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Thin-film optical components of hybride structure formed of Ta_2O_5 on a diffusion lightguide

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A new structure useful for thin film optical components was elaborated. It is a hybride-formed Ta_2O_5 island in the window of planar diffusion lightguide. Some attempts have been made to apply this structure in forming a lens and a prism. The results proved positive.

1. Hybride structure: Ta_2O_5 layer - diffusion lightguide

Production of a new thin film structure was inspired by the work of WILKINSON and WALKER [1] of Department of Electronics and Electrical Engineering, University of Glasgow. These authors calculated the concentration profiles at the mask edge, which appear in the course of the ion exchange process from Na^+ to Ag^- in the glass layer close to glass surface. (This is a known method of diffusion lightguide production [2, 3]). They took account of two kinds of masks: dielectric and conducting ones. In the case when a dielectric mask is applied the characteristic concentration profile of Ag ions that appears at the mask edge creates an almost wedge-ending of lightguide rim. This wedge extends the rim to few micrometers under the mask and may be used as a mild optical transition to the mask region.

If the mask has simultaneously the properties of a lightguide a structure helpful in hybride-junctions of two optical waveguides or that applicable to integrated optics components may be produced.

A simplified scheme of the said structure with the ray-tracing marked is shown in Fig. 1. In our works aiming at elaboration and production of optical components a thin lightguide layer of Ta_2O_5 was applied to masking. The structure presented was produced in the region where shapes and sizes corresponded to a chosen component. Rounded lenses and triangle prisms were produced.

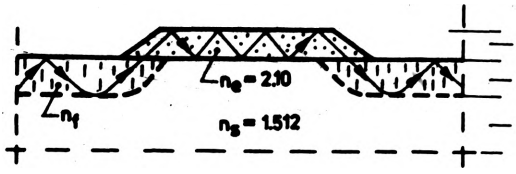


Fig. 1. Scheme of the hybride structure of diffusion lightguide-dielectric mask type. n_e, n_f, n_s - refractive indices at $\lambda = 5.461$ nm. 1 - Ta_2O_5 island, 2 - diffusion lightguide, 3 - glass substrate

The production of each of the said optical components was realized in two technological steps. The first of them was the creation of a Ta_2O_5 island on the cleaned glass substrate determining the topography of the component. The island formation was realized by using the d.c. reactive ion sputtering method in a modified three-electrode system in the Ar + O_2(50/50%) atmosphere. The layers obtained had the refractive index n_e of the value ranging from 2.08 to 2.10 for $\lambda = 5.461$ nm. The sputtering was carried out with application of metallic non-contact masks. The distance of the mask from the surface allows to produce the tapered edge of the island. This is a pure geometric wedge of basic importance for creating a mild change of effective refractive index at the edge structure [4].

Second technological process consists in production of planar lightguide by using the ion exchange method. The Ta_2O_5 islands formed previously played here the role of localized masks. In the course of this process a concentration wedge is formed in the lightguide under the tapered edge of the mask. This constitutes a region of tapered transition from the diffusion lightguide to the lightguide layer Ta_2O_5. In this way suitable conditions for lossless transition of a ray are created on both edges of the produced structure. Such transitions have been confirmed experimentally in components produced.

2. Experimental results

The experiments carried out resulted in production of the said structure in optical components. Two series of lenses of diameters: 1, 1.5, 2, 2.5 nad 3 mm with two values of Ta_2O_5 island thickness amounting to 500 and 1000 nm, as well as one series of prisms of prism angles equal to 60, 90 and 120°, and of base sizes equal to 5, 6 and 8 mm, respectively, have been obtained. In all cases the thickness of the Ta_2O_5 layers was 500 nm, the planar lightguide had the six-mode thickness for $\lambda = 6.328$ nm. The applicability of the obtained optical components was examined.

