Fibre gratings written through the coating at 244nm and 248nm

Laurence Reekie, Lu Chao* and Morten Ibsen

Abstract

Fibre Bragg gratings have been written through the fibre coating using 244nm frequency-doubled Ar^+-ion 248nm KrF excimer lasers for the first time. A standard off-the-shelf coating was used, and 92% reflectivity gratings were obtained with an index change of 2.4×10^{-4}.

Introduction

Fibre Bragg gratings are widely used in the fields of optical fibre communication and fibre sensor systems. In the normal process of fibre grating fabrication, all coatings must be stripped off before the grating can be written and, in order to preserve the mechanical strength of the fibre, it must be re-coated soon after the grating is written. This method is both time consuming and has the potential of reducing the fibre strength due to exposure of the bare fibre to the air. To solve the problem, a number of solutions have been proposed. These include using a specially developed UV-transparent polymer coating [1], writing the grating using near UV light around 330nm instead of at more conventional wavelengths [2], writing on-line as the fibre is being pulled [3] and using a specially developed coating which can be removed thermally then immediately re-coating in an automated production system [4]. The polymer used in [1], although it has a lower absorption than the normal UV-curable polymer coating, still has a strong absorption below 260nm. This increases the grating writing time and reduces the mechanical strength of the fibre when higher UV exposure power is used [5]. In [2], a specially developed phase mask is needed in order to operate at the non-standard wavelength. In addition, care is also required to control the average laser power in order to reduce damage to the coating. On-line production of fibre gratings [3] is limited to the manufacture of gratings which can be made with a single laser pulse. The method proposed in [4], although attractive, requires both a special coating and an automatic production system. The thermally strippable coating also has a low heat resistance in many applications. In this letter, we demonstrate for the first time writing of a fibre grating through a normal off-the-shelf fibre coating using wavelengths of 244 and 248nm. We show that the scheme is both easy and cost effective.

Experiment and results

The coating we used is General Electric RTV 615 silicone rubber. This coating is thermally curable and thus does not require a UV absorbing photoinitiator. With a normal specified useful temperature range of –60°C to 204°C, the coating has a better thermal tolerance than standard UV curable polymer coating. This is an important advantage in many applications. To determine the absorption of the material in the UV region, a 150μm thick film of cured silicone rubber was formed between

Optoelectronics Research Centre, University Southampton, Southampton, SO17 1BJ, U.K.
Tel : +44 1703 593186, Fax: +44 1703 593149. Email: lr@orc.soton.ac.uk

**Permanent address: School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore 639798*

two silica plates. The absorption characteristics of the coating as measured using a spectrophotometer is shown in Figure 1. A silica plate was used as the reference to improve the

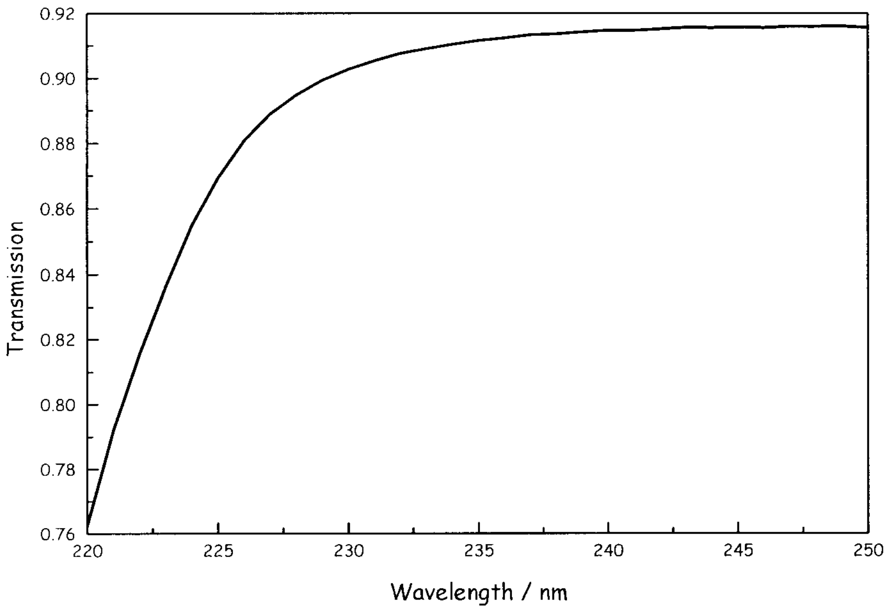

Figure 1: UV transmission characteristics of 150µm thick film of silicone rubber RTV 615.

