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Photosensitivity in tin-doped silica optical fibres

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Abstract

Permanent gratings (refractive index modulation ~$3x10^{-4}$) were written in tin-doped silica optical fibres with low levels of SnO_2 (~0.15 mol %). In Ge-doped silica, ~10 mol% GeO_2 is required to produce comparable photorefractivity under similar conditions.

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Post-fabrication methods (such as hydrogen loading and flame brushing) and co-doping (B, Sn and rare earths) have been used to increase the photosensitivity of silica optical fibres [1] for the production of Bragg gratings. Compared to hydrogen loading and flame brushing the use of Sn keeps the absorption in the third telecom window at 1.5 μm low, is less time consuming and potentially cheaper. Tin also provides better temperature stability of the grating than other techniques, e.g. boron co-doping. So far tin has been used as a codopant to increase the photosensitivity of germanosilicate [2,3] and phosphosilicate [4] optical fibres. To our knowledge pure SnO_2 doped silicate fibres have never been investigated. In this work we show that small concentrations (~0.15 mol %) of Sn in the core of a silica fibre provide the means to write permanent refractive index gratings with a high degree of photosensitivity. A comparison with germanosilicate fibres shows that GeO_2 concentrations nearly two order of magnitudes higher are needed to produce the same photorefractivity under similar UV irradiation in silica glass. SiO_2 doped with only SnO_2 could potentially lead to the production of fibres with high enough photosensitivity and at the same time relatively low NA (0.1-0.12), thus compatible with standard telecom fibres.

The fibres used in the experiments were produced via MCVD (modified chemical vapour deposition) by depositing a soot rich in SnO_2 at 1300 ^{0}C and then consolidating at 1800 ^{0}C. The fibre produced had NA ~ 0.097 and cut-off wavelength λc=1.36 μm. The UV source was a KrF excimer laser (wavelength 248 nm) which delivered pulses of about 20 ns duration with a repetition rate of 20 Hz. A phase-mask was used to create the interference pattern for grating writing.

Fig. 1 shows the evolution of the refractive index modulation as a function of exposure time The maximum refractive index modulation achieved in these preliminary experiments was ~ $2.8 \cdot 10^{-4}$ after an exposure of 3.7 hours to pulses of 80 mJ/cm^2. Measurements at different fluence per pulse (i.e. intensity) show an initial growth rate which increases linearly with intensity, indicating that the photosensitivity in our experiment is based on one-photon process [5]. Similar refractive index changes under the same experimental conditions have been obtained in GeO_2:SiO_2 optical fibres with ~10% of GeO_2 [6,7] and also when a shorter UV writing wavelength (193 nm) was used in a 8 mol % GeO_2 fibre [5]. Standard telecom fibres (about 3% mol of GeO_2) produced index changes one order of magnitude lower ($\sim 2.6\cdot10^{-5}$) [8]. It has to be remarked that also the grating dynamics is different. The growth of the grating in germanosilicate fibres is faster than in our experiment. In fact, as clearly seen from Fig. 1, saturation was not achieved even after very long exposures at a considerable UV fluence per pulse.

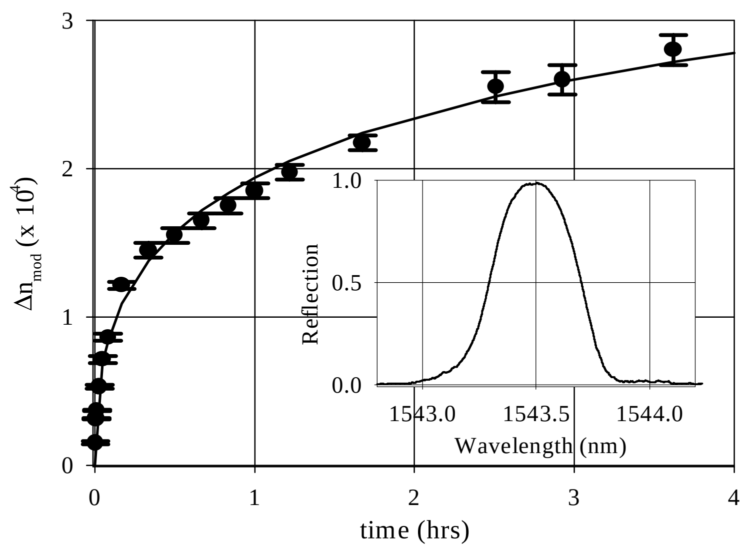

Fig. 1. Dependence of Δn_{mod} on UV laser exposure time in tin-doped silica fibres (pulse fluence 80 mJ/cm^2, grating length 3.9 mm). Inset: reflection spectrum for 3.7 hrs exposure.

