Optica Applicata, Vol. XIV, No. 4, 1984

Gradient resistivity to ionizing radiation in lightguide preforms

Stanisław Gębala

Institute of Physics, Technical University of Wrocław, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland.

1. Introduction

In production and examination of gradient materials the concentration of their composition being programmed, the main attention of the producers is paid to the refractive index distributions. It appears that the resistivity to γ-radiation is also of gradient type. In the examined samples of the lightguide preforms we deal with some distributions of the colour centres, their appearance and strength being the function of the basic composition and by the same means a function of the preform radius.

The subject of our examination were the plates cut perpendicularly to the preform corn. The structure and the composition of the preforms are approximately the same as those of the lightguide. The corn of the preform is made of a three-component glass GeO_2–P_2O_5–SiO_2, while the clad is produced of pure quartz glass. The change in refractive index is due to the change in concentration of GeO_2 which ranges from zero in the outer part to its maximum value inside the corn. The preforms were produced at the Maria Skłodowska-Curie University in Lublin (Poland). Although the interaction of the radiation on the lightguide has been the subject of interest for a long time, it was, however, limited to the averaged measurement of the transmittivity spectra for the whole fibre [1, 2].

2. Results of experiments

Photography is one of the perspicious forms of presentation of colour effects after γ-irradiation of the gradient material. An example is shown in Fig. 1. It presents the corn illuminated with a white light beam, the plate being previously exposed to γ-radiation of 4×10^6 rad. The red colouring is connected with the presence of absorption bands within the region between 400 and 600 nm. The colouring is the most intensive in the external part of the corn and diminishes toward its centre, inversely as it is the case with the concentration of GeO_2. It may be preliminarily supposed that the restrictivity to γ-irradiation is proportional to the GeO_2 concentration. The irradiation, moreover, increases strongly the contrast of colouring between particular layers. Another practical way of showing the gradient effects is to draw transmittivity curves along the chosen diameters of the preform, for different light wavelengths.

The results for a similar plate of the same preform, but irradiated by a dose equal to one fourth of the former, are shown in Fig. 2. The curves corre-

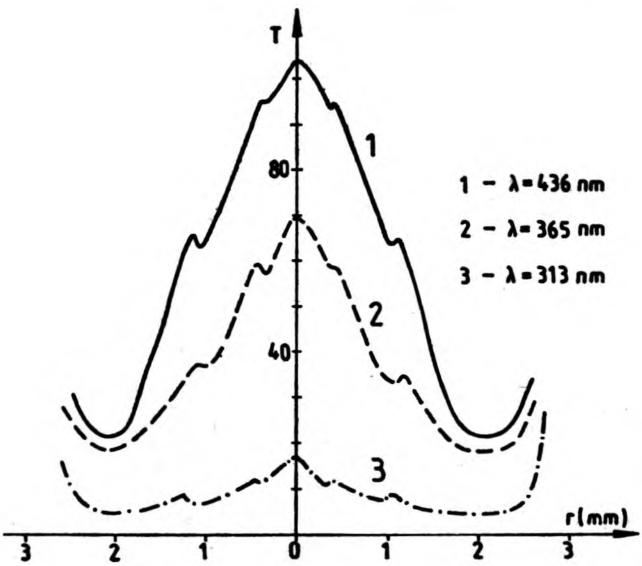

Fig. 2. Transmittivity curves as the function of the radius of the preform core exposed to γ-radiation (for explanation see text)

spond to the following wavelengths: 1 – 436 nm, 2 – 365 nm and 3 – 313 nm. The wavelengths were selected by controlling SPM-2 quartz prism monochromator illuminated by a mercury lamp. The irradiated plate was transversally shifted close to the aperture supplying the light to M12FQS39 photomultiplier. This

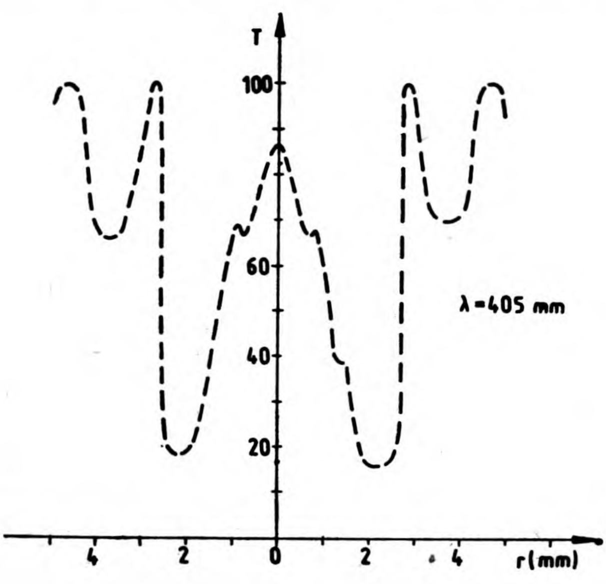

Fig. 3. Transmittivity of the preform plate irradiated by γ-radiation as a function of preform core radius

aperture was slightly greater than the thickness of the single layers of the corn. The curves obtained are similar not only to the curves of GeO_2 concentration but also to those of the refractive index distributions. A similar record of the transmittivity of a plate from the other preform is shown in Fig. 3. The curve of transmittivity obtained from the measurement made at the wavelength of 405 nm concerns not only the corn but also the layers of the clad. In addition to the colour centres existing in the preform corn there appear also the colour centres in its clad. It is of interest to notice that the distribution of centres within the whole thickness of the clad is not the same and also differs from one preform to another. A high transmittivity is observed in the synthetic quartz layer between the core and the clad.

