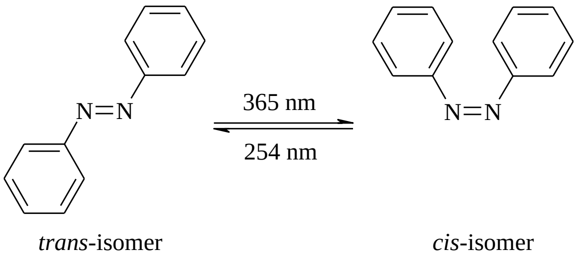

Figure 1. The reversible photoisomerism of the azobenzene motif, upon exposure to UV light.

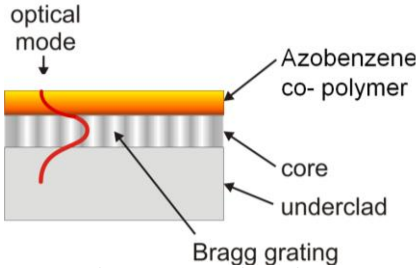

Figure 2. A schematic of the evanescent field of the waveguide penetrating into the photo-responsive azobenzene polymer layer.

Upon isomerisation between the *trans* and *cis*-isomer there is a change in the polarisability of the azobenzene molecule, resulting in a change in refractive index. Barley [6] has reported an example of a siloxane-based polymer functionalised with an azobenzene derivative. The polymer contained only 5% azobenzene but still exhibited a change in refractive index of 3.5×10^{-3}. Incorporation of such a polymer into an integrated Bragg grating device will allow for a latched reconfiguration of the Bragg wavelength without the need for continual electrical input.

II. EXPERIMENTAL

In this work, a methacrylate based co-polymer was synthesised incorporating 4.8% *p*-methoxy azobenzene units along the polymer backbone.

A silica-on-silicon sample was fabricated via flame hydrolysis deposition where the core layer was doped with germanium to provide photosensitivity. On exposure to UV light ($\lambda = 244$nm) the refractive index of the germanium doped glass was locally increased, forming the waveguide. Using an interferometer, Bragg gratings of different period may be simultaneously written into the device [7]. No overclad was deposited onto the core layer allowing the evanescent optical mode to penetrate up a micron from the waveguide surface onto which a ~100 nm film of the azobenzene functionalised co-polymer was spun (Fig. 2). The presence of the film and its ability to photoisomerise was confirmed by diffuse-reflectance UV-visible spectroscopy.

Interrogation of the Bragg grating was carried out with by a 780 nm broadband source, generated from a frequency doubled 1550 nm femtosecond laser source. A 600 nm band pass filter was used to remove any third harmonic light at 515 nm that would interfere with photoisomerism.

We would like to thank the EPSRC for funding this research.

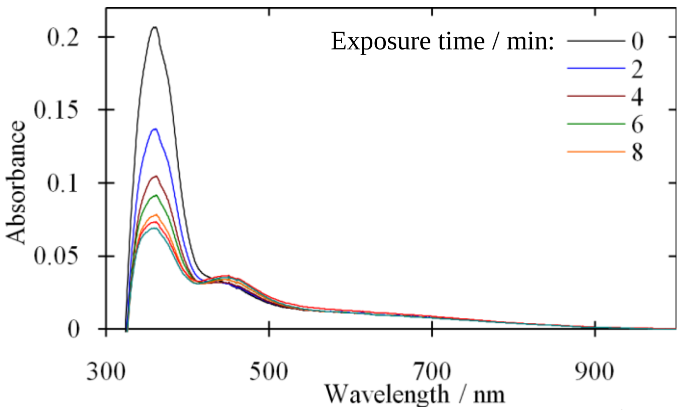

Figure 3. Time-lapse UV-vis spectra showing the *trans- cis* transition of a 191 nm thick *p*-methoxy azobenzene containing methacrylate co-polymer spun onto a silica surface, on exposure to ultraviolet light (354 nm) over 8 minutes.

III. RESULTS

Azobenzene can undergo photoisomerisation efficiently on irradiation with UV light. The transmission UV-visible spectra for the co-polymer film (Fig. 3) shows that there is an intense absorption peak at 361 nm corresponding to the π-π* electronic transition of the *trans*-isomer and a weak peak at 451 nm which originates from the weak n–π* electronic transition of the *cis*-isomer [8]. When the film is irradiated by UV light at 365 nm, the azobenzene units inside the co-polymer undergo *trans-cis* isomerisation, with no further change detected after ~8 minutes. In contrast the reverse *cis-trans* isomerisation takes ~15 minutes. This results in the absorption at the *trans*- isomers π-π* peak decreasing while the weaker *cis*- isomer's n–π* peak increases.

Initial work focused on the interrogation of the Bragg response at 780 nm, spectrally near to the absorption feature. At this wavelength, the co-polymer induced high optical loss to the waveguide device, with almost total loss of the optical mode after travelling only 6 mm along the polymer coated waveguide. This was sufficient, however, to interrogate two Bragg gratings within the waveguide. The sample was alternately exposed to ultraviolet light at 365 and 254 nm; with thermal changes monitored by a thermocouple in thermal contact with the optical device. The Bragg response demonstrated reproducible switching between the two isomeric states, separated by 35 pm – a well resolved transition (Fig. 4). The index change shows the *trans-cis* transition is faster than the reverse, consistent with observations in the time-lapse UV-visible absorption measurements.

The *cis*-isomer is unstable at room temperature, with Barley [6] reporting ~20 h for a 50 % reconversion. For this methacrylate polymer, a slower thermal reconversion occurred linearly over 5 days, with a 17 pm reconversion taking ~60 h.

Initial work investigating if this effect is observable at 1550 nm has observed a slightly smaller shift for this same polymer film. However the high loss observed at 780 nm is not present at 1550 nm, allowing for the entire waveguide to be interrogated. The low loss allows for a thicker polymer film to be deposited onto the sensor surface that will further increase the isomeric shift to an order of a nanometre.

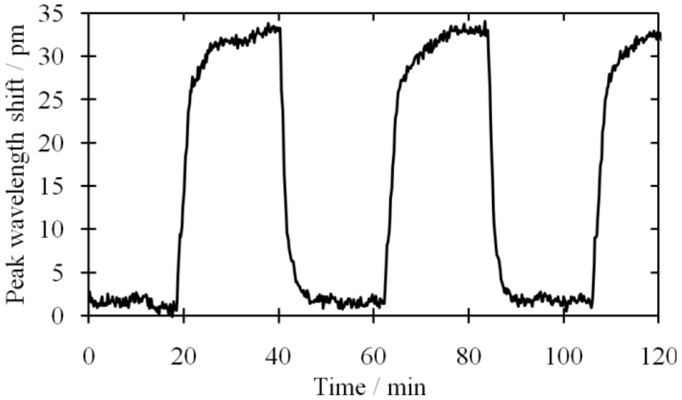

Figure 4. Reversible switching between the two isomeric states results in a detectable optical switch in the Bragg wavelength.

IV. CONCLUSION

A *p*-methoxy azobenzene functionalised methacrylate co-polymer has been synthesised. This has been shown to undergo reversible photoisomerism when exposed to UV light, producing a corresponding significant change in refractive index that is thermally stable. When deposited upon an optical surface a reconfigurable Bragg grating is formed that has potential for a range of applications. In this initial device the maximum observed tuning was 35 pm, corresponding to 17 GHz. This indicates that future devices could find application for wavelength trimming of lasers or for reconfigurable dispersion compensation. We will present our latest developments of this device, focusing on enhancing the magnitude of the refractive index response at 1550 nm.

ACKNOWLEDGMENT

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