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Letter to the Editor

Electron emission stimulated by waveguide radiation

Stanisława Szarska, Wojciech Magierski

Institute of Physics, Wrocław University of Technology, Wybrzeże Wyspiańskiego 27, 50–370 Wrocław, Poland.

The influence of laser light simulation on electron emission from planar waveguide surface has been investigated. The measurement technique proposed by Zatsepin has been applied to stimulate electron emission under the action of intrinsic UV radiation of the waveguide. The results obtained are discussed in terms of point defects in the structure.

1. Introduction

Planar waveguides have been applied for optical recording, storing and imaging of information in different connection and control systems. One of the most popular methods of obtaining a planar waveguide is the ion exchange method. When a glass slab is put into contact with molten salt, cations of the molten salt can exchange with ions existing at the glass surface, and then the exchanged ions migrate into the glass, which in turn may change the index through two mechanisms:

– chemical change in the structure,

– new ions may be different in size and in polarizability and induce strains in the glass which in turn may change the index.

The refractive index profile depends upon the composition of the initial glass as well as the condition of ion exchange technological process, such as the kind of dopant ions, time and temperature of the process. Thus this profile can change in different ways:

– change of the composition of the initial glass,

– change of the composition of the molten salts,

– change of the ion exchange technological process.

The different temperatures at which the diffusion processes take place are connected with the fact that ions exchange most effectively in the vicinity of the glass softening point T_g and depend on the choice of the composition of mixture of molten salts.

From investigations of Sheshukova *et al.* [1] it follows that for effective ion exchange Na^+ (glass) – Ag^+ (salt) which takes place for the relation $AgNO_3/NaNO_3 \approx 0.4$ it is necessary to prepare a mixture of silver + sodium nitrate, because in this case the production process of planar waveguide is cheaper.

Waveguide structures are characterized, besides refractive index profile, by low material loss and high thermal stability. Particular attention is paid to the surface quality of the glass plates. It is necessary that the surface quality (number of point defects and scratches) of each substrate plates be accurately assessed both before and after the technological process. From ORLOV'S investigations [2] it results that a low temperature ion exchange process leads to an increase in mechanical strength of glass. On the other hand, the substitution of larger K^+ ion on the site of the Na^+ in glass at about 450–500 °C induces a compressive force at the surface [3]. The replacement of $Na^+ - Li^+$ or $K^+ - Na^+$ favours the network breakdown accompanied by the phase separation, crystallization and crack formation. The reverse substitution does not cause such large stresses.

One of the basic parameters describing an optical waveguide is its attenuation expressed in dB/cm. Attenuation depends on material losses. Losses of this type are mostly caused either by OH^- trap centers or by absorption of radiation by OH ions, or by the stresses caused by the heat treatment and an intrinsic and extrinsic electron colour centers localized in near-surface layer.

One of the most sensitive methods of examining the surface properties is an excited electron emission method. Electron emission of glass waveguides under external action of light has been described in several papers. In this paper, we will present the result of applying a new technique to study the quality of waveguide using the electron emission method.

2. Materials and methods

Samples of two types of glass (a change of composition of the initial glass) were subject to ion exchange process, with the composition (in percentage by weight) being as follows:

[C] $40SiO_2 40B_2O_3 20Na_2O$,

[H] $74.4SiO_2 13.5Na_2O 4.3MgO 3.6CaO 2.6Al_2O_3 1K_2O$.

The ion exchange process was carried out in the furnace from 0.5 h to 6 h at 220–670 °C for different salts and glasses, respectively (a change of the ion exchange technological process). The following salts were used for ion exchange: $AgNO_3$, KNO_3 (a change of the composition of the molten salts).

Measurements were performed in vacuum (10^{-4} Pa) at room temperature. Electron emission was registered by secondary-electron multiplier [4]. Glass samples

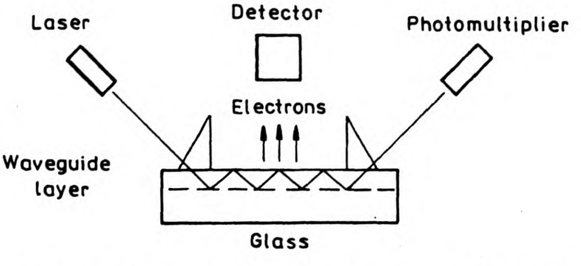

Fig. 1. Experimental scheme for electron emission stimulation by waveguide radiation

were irradiated with an N_2 laser. The laser emitted light of wavelength 337 nm, pulse repetition frequency was 30 Hz, and density of excitation during the pulse 100 kW.

ZATSEPIN *et al.* [5] proposed a new method of detecting the local centers, which dissipate and absorb the radiation in waveguide based on the registration of electron emission stimulated by intrinsic radiation of waveguide (*i.e.*, under operating regime of waveguide). The scheme of experimental set-up is shown in Fig. 1. Laser line allowed selective excitation of resonance modes in the waveguide. Prismatic devices were used for entrance and exit of laser radiation. Simultaneously, attenuation and number of modes were measured in the position described in [6].