measurement accuracy. The result clearly indicates a transmission of almost 92% at a wavelength of 248nm. This low UV absorption suggests the possibility of Bragg grating writing through the silicone

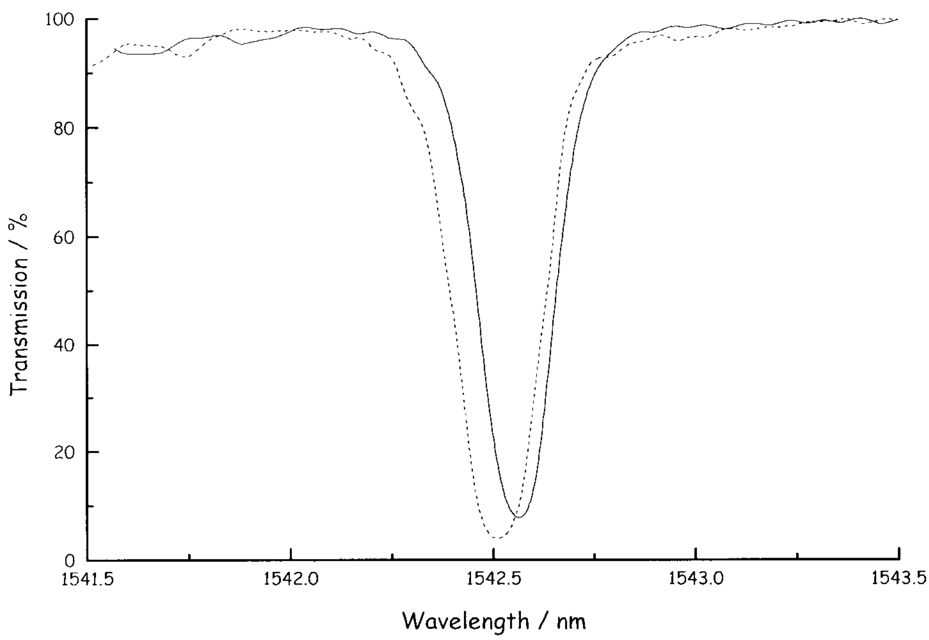

Figure 2: Transmission spectrum of Bragg grating written in coated (solid line) and un-coated (dotted line) fibre.

rubber coating using either a frequency-doubled Ar^+-ion laser at 244nm or a KrF excimer laser at 248nm. To verify this, we coated a photosensitive boron co-doped silica/germania photosensitive fibre (NA=0.12, $\lambda_{cut-off}$=1050nm, diameter=125μm) with the silicone rubber coating. The average coating thickness was 60μm, similar to a normal fibre coating. Grating inscription was initially carried out using a 248nm excimer laser and a 1540nm phase mask optimised for 248nm operation. A 1cm long grating was produced by scanning a 3mm wide beam over a section of the coated fibre, each individual part of the fibre receiving an exposure of 3 minutes at 20Hz. The spectrum was monitored using an optical spectrum analyser and 1.55μm LED. The individual pulse fluence was set at 64mJ/cm^2. A grating with a reflectivity of 92% was obtained, limited by the resolution of the optical spectrum analyser (approximately 0.1nm), corresponding to an index change of 2.4×10^{-4}, and the resulting grating is shown in figure 2. For comparison, we also stripped off the coating and exposed the fibre under identical conditions, and this grating is also shown in figure 2. The almost identical result suggests that the effect of writing through the coating is almost negligible.