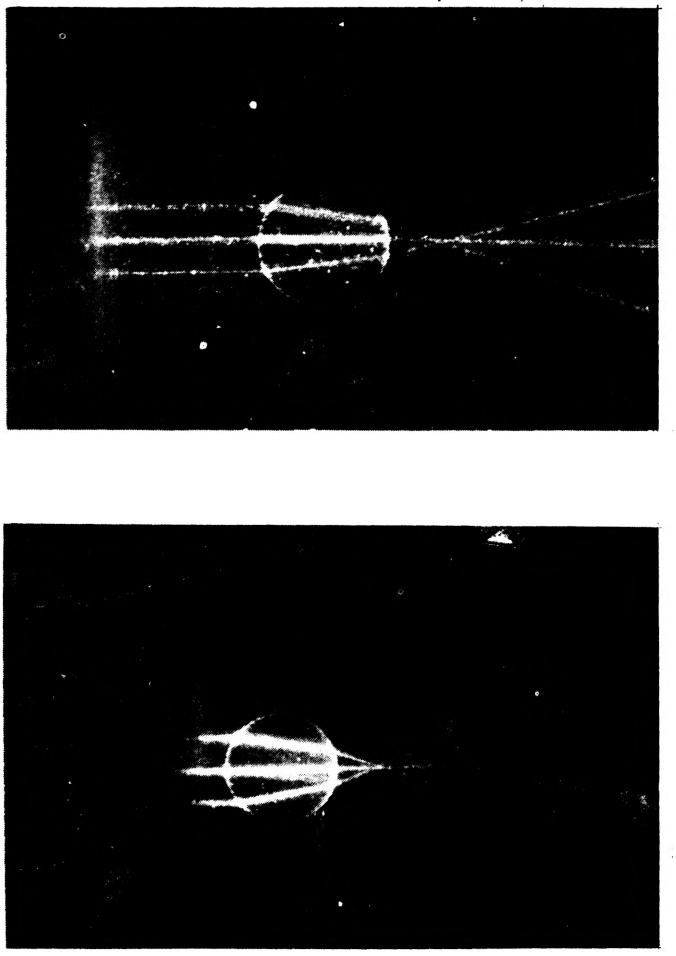
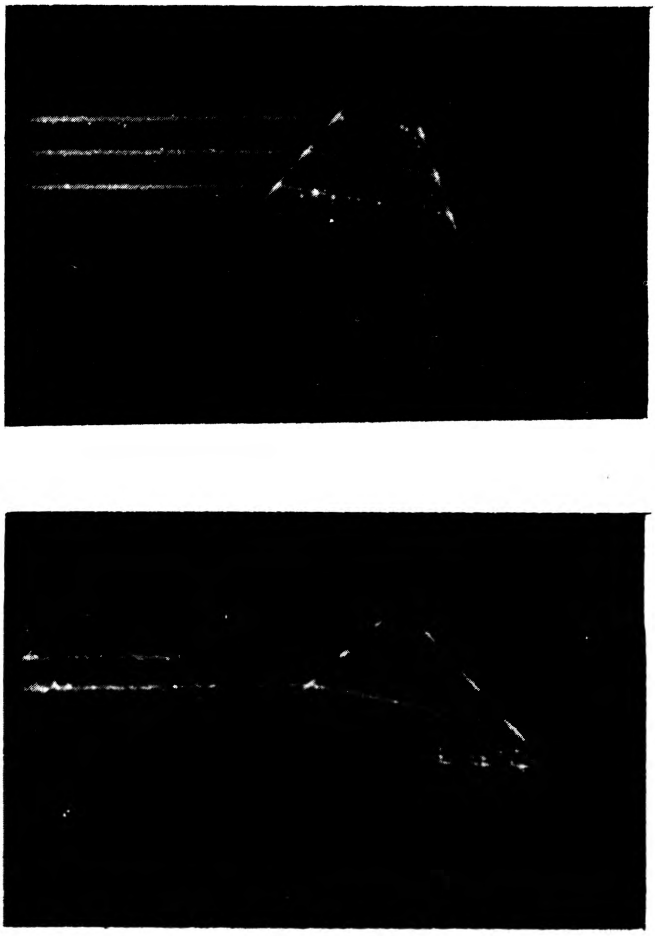


Fig. 2. Photos of acting lenses: lens diameters - a - 3 mm, b - 2.5 mm. The thickness of Ta_2O_5 layer is 500 nm in both cases

The lenses exhibit distinct converging properties. The focal lengths are small, ranging from 1.5 mm for a 1 mm diameter to about 2 mm for 3 mm diameter. This is caused by a great value of the refractive index jump at the border between the glass substrate and the Ta_2O_5 island layer. Small positive aberration of order of 0.2 mm is characteristic of all the lenses the aperture of which is equal to 0.8 mm of their diameter. Examples of two working lenses are presented in Fig. 2.

The prism showed correct refractive powers occurring for all angles of the prisms. Figure 3 shows the photos of the prism. Part a of the figure shows the deviating action for a symmetric transition of the chief rays. The part b illustrates the nonsymmetric transition of the rays with total internal reflection at the rim of the prism.



a

b

Fig. 3. Photos of deviating prisms: angle of prism a - 60°, b - 90°

It has been stated that in all the elements examined there exists a possibility of transition without light scattering by both the edges. The structures with thinner layers of Ta_2O_5 - amounting to 500 mm - are single mode and transmit only the basic mode TE, whereas the structures of Ta_2O_5 layer of thickness 1000 nm are of two-mode type and transmit the TE_0 and TE_1.

3. Summary

The structure proposed has been verified in praxis in optical elements produced on a glass substrate. Positive results have been obtained. It is characteristic of this structure that a mild optical transition

at its edges occurs in a natural way during the technological process used. It may be supposed that these properties will occur also in the case of other substrate material, for instance, that of $LiNbO_3$ in which the lightguide would be formed by using the diffusion methods.

References

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ТОНКОСЛОЙНЫЕ ОПТИЧЕСКИЕ ЭЛЕМЕНТЫ С ГИБРИДНОЙ СТРУКТУРОЙ, ФОРМИРОВАННОЙ ИЗ Ta_2O_5 НА ДИФФУЗНОМ СВЕТОВОДЕ

Разработана новая структура, пригодная для осуществления тонкослойных оптических элементов. Это гибридноформированный остров на "окне" в планарном диффузном световоде. Проведены попытки применения этой структуры в осуществлении линзы и призмы. Были получены положительные результаты.