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Large Photo-Induced Index Changes in Sn-codoped Germanosilicate Fibres

L. Dong, J.L. Cruz*, L. Reekie, M.G. Xu and D.N. Payne

Optoelectronics Research Centre, The University of Southampton,
Southampton SO17 1BJ, U.K., Tel: +44 1703 593163,
Fax: +44 1703 593149, Email: LD@ORC.SOTON.AC.UK

*On leave from Departamento Física Aplicada,
Universidad de Valencia, Dr. Moliner 50,
Burjassot, 46100, Valencia, Spain.

Summary: Index change (~1.4×10^{-3}) of 3 times larger than in germanosilicate fibres is demonstrated. Both fibre loss at 1.55 μm and high temperature stability of the gratings are much improved comparing to those in B-codoped germanosilicate fibres.

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Background: There has been a surge of interests in photosensitive fibre gratings in recent years chiefly due to their ease of fabrication and numerous application. Although very large photo-induced index changes have been achieved in pure germanosilicate fibres, an enhanced photosensitivity is desirable to enable gratings to be written with ease and with much cheaper laser source. Stronger photosensitivity also opens up many new applications. Boron-codoping in germanosilicate fibres has been reported to give a much enhanced photosensitivity comparing to that in pure germanosilicate fibres [1], but gratings in those fibres have a much poorer high temperature stability and the B-codoping can also give rise to excessive loss at the important telecommunication window of 1.55 μm. Some post-fabrication techniques have also been devised, i.e. H_2/O_2 flame-brushing of a germanium doped fibre [2] and Low-temperature hydrogen loading [3], but they are very time-consuming and there are also large induced losses [3]. In this paper, we report on enhanced photosensitivity in Sn-codoped germanosilicate fibres. The gratings in the Sn-doped fibres also have a much improved high temperature stability than those in B-codoped fibres. Unlike B-codoping, Sn-codoping does not introduce significant loss at the important telecommunication window of 1.55 μm.

Experiments: Two Sn-codoped germanosilicate fibres were fabricated for this experiment by introducing $SnCl_4$ vapour during a MCVD process. The first fibre (fibre I) had a NA of 0.20, first-order mode cut-off wavelength of 1.25 μm and loss of 2 dB/km at 1.55 μm. The second fibre (fibre II) had a NA of 0.29, first-order mode cut-off wavelength of 1.32 μm, and loss of 25 dB/km at 1.55 μm.

The absorption of the core glass in the first preform (preform I) was measured with the technique described in [4] before and after an exposure to a line-narrowed pulsed KrF excimer laser operating at 248.5 nm. The pulse duration was 20 ns and pulse repetition rate was 20 Hz. The original absorption of the preform core shows an tail of an absorption band centred below 190 nm with a peak at ~ 250 nm. (see fig.1). The 248 nm exposure caused a general increase of the absorption, in contrast to that in pure germanosilicate fibres where a reduction of the 240 nm band is observed. The excimer laser induced loss at infrared was also measured in fibre I after a 5 minute exposure. There was a relatively strong induced loss in the near visible (~ 0.44 dB/mm at 600 nm), but virtually no induced loss above 0.9 μm. A slightly stronger temporary induced loss was also noted during exposure, but only a smaller permanent induced loss remained after the exposure.

Fibre gratings were then imprinted in sections of the fibres using an interferometric set-up. The pulse fluence was set at ~0.25 J/cm^2 for the grating writing. The grating length was ~15 mm in length. The grating in fibre I reached ~100% reflectivity within ~1 mins (i.e. ~0.3 kJ/cm^2). After 30 minutes, the FWHM bandwidth attained a saturation level of ~0.75 nm (see fig.2). An index change of ~1.4×10^{-3} can be deduced from the grating. Fig.3 gives a comparison between saturated photo-induced index changes deduced from gratings written by the interferometric set-up in fibres of the following core compositions, A)SiO_2/GeO_2, B)$SiO_2/GeO_2/B_2O_3$, C)$SiO_2/GeO_2/SnO_2$. The saturated photo-induced index changes in the Sn-codoped germanosilicate fibre are comparable with those in B-codoped germanosilicate fibres and are several times larger than those in pure germanosilicate fibres. Although index change of ~1.2×10^{-3} has been reported in a pure germanosilicate fibre (depressed cladding PCVD fibre) [5], similar result has not been repeated by other groups in very similar fibres. It must be pointed out that the B-codoped fibre in which ~1.2×10^{-3} index change was achieved had a very high loss of ~100 dB/km at 1.55 μm. The results of high-temperature stability tests for gratings in fibres with the three core compositions A) SiO_2/GeO_2, B) $SiO_2/GeO_2/B_2O_3$, C) $SiO_2/GeO_2/SnO_2$ are shown in fig.4. The grating in a Sn-codoped germanosilicate fibre (fibre I) is much more stable than that in a B-codoped germanosilicate fibre.

