ELECTROPHYSICAL AND OPTICAL PROPERTIES OF A PMN-PT CRYSTAL OF P4mm SPACE GROUP

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$(1 - x)Pb(Mg_{1/3}Nb_{2/3})O_3$- $xPbTiO_3$ (PMN - PT) single crystals have been reported to exhibit ultrahigh piezoelectric constants (d_{33} > 2000 pC N^{-1}), extremely large piezoelectric strains (> 1.7%), and very high electromechanical coupling coefficients (k_{33} > 92%) [1,2]. Estimations show that changing the component composition of these media in percentage it is possible to obtain fundamentally new by physical properties materials. In the present report we investigated electrophysical and optical properties of PMN-PT single crystal with x=0.37 - 0.38 mole ratio of PT and poled along the [001] direction.

Investigated patterns had the form of rectangular yellow colored parallelepipeds with size 7x7x7 mm^3 along crystallographic axes a,b,c respectively and brightly expressed block structure. X-ray crystallographic analysis (fig. 1) was carried out by the Rietveld's method using the GSAS program package. Both tetragonal unit cell (space group P4mm) and cubic perovskite one (space group Pm3m) were identified in the investigated specimen. The lattice parameters are a=b=4.032(8) Å, c=4.037(3) Å for tetragonal unit cells and a=4.0353 (8) Å for cubic perovskite ones. An existence of two different unit cells in the crystal can indicate a presence of the „growth defects" like twins and striations. The energy dispersive X-ray spectrometry (EDS) of the blocks and their boundaries was carried out to determine an elemental composition ((fig. 2).

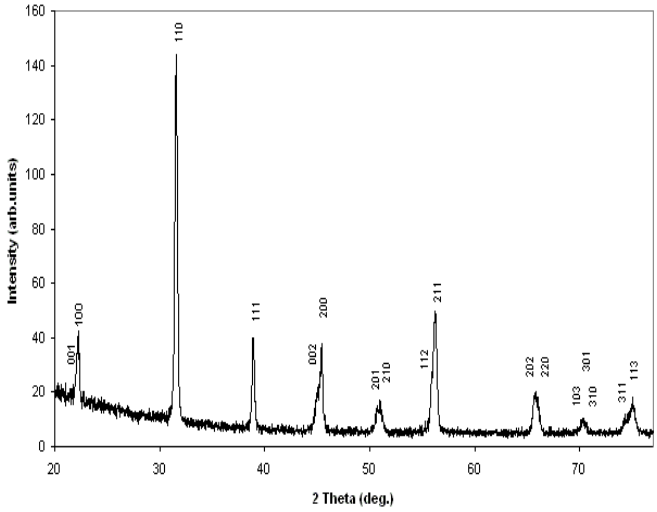

Fig. 1. X-ray powder diffraction.

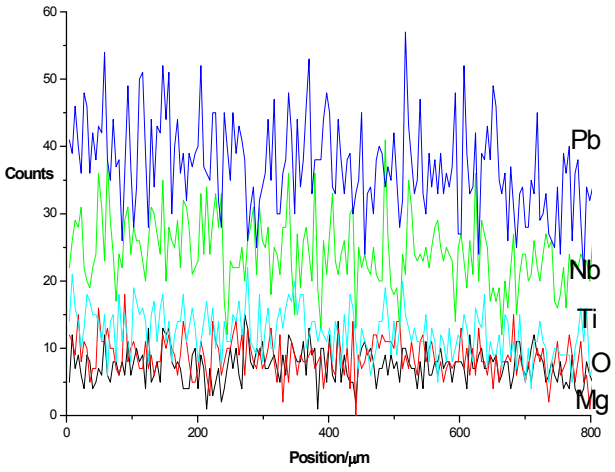

Fig. 2. Elements distribution along the block

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For the measurement of optical constants of the medium at the present stage of the work we applied a method based on the use of Frenel formulas and Kramers- Kroning method. The reflection spectrum in the visible and near IR spectral area is measured on spectrometer Carry 500 UV-VIS-NIR (*Varian*) and Fourier-transform spectrometer Nexus FT-IR (ThermoNicolet). Two IR resonant bands corresponding to the frequencies 300 – 380cm^{-1} and 480 – 650 cm^{-1} were found from the frequency dependencies of the reflectance coefficient (fig.3). These bands have relationship to the

phonon spectrum of the crystal lattice and can be attributed to the vibrations of the atoms of the oxygen $(Mg/Nb/Ti)O_6$ octahedron.

