Germania-glass-core silica-glass-cladding MCVD optical fibres

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Abstract *Germania-glass-core silica-glass-cladding singlemode fibres (Δn up to 0.142) with minimum loss of 20 dB/km at 1850 nm have been fabricated by MCVD method. These fibres exhibit strong photorefractivity with the value of saturated type IIa index modulation of 0.002 at 3 kJ/cm^2.*

Introduction

Vitreous germanium dioxide (germania glass) is a promising fibre optic material for 2-µm applications because of potentially low optical loss in this spectral range [1, 2] and high nonlinearity [3, 4]. Earlier fibres of this type were prepared by the VAD method (GeO_2-based core and cladding, minimum loss value of 4 dB/km at 2 µm) [5] and by the MCVD method (the so-called GeSi-fibres that had a core with up to 45 mol.% GeO_2 and SiO_2-based cladding) [6]. GeSi-fibres seem to be more suitable for telecommunication applications because of the excellent physical properties of silica glass and better compatibility with common silica-based fibres.

In this paper we report on the development of singlemode (SM) MCVD fibres composed of the core with the concentration of GeO_2 as high as 97 mol.%, intermediate germanosilicate cladding, matched P/F-doped silica glass cladding, and silica glass support tube.

Results and discussion

There were prepared two fibre preforms with GeO_2 content of 97 mol.% (preform A) and of 75 mol.% (preform B) in the core. Radial distributions of glass composition measured by X-ray microanalysis in multimode (MM) fibres with core diameters of about 8 µm drawn from these preforms are shown in Fig. 1.

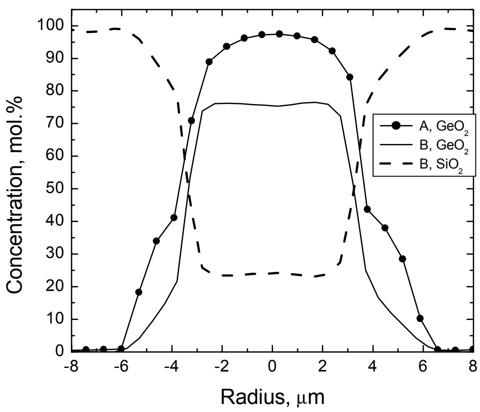

Fig.1. GeO_2 and SiO_2 concentration profiles measured in MM fibres A and B by X-ray microanalysis

The limited dynamic range of the available preform analyser (York Technology P102) did not allow us to measure the core/cladding index difference directly, therefore this value was calculated using the measured GeO_2 concentration in the fibre core. In order to do this we assumed the linear dependence of index difference on the germania concentration (in mol.%) $\Delta n = 1.46\times10^{-3}\times[GeO_2]$. Thus, we determined $\Delta n(A)=0.142$ and $\Delta n(B)=0.110$. The core/cladding index difference obtained for MM fibre A by measuring the numerical aperture ($\Delta n(A)=0.145 \pm0.003$) confirmed the calculated value. These results were used for a cutoff wavelength correction in SM fibres that were drawn from the preforms A and B after additional jacketing. The SM fibres obtained had the outer diameter of 125 µm. Core diameters and cutoff wavelengths varied for different samples in ranges of 1.4÷2 and 1÷1.4 µm, respectively.

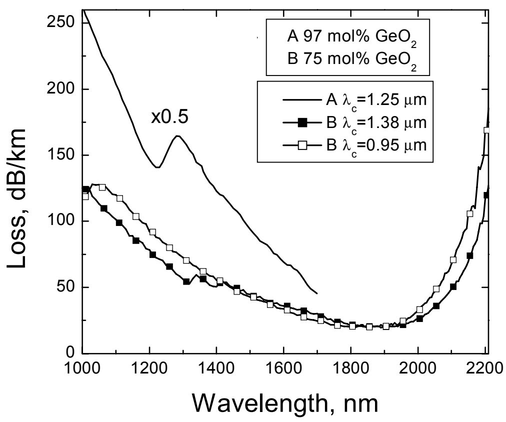

Fig.2. Optical loss spectra in SMFs A and B

Fig. 2 shows optical loss spectra in these SM fibres. The loss value of about 90 dB/km at 1.7 µm in the fibre A with a cutoff of 1.25 µm was obtained, whereas it was about 45 dB/km at 1.7 µm in the MM fibre A (not shown in Fig.2). The minimum loss value of 20±1 dB/km at 1.85 µm was achieved in both SM fibres B. Significant polarization splitting of the cutoff wavelength of about 80 nm caused by a core ellipticity was observed in SM fibres B. The increased loss observed in the fibre with λ_c = 0.95 µm in the long wavelength region (λ > 2 µm) is probably related to the intrinsic absorption of the cladding glass (lower value of V-parameter results in larger mode field diameter in this fibre).