Conclusions: A factor of ~3 larger photo-induced index changes have been demonstrated, a result comparable to B-codoping. The gratings in the Sn-doped fibres also have a much improved high temperature stability than those in B-codoped fibres. Unlike B-codoping, Sn-codoping does not introduce significant loss at the important telecommunication window of 1.55 μm. Tin can also be easily introduced in the vapour phase as $SnCl_4$ into the state of art optical fibre fabrication process using vapour-phase deposition.

References:

1. D.L. Williams, B.J. Ainslie, J.R. Armitage, R. Kashyap and R, Campbell: "Enhance UV photosensitivity in boron codoped germanosilicate fibres", Elect. Lett., **29**, 1993, pp.45-47.
2. F. Bilodeau, B. Malo, J. Albert, D.C. Johnson and K.O. Hill: "Photosensitization of optical fibre and silica-on-silicon/silica waveguides", Opt. Lett., **18**, 1993, pp.953-955.
3. P.J. Lemaire, R.M. Atkins, V. Mizrahi and W.A. Reed: "High pressure H_2 loading as a technique for achieving ultrahigh UV photosensitivity and thermal sensitivity in GeO_2 doped optical fibres", Elect. Lett., **29**, 1993, pp.1191-1193.
4. L. Dong, J. Pinkstone, P.St.J. Russell and D.N. Payne: "Ultraviolet absorption in modified chemical vapour deposition preforms", J. Opt. Soc. Am. B, **11**, 1994, pp.2106-2111.
5. H.G. Limberger, P.Y. Fonjallaz and R.P. Salathé: "Spectral characterisation of photoinduced high efficient Bragg gratings in standard telecommunication fibres", Elect. Lett., **29**,1993, pp.47-48.

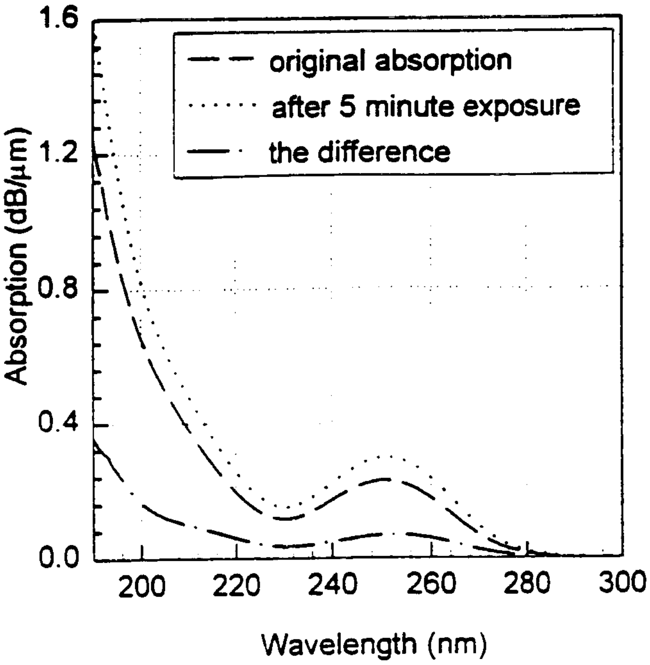

Fig. 1 The UV absorption spectra measured in the Sn-codoped germanosilicate preform before and after exposure to a KrF excimer laser beam for 5 mins. The pulse fluence was set at ~50 mJ/cm^2 for this exposure.