To understand better the results obtained with the fibres, we carried out absorption measurements before and after UV exposure on thin plates obtained from the preform used to produce the fibre. It is

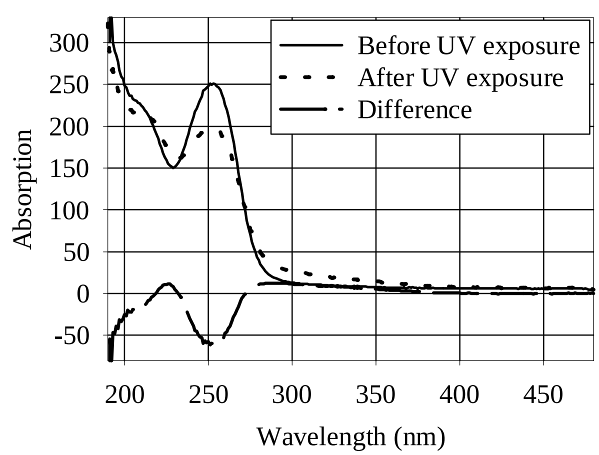

Fig. 2. Absorption spectra of a tin-doped silica optical preform slice (60μm thick) before and after KrF excimer laser exposure (repetition rate 20Hz, energy 100 mJ/cm^2, $3\cdot10^5$ pulses).

clear from figure 2 that the initial absorption (unexposed sample) spectrum is similar to that of a GeO_2:SiO_2 glass, with values comparable to those with 3% mol of GeO_2 [8]. Note that the peaks are shifted toward slightly longer wavelengths, in agreement with the fact that Sn has a lower band-gap than Ge. Similarly to GeO_2:SiO_2, in the SnO_2:SiO_2 glass after UV exposure the ~250 nm band is bleached and there is an increase in absorption at longer wavelengths. However a negative absorption change is present in SnO_2:SiO_2 below 200 nm and was completely absent in GeO_2:SiO_2 down to 160 nm [6-8]. Kramers-Kronig performed on the absorption changes measured in a thin GeO_2:SiO_2 accounts for the refractive index changes in the optical fibres [6-8]. In our experiments the absorption change seems to be significantly smaller and mostly negative (at least at wavelengths longer than 190 nm) although the refractive index change is positive. This could be an indication that the photosensitivity in SnO_2:SiO_2 fibres is somehow related to the fibre itself (fabrication, geometry, stress...) and it is not only a consequence of material properties.

In summary significant photorefrativity has been achieved in pure SnO_2:SiO_2 optical fibres, even at very low concentration of SnO_2. A comparison with GeO_2:SiO_2 is presented and it shows two-orders of magnitude greater photosensitivity (in terms of dopant concentration needed to produce the same refractive index modulation). Future work should lead to a better understanding of how Sn enhances the photosensitivity, fibres with greater Sn concentrations and thus higher index modulations. It is hoped that this research will lead to the production of highly photosensitive optical fibres with low loss at 1.5 μm and compatible with standard telecom fibre (same NA).

References

1 K.O. Hill, G. Meltz, Journ. Lightwave Tech. **15**, 1263 (1997).

2 L. Dong, J.L. Cruz, L. Reekie, M.G. Xu, and D.N. Payne, IEEE Photonics Tech. Lett. **7**, 1048 (1995).

3 K. Imamura, T. Nakai, Y. Sudo and Y. Imada, Electronics Lett. **34**, 1772 (1998).

4 L. Dong, J.L. Cruz, J.A. Tucknott, L. Reekie, and D.N. Payne, Optics Lett. **20**, 1982 (1995).

5 J. Albert, B. Malo, K.O. Hill, F. Bilodeau, and D.C. Johnson, Applied Physics Lett. **67**, 3529 (1995).

6 G. Meltz W. W. Morey, and W. H. Glenn, Opt. Lett. **14**, 823 (1989); H. Patrick, S. L. Gilbert, A. Lidgard, and M.D. Gallagher, J. Appl. Phys. **78**, 2940 (1995).

7 L. Dong, J.L. Archambault, L. Reekie, P. St. J. Russell, D.N. Payne, Appl. Opt. **34**, 3436 (1995).

8 R.M. Atkins, V. Mizrahi, and T. Erdogan, Electronics Lett. **29**, 385 (1993).