Scattering loss measured in the fibres A using an integrating sphere technique occurred about 170 dB/km at 0.647 μm in the MM fibre and about 470 dB/km at 1.064 μm in the SM fibre. These values are equal to the measured total loss (see Fig.2) within the experimental error. Scattering strongly increases with a core diameter decrease and exceeds Rayleigh scattering in bulk GeO_2 [2] in 10 - 100 times. It has been revealed that angle distribution of the scattered light shows an intense forward-propagating component ($\alpha \leq 60°$). We suppose that this component is caused by a large-scale composition heterogeneity arising during fibre drawing due to large gradients of both the GeO_2 concentration and the viscosity at the core-cladding interface. This assumption is confirmed by the lack of central dip in the GeO_2 concentration profile in the sample B (Fig.1) and by a short fibre length (less than 10 cm) necessary to fill all the fibre numerical aperture that was observed in our experiments.

It is well known that the photosensitivity of germanosilicate fibres increases with the increase of GeO_2 concentration. Therefore a study of photosensitive properties of GeO_2 glass fibres could provide useful information about the photosensitivity mechanisms and about the limits of the UV-induced index change that can be achieved in such glass compositions. We performed a comparative study of the dynamics of Bragg grating formation in SM fibres A, B and C (fibre C had 24.5 mol.% GeO_2 in the core). The gratings were written in the interferometric scheme by cw 244-nm radiation ($I = 25$ W/cm^2, $\lambda_{Br} \approx$ 1.55 μm, L = 4.5 mm). The fibres were not hydrogen loaded. All the tested fibres exhibited type IIa dynamics of Bragg grating formation (Fig.3). As it is seen in Fig. 3a the larger the GeO_2 concentration the higher index modulation amplitude Δn_{mod} is and the lower exposure dose is required to saturate the grating. The value of Δn_{mod} of 2×10^{-3} at UV-dose of 3 kJ/cm^2 in germania-glass-core fibre has been achieved, whereas in fibre C type IIa grating with $\Delta n_{mod} \approx 3\times10^{-4}$ was written with the dose of about 200 kJ/cm^2.

Even stronger concentration effect was observed in the dynamics of the mean index change Δn_{mean} calculated from the Bragg wavelength shift (Fig. 3b). In fibre C the value of Δn_{mean} is always positive and only slightly decreases after the dose of about 100 kJ/cm^2, whereas in fibres A and B after a short-time initial growth it becomes negative and reaches the magnitude of -1.5×10^{-3}. To our best knowledge this is the highest value of negative mean-index change observed in Bragg gratings (see, e.g., [7]).

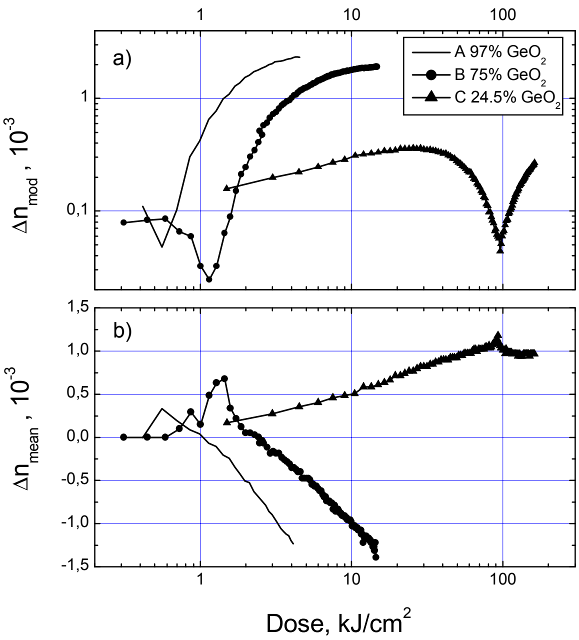

Fig.3. Index modulation Δn_{mod} (a) and of mean index change Δn_{mean} (b) in the Bragg gratings written in fibes A, B and C vs dose of 244-nm radiation.

Conclusions

Germania-glass-core silica-glass-cladding single-mode fibres (Δn up to 0.142) were fabricated by the MCVD method. Minimum optical loss value of 20 dB/km at 1.85 μm has been achieved. Scattering was the main source of the loss. The addition of SiO_2 to GeO_2 decreased the loss magnitude.

Type IIa grating behaviour manifests itself up to 97 mol.% GeO_2 concentration in the fibre core. Growth of GeO_2 content strongly increases both index modulation and mean index in type IIa region and hence reduces the grating fabrication time.

Acknowledgement

The authors are grateful to S.V. Lavrishchev and E.V. Pershina for the X-ray measurements, Dr. Yu.N. Pyrkov for loss measurements in the range of λ>1.8 μm, N.N. Vechkanov, A.G. Shchebunyaev and A.K. Mikhailov for fibre drawing.

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