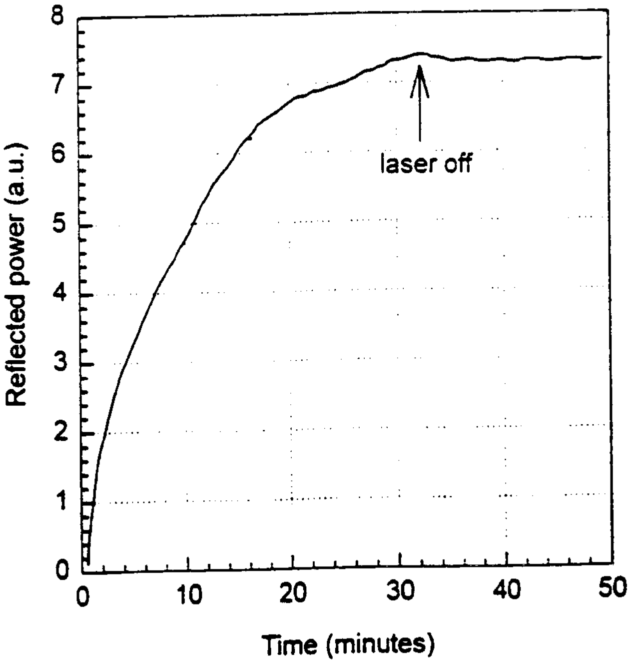

Fig. 2 Growth of a grating in fibre I when writing with a KrF excimer laser at 20 Hz with a pulse fluence of 0.25 J/cm^2.

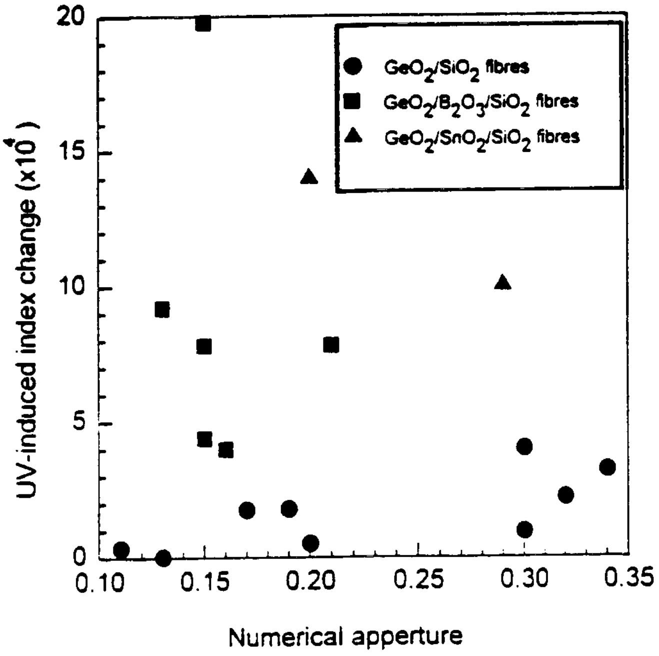

Fig.3 248 nm-induced refractive index changes in three types of fibres A)SiO_2/GeO_2, B)$SiO_2/GeO_2/B_2O_3$ and C)$SiO_2/GeO_2/SnO_2$.

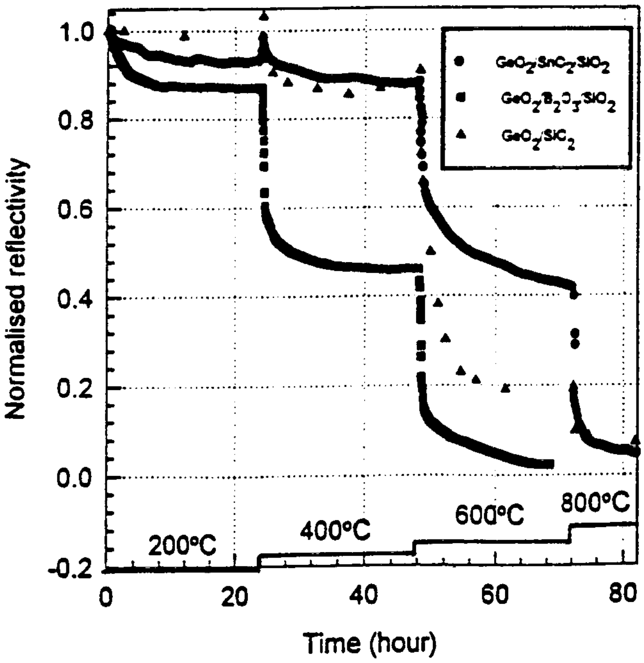

Fig.4 Decay of the UV-induced index changes at elevated temperatures in fibres containing A)SiO_2/GeO_2, B)$SiO_2/GeO_2/B_2O_3$ and C)$SiO_2/GeO_2/SnO_2$.