3. Results and discussion

Figure 2 presents the dependence of the refractive index change for H glass on the ion exchange time in molten KNO_3. From measurements of electron emission stimulated by outside and inside laser radiation (in configuration like that of Fig. 1) it follows that for this H sample treated ion exchange process at 520 °C no emission has been observed. It had 3 modes and attenuation of about 2 db/cm.

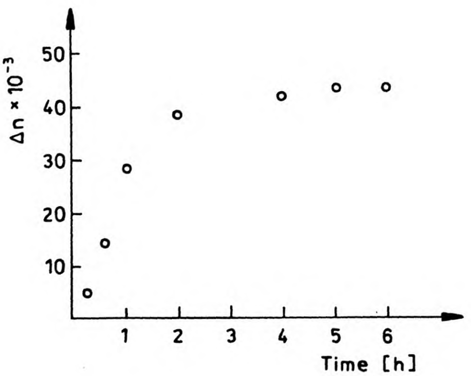

Fig. 2. Dependence of refractive index change on the ion exchange time in molten KNO_3 for H glass

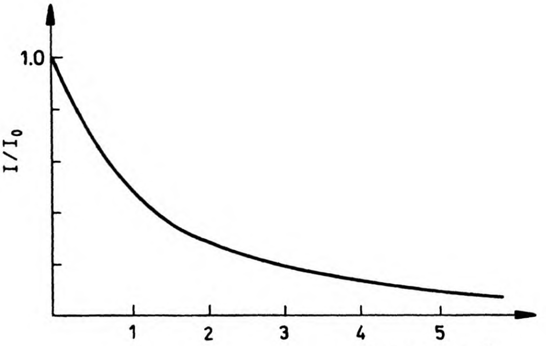

Fig. 3. Decay curve for optical stimulated electron emission for C glass after KNO_3 bath (520 °C)

The other shape of electron emission has been observed for C glass treated KNO_3 ion exchange process. Decay curve of optical stimulated electron emission (OSEE) for this glass stimulated by outside laser beam is presented in Fig. 3. This sample has 5 optical waveguide modes. Figure 4**a** shows the light beam intensity in waveguide as a function of radiation entrance angle (inside radiation). Angular dependence of electron emission intensity has the form of mode spectrum as well (Fig. 4**b**), but only for 4 modes and waveguide light radiation intensity the electron emission current value decreases greatly with increasing mode number. This sample had 5 modes and 10 dB/cm attenuation. The glass contains boron, which interferes with the ion exchange, intensifying the effect of the location of the centers near the glass surface.

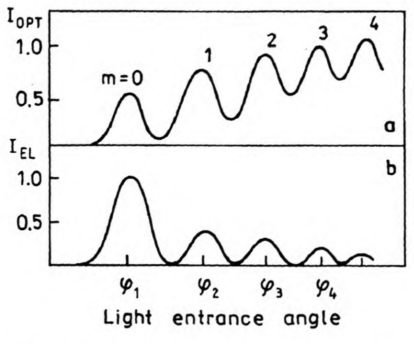

Fig. 4. Distribution of intensity as a function of light entrance angle for C glass (KNO_3). **a** — optical waveguide, **b** — electron emission

After the treatment the sample of C glass in $AgNO_3$ molten salt at 230 °C had 7 waveguide modes with 2 dB/cm attenuation. For this sample no electron emission was observed. In the diffusion region of the sample under investigation, silver ions exchanging sodium ions did not evoke any stresses, which could be measured by optical methods [7]. It is a very important property resulting from that the ionic radius Ag^+ [1.03 Å] and Na^+ [0.98 Å] are slightly different.

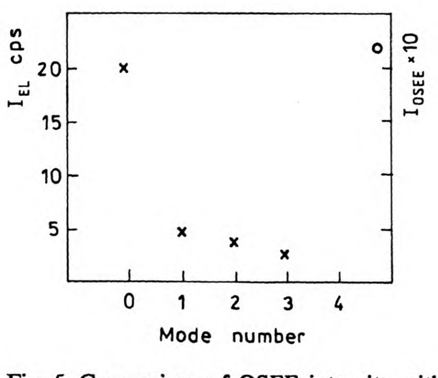

Fig. 5. Comparison of OSEE intensity with electron emission intensity excited by different waveguide modes

According to Zatsepin notions the reason for emission current origination is photostimulated formation of intrinsic non-stable electron E^- centers on conduction band tail states followed by center decay. From our investigation it results that E^- centers are not the only source of electrons. Because the intensity of optical stimulated electron emission is greater than that of waveguide radiation intensity mode (Fig. 5), the additional source of electrons is associated with the crack and pore formation at the glass surface. In the glass submitted to the ion process a space charge polarization takes place on the phase boundary. These polarization processes could cause either more intensive or blocking electron emission. A specific mechanism of this process needs additional investigations.

4. Conclusions

The following conclusions can be drawn from our investigation of the electron emission simulation by waveguide radiation:

1. The electron emission stimulated by waveguide radiation is a very interesting method of examining the near surface of the ion exchange glass.

2. The E^- centers of glass surface are not the only source of electrons. Another source are defects connected with surface stresses.

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