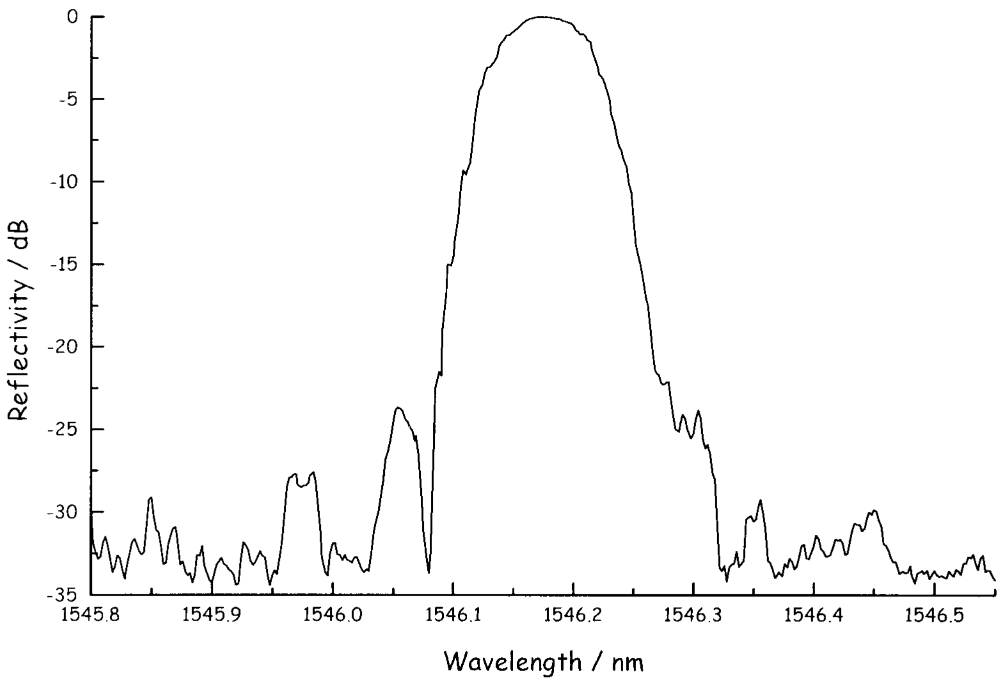

Figure 3: Transmission spectrum of Blackman apodised Bragg grating written in coated fibre.

In order to test for possible coating-induced thermal effects on grating uniformity, a 25mm long Blackmann apodised grating was written through the coating at 244nm using a frequency-doubled Ar^+-ion laser in the same fibre, and the reflection characteristic is shown in figure 3. The intensity was 2.2kW/cm^2 with a total fluence of 1kJ/cm^2. It can be seen that most of the reflected light outside of the central peak is >30dB down on the peak reflectivity, showing excellent grating uniformity. The index change obtained was 1.0×10^{-4}.

To verify the heat resistance of the coating we have placed a fibre with the silicone rubber coating together with a fibre coated with UV curable polymer on a hot plate with a temperature of 300°C for 3 minutes. A visible darkening of the polymer was observed. However, the effect on the silicone rubber coated fibre was negligible.

Conclusions

In this letter we have demonstrated for the first time the ability to write fibre gratings through standard fibre coating at 244 and 248nm. We have shown that the scheme is not only simple but also has several advantages over other previously demonstrated techniques. The ability to write through the fibre coating at these wavelengths is most useful since it will significantly simplify the grating writing process, particularly for long arrays of gratings as required for fibre sensors.. The better heat resistance not only means that it can be used in many different applications but also allows the grating to be annealed if there is such a requirement, *e.g.* after hydrogen loading. One potential drawback is the refractive index of the coating which, at 1.406, does not allow for complete stripping of cladding modes. Further work is required to eliminate this problem.

Acknowledgements

The financial support of the Tan Chin Tuan exchange fellowship of the Nanyang Technological University to allow Lu Chao to be attached to the ORC and EPSRC funding for the project is acknowledged. We would also like to acknowledge useful discussions with Dr. Eleanor Tarbox and Dr. David Richardson and the assistance of Michael Langton in coating the fibre.

References

1. Espindola, R.P., Atkins, R.M., Simoff, D.A., Nelson, K.T., and Paczkowski, M.A.: 'Fibre Bragg Grating Written Through a Fibre Coating', OFC'97 Tech. Dig., 1997, Postdeadline paper PD-4.

2. Starodubov, D.S., Grubsky, V., and Feinberg J.: 'Efficient Bragg grating fabrication in a fibre through its polymer jacket using near-UV light', Electron. Lett. 1997, **33**, pp.1331-1333.

3. Dong, L., Archambault, J.-L., Reekie, L., Russell, P.St.J. and Payne, D.N.: 'Single pulse Bragg gratings written during fibre drawing', Electron. Lett., 1993, **29**, pp.1577-1578.

4. Singh, H., Cronk, B., Speaks, S. and Novak, J.: 'Automated In-Line Production of Fibre Bragg Grating Using Special Coatings', Proc. ECOC 97, IEE Conference Publication No. 488. pp.173-176.

5. Imamura, K., Nakai, T., Moriura, K., Sudo, Y., and Imada, Y., 'Mechanical Strength Characteristics of Tin-Codoped Germanosilicate Fibre Bragg Grating by Writing Through UV-Transparent Coating ' Electron. Lett. 1998, **34**, pp.1016-1017.