

PACS number(s): 33.55.Ad; 81.05.Lg

## INVESTIGATIONS OF OXIDE GLASSES WITH USE OF FARADAY EFFECT METHOD

E. Golis<sup>1</sup>, M. Reben<sup>2</sup>

<sup>1</sup>*Institute of Physics, Jan Dlugosz University  
Armii Krajowej ave. 13/15, 42-200 Czestochowa, Poland*

<sup>2</sup>*Faculty of Materials Science and Ceramics  
AGH University of Science and Technology  
Mickiewicz ave. 30, 30-059 Kraków, Poland  
e-mail: e.golis@ajd.czest.pl*

Presented work is a continuations of investigations of oxide glasses with use of Faraday effect method. Investigation was performed for lead-bismuth oxide glasses and tellurite glasses from the  $\text{TeO}_2\text{--WO}_3\text{--PbO}$  system  $\text{La}_2\text{O}_3$  modified. The investigations have shown existence very strong Faraday effect in lead-bismuth oxide glasses. In the  $\text{TeO}_2\text{--WO}_3\text{--PbO}$  glass system the magneto-optical properties was observed thanks to  $\text{La}_2\text{O}_3$  addition. For further application of oxide glasses as a optical shutters and optical modulators a dynamic method will be proposed to monitor Faraday effect.

*Key words:* oxide glasses, Faraday effect, magneto-optical devices.

Oxide glasses with lead and bismuth oxides, due to the big mass and polarizability of ions  $\text{Pb}^{2+}$  and  $\text{Bi}^{3+}$ , posses interesting properties in infrared optics and nonlinear optics. These glasses are characterized by great value of the nonlinear refractive index what it suggest the possibility of observation great value of the Verdet constant [1].

$\text{TeO}_2$  based glasses are of great interested for use in optical communication system. The refractive index of tellurite glass from  $\text{TeO}_2\text{--WO}_3\text{--PbO}$  system reach the value up to 2,30 [2]. Relatively high refractive index is a consequence of high polarizability of tellurium ions. Their highest refractive indices among oxide glass in the visible and near IR region causes that  $\text{TeO}_2$  based glass systems are the most promising materials in optoelectronical devices [3].

Properties of oxide glasses in the range of magneto- optics phenomena are very interesting for optoelectronics. Faraday rotation has a practical application in optical isolators. An optical isolator is a device that allows light to go through in one direction but severely attenuates reflected light propagating in the opposite direction. Optical isolators have important applications in telecommunications preventing reflected signals on fiber optic cables from producing unwanted signals. Isolators are important when lasers are used because reflected light can cause havoc with the operation of the laser itself [4].

The Faraday effect depends on to turn the plane of polarization of linearly polarized light in isotropic transparent materials under the magnetic field. An extensive description of this effect may be found in [5].

The experimental of the method probing the Faraday effect was carried out in magnetic field with induction  $B=0,06$  T. The measurements of steering angle were

executed in the range from 480 to 700 nm. From the value of the rotation of the polarization plane the value of Verdet constant was estimated. Maximum error of measurement rich the value 4%. The block diagram of measuring system to investigation of Faraday effect are given in [6].

Detailed investigation of magneto optic properties was made for the oxide glasses PbO(25%mol)–BiO<sub>1,5</sub>(50%mol)–GaO<sub>1,5</sub>(25%mol), PbO(25%mol)–BiO<sub>1,5</sub>(30%mol)–GeO<sub>2</sub>(45%mol), TeO<sub>2</sub>(60%mol)–WO<sub>3</sub>(30%mol)–PbO(10%mol) and TeO<sub>2</sub>(57%mol)–WO<sub>3</sub>(30%mol)–PbO(10%mol)–La<sub>2</sub>O<sub>3</sub>(3%mol). Lead-bismuth glasses was synthesis carried out in platinum crucibles in an electric furnace at the temperature about 1 100°C. The melts was poured out into a cast iron form and then relief annealed. Tellurite glasses have been obtained by melting 100 g batches in a gold crucibles in an electric furnace at the temperature 850°C in air atmosphere. The melts were poured out into a steel form. The glasses prepared in such manner was thermoannealed at 350°C for 12 hours. Samples used for studies were mechanically treated by grinding and polishing.

The received results of investigations on figure 1 was presented.

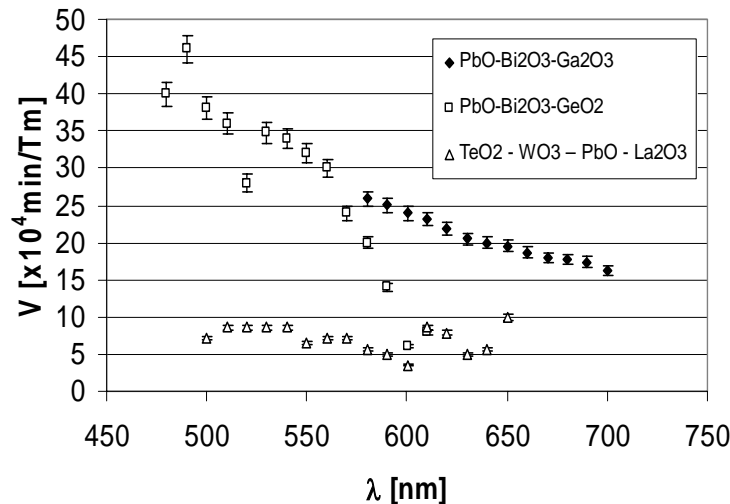


Fig. 1. The dependence Verdet constant from wavelength in constant magnetic field about induction 0,06 T for investigated oxide glasses

The investigations have shown existence very strong Faraday effect in lead-bismuth oxide glasses. The maximum value of turn angle the plane of polarization was received for wavelength  $\lambda=490$  nm for PbO–Bi<sub>2</sub>O<sub>3</sub>–GeO<sub>2</sub> glass system. Calculating for this value Verdet constant carries out  $46,00 \cdot 10^4$  min/Tm.