As a complementary information, the curves of spectral transmittivity for the clad and for the core of the preform are shown separately. Difference between transmittivity attributed to the part of the quartz tube forming the clad and subjected to γ-radiation of 4×10^6 rad and that attributed to nonirradiated plate is shown in Fig. 4. The curve 1 refers to Heralux WG quartz

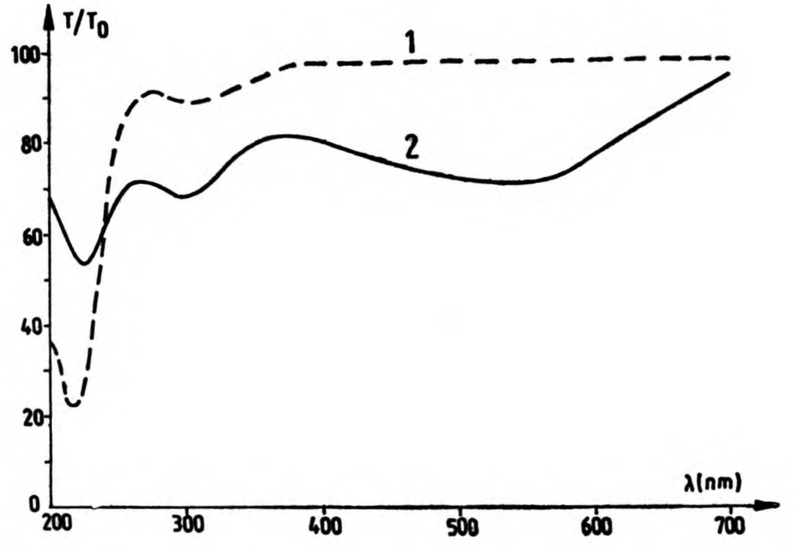

Fig. 4. Spectrum of relative transmittivity of the quartz plate (1 – Haeraus make, 2 – Sovieren make) exposed to γ-radiation

glass of Haeraus make while the curve 2 concerns the analogous glass of Sovieren (France) make. As a result of γ-irradiation there appear the bands 210–220 nm, 300 nm and 550 nm known from the literature [3, 4, 5]. The 210–220 band corresponds to the colour centre E' and the bands 300 nm and 550 nm are attributed to the nonbridging oxides at the presence of modifiers, such as hydrogen and aluminium, for instance. They appear in the quartz glasses with material contaminations. The lack of the band 550 nm and of much weaker one, 330 nm in the curve 1 for glass of Haeraus can be attributed to a higher purity of glass or to greater participation of molecular hydrogen. No absorption band of 260 nm is observed in the curves.

In Figure 5 the spectral responses of optical density are shown for the plate from the 1 mm-thick preform clad. The curve 1 corresponds to the nonirradiated plate and the curve 2 – to that after irradiation by a 1×10^6 rad dose. The curve 2 has been recorded in another place of the plate due to too high increment of the density exceeding the measurement range of the spectrometer. The density increments due to γ-irradiation are so great that their provenience is unquestionable. The density curve after irradiation is exceptionally complex. It is noticeable, however, that the bands connected with the presence of P_2O_5, 530 nm and about 400 nm are the most visible. These are due to the colour centres connected with nonbridging oxides PO_4^{2-} [3, 4, 6] at the presence of germanium ions.

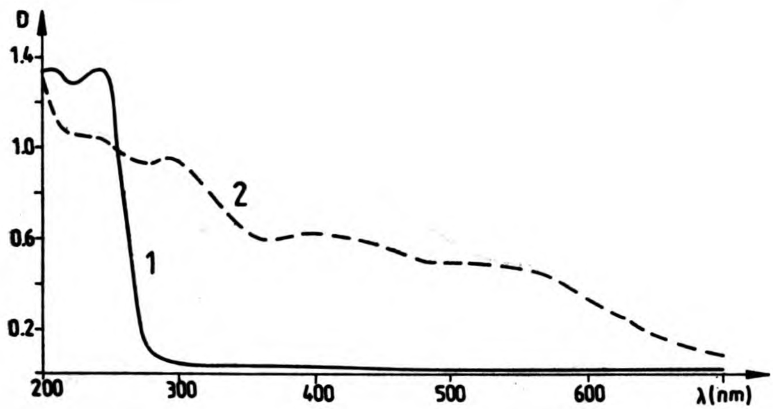

Fig. 5. Spectrum of transmittivity of the preform plate: 1–before irradiation, 2–after exposure to γ-radiation

3. Conclusion

The method of examination proposed above allows us to recognize the distribution of imperfections more quickly than it would be possible by using traditional methods. The practical application of γ-irradiation is a basis of quick estimation of GeO_2 concentration as well.

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Received May 8, 1984