PMN-PT crystal is transparent in a wide spectral area above 0,42 microns. For a wavelength range over 1-3 microns an optical transmission is practically invariable and makes ~ 65 %. Measurements of reflection from other crystallographic planes give insignificant changes of character of dispersion of refractive index (about ± 2%). The calculated refraction coefficients vary for the frequencies 2000 – 5000 cm^{-1} within the values ranges (2.52 - 2.82), (2.50 - 2.78) and (2.52 - 2.87) for the planes (100), (010), and (001) correspondingly. Measured values of refractive index are in good agreement with data of spertrophotometric investigations (fig.4).

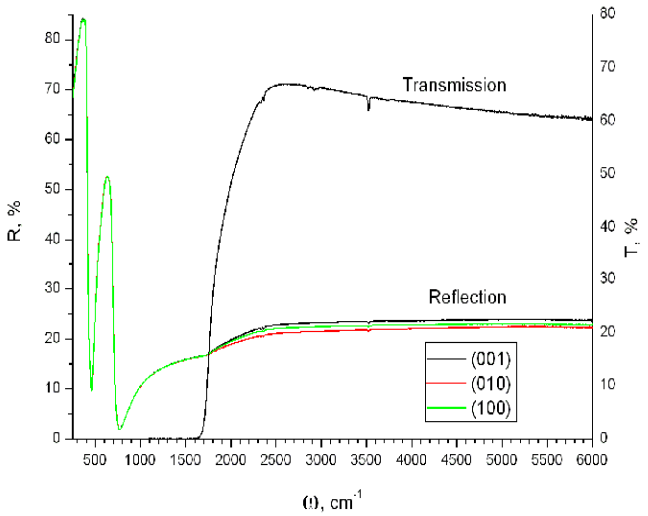

Fig. 3. Reflectance and transmission spectrum.

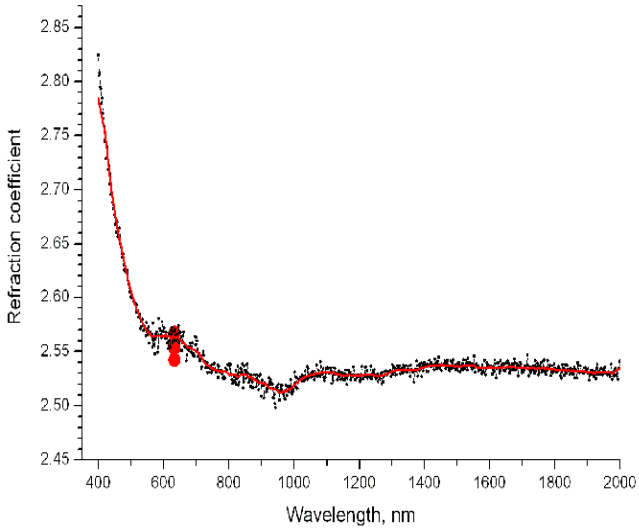

Fig. 4. Dispersion of refractive index.

An analysis of the spectral dependencies of the refractive index and coefficient of absorption, calculated from date of fig.3 using Kramers- Kroning' method, shows agreement with each other in wide range. However, the anisotropy is observed for coefficient of absorption. The value of the latter is lower along the (001) direction as compared to one along the (010) and (001) directions. So, the conductivity of the crystal should be lower along (001) direction as compared to (010) and (001) directions.

The first estimated measuring of electrooptical coefficients are carried out. The measurement is spent by an interference method in local homogeneous sites of examples by the sizes ~ 30 - 40 microns. The first obtained results testify to extremely high electrooptical efficiency of the crystal. The estimation have shown extremely high coefficients r_{13} ~ 33 pm/V and r_{33} ~ 80 pm/V. The half-wave voltage for an extraordinary wave has value180 - 220 V.

In the PMN-PT crystal we observed non-synchronous generation of second harmonic of Q-switched Nd^{3+}: YAG laser with pulse duration ~5 nc and energy generation ~10 mJ. Non-synchronous generation of the second harmonic in the crystal marginally confirms existence of anisotropy of refraction index.

Thus, in the present report we investigated new single crystal of PMN-PT type. Date of experimental observations show existence of anisotropy of electrophysical and optical properties. Big value of refractive index permits to assume high sensitiveness given crystal to electric influence.

References

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