For the PbO–Bi<sub>2</sub>O<sub>3</sub>–Ga<sub>2</sub>O<sub>3</sub> glass system the maximum value of turn angle the plane of polarization was received for wavelength  $\lambda=580$  nm. Calculating for this value Verdet constant carries out  $25,83 \cdot 10^4$  min/Tm.

For the tellurite glass TeO<sub>2</sub>–WO<sub>3</sub>–PbO the dependence of turn angle of the plane of polarization on light wavelength under magnetic field was not observed.

In case of glass TeO<sub>2</sub>–WO<sub>3</sub>–PbO–La<sub>2</sub>O<sub>3</sub> the investigation have shown the dependence of turn angle of plane of polarization and Verdet constant on magnetic field induction for the range of wavelength 490–650 nm. The maximum value of turn angle was received for wavelength  $\lambda=650$  nm. Calculating for this wavelength Verdet constant gives the value of  $10 \cdot 10^4$  min/Tm.

The magneto-optical properties are observed in the  $\text{TeO}_2\text{-WO}_3\text{-PbO}$  glass system thanks to  $\text{La}_2\text{O}_3$  addition, it has been confirmed by a Faraday effect occurrence. The polarization of the glass is not only the result of electron polarization but also includes the contribution of the orientation of charged defects in glass. Those phenomena have influence on calculated Verdet constant.

Thanks to the addition of La ions into the tellurite glass structure, those glass system can be considered as promising material for optoelectronics. However obtained results could be suggested that lead-bismuth oxide glasses are to possibly better materials for magneto-optical devices.

For further application of oxide glasses as a optical shutters and optical modulators a dynamic method will be proposed to monitor Faraday effect.

1. *Janewicz M., Wasylak J.* Struktura i własności szkieł germanianowych Szkoło i Ceramika. Vol. 42. N 3. 1991.
2. *Ovcharenko N.V., Smirnowa T.V.* // J. of Non-Cryst. Solids. 2001. Vol. 291. P. 121–126.
3. *Hagemuller P. (Ed.)* Inorganic Solid Fluorides, Chemistry and Physics, Academic Press, New York, 1985.
4. *Gaj J.A., Gałazka R.R., Nawrocki M.* // Solid State Commun. 1978. Vol. 25. N 193.
5. *Oleś A.* Metody doświadczalne fizyki ciała stałego, Warszawa, WNT. 1998. P. 401–405.
6. *Golis E. P., Filipiecki J.* Investigations of Faraday effect in oxide glasses for optoelectronics devices Proc. of SPIE. 2007. Vol. 660.

## ДОСЛІДЖЕННЯ ОКСИДНИХ СТЕКОЛ З ВИКОРИСТАННЯМ МЕТОДУ ЕФЕКТУ ФАРАДЕЯ

Е. Голіс<sup>1</sup>, М. Ребен<sup>2</sup>

<sup>1</sup>Інститут фізики, Університет Яна Длугоша  
вул. Армії Крайової 13/15, 42201 Ченстохова, Республіка Польща

<sup>2</sup>Факультет матеріалознавства і кераміки АГН університету наук і технології  
пл. Міцкевича 30, 30-059 Краків, Республіка Польща

Наведено результати досліджень оксидних стекол з використанням ефекту Фарадея. Дослідження проводили для свинцево-вісмуткових та телуридних стекол системи  $\text{TeO}_2\text{-WO}_3\text{-PbO}$ , модифікованої  $\text{La}_2\text{O}_3$ . Виявлено сильний ефект Фарадея у свинцево-вісмуткових стеклах. Показано, що завдяки додаткам  $\text{La}_2\text{O}_3$  в стеклах системи  $\text{TeO}_2\text{-WO}_3\text{-PbO}$  спостерігаються магнітооптичні властивості.

*Ключові слова:* оксидні стекла, ефект Фарадея, магнітооптичні пристрої.

**ИССЛЕДОВАНИЕ ОКИСЛЁННЫХ СТЕКОЛ  
С ИСПОЛЬЗОВАНИЕМ МЕТОДА ЭФФЕКТА ФАРАДЕЯ**

**Э. Голис<sup>1</sup>, М. Ребен<sup>2</sup>**

<sup>1</sup>*Институт физики, Университет Яна Длугоша  
ул. Армии Краевой 13/15, 42201 Ченстохова, Республика Польша*

<sup>2</sup>*Факультет материаловедения и керамики AGH  
университета наук и технологии*

*пл. Мицкевича 30, 30-059 Краков, Республика Польша*

Приведены результаты исследований окислённых стекол с использованием эффекта Фарадея. Исследования проводили для свинцово-висмутовых и телуридных стекол системы  $\text{TeO}_2\text{-WO}_3\text{-PbO}$ , модифицированных соединением  $\text{La}_2\text{O}_3$ . Обнаружен сильный эффект Фарадея в свинцово-висмутовых стеклах. Показано, что благодаря дополнениям  $\text{La}_2\text{O}_3$  в стеклах системы  $\text{TeO}_2\text{-WO}_3\text{-PbO}$  наблюдаются магнитооптические свойства.

*Ключевые слова:* окислённые стекла, эффект Фарадея, магнитооптические устройства.

Стаття надійшла до редколегії 04.06.2008

Прийнята до друку 25.03.2009