불순물 도핑에 의한 lead tugnstate 결정의 굴절율 연구

Studies of refractive indexes of lead tungstate crystals by impurity ions doping

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In recent years, $PbWO_4$ has attracted much interest since it was chosen as scintillator material for large-scale applications in CMS at LHC (Large Hadron Collider) [1]. Many ions doping have been conducted to improve the scintillating characteristics [2]. In this work, the experiment is mainly reported for the main refractive indices of PWO doped with Li^+ and La^{3+}.

The PWO were grown by Czochralski method. The Li^+ and La^{3+} doping are 2000 ppm and 2.0 mol %, respectively. The refractive indexes were measured by the minimum deviation method [3], which were kept the temperature constant at 24.0 °C±0.3 °C. The ordinary indices (n_o) and extraordinary indices (n_e) of pure and doped PWO are shown in **Table 1**. To fully characterize an optical material in terms of refractive index, its Sellmeier curve has to be determined to know the refractive index at all wavelengths. A more exact fit of the equation was obtained according to the modified Sellmeier's equation [3]:

$$n_i^2(\lambda) = A_i + \frac{B_i}{\lambda^2 - C_i} - D_i \times \lambda^2 \qquad (1)$$

where λ is in units of 1×10^{-1} μm, and i = *1, 2* correspond to the two principal refractive indices. The parameters A_i, B_i, C_i, and D_i parameters were obtained in terms of full-matrix least-squares techniques and shown in Table 2. It could be seen that the refractive indices are frequency dependent in visible spectrum in the investigated wavelengths. All the refractive indices dramatically increase when the wavelength decreases. The dispersion curves Δn (λ) of the investigated crystals are shown in Figure 1. Compared with pure PWO the birefringence Δn in PWO:Li^+ have an increasing trend towards longer wavelength, and that of decreasing in PWO:La^{3+}. The refractive index of any optical material is determined by two types of resonance absorption: one is the electronic transitions of oscillators, i.e., the average resonance of electronic absorption in the UV and the other is the lattice vibrations of the material in the IR [4]. Also the birefringence and their dispersions have been determined to base on the average electronic absorption gap in UV region and the effective lattice resonance absorption gap in the IR [4]. The different doping effects on the birefringence are due to the different doping mechanism for Li^+ and La^{3+}. Li^+ ions are considered to predominantly enter interstitial sites. But the La^{3+} enter Pb^{2+} site and charge balance is compensated by V_{Pb} [6]. So in PWO Scheelite-type structure, the different polarization effects are existed for these two different doping, consequentially they give the different influence on the principal refractive indices and the birefringence index.

For $PbWO_4$ doped with Li^+ and La^{3+} ions, ordinary indices (n_o) and extraordinary indices (n_e), were measured by the least deviation angle method. In addition, the birefringence of crystals was investigated based on the dispersion curves by fitting different dispersion Sellemeier functions. The birefringence of $PbWO_4$ crystal could be enhanced by Li^+doping, not by La^{3+} doping.

Table 1. Experimental values of principal refractive indices n_e and n_o of the PWO crystals.

Wavelength(nm)	Pure PWO		PWO:La^{3+}		PWO:Li^+	
	N_o	N_e	N_o	N_e	N_o	N_e
435.8	2.3779	2.2581	2.3727	2.2555	2.3798	2.2597
486.1	2.3258	2.2223	2.3212	2.2198	2.3277	2.2239
546.1	2.2877	2.1952	2.2833	2.192	2.2899	2.1963
587.6	2.2693	2.1819	2.2650	2.179	2.2706	2.1816
656.3	2.2476	2.1665	2.2435	2.1628	2.2537	2.1663
706.5			2.2408	2.1606	2.2458	2.1642

Table 2. Refractive index parameters for the pure and doped PWO crystals

	Pure PWO		PWO:La^{3+}		PWO:Li^+	
	N_o	N_e	N_o	N_e	N_o	N_e
Ai	4.66274	4.52794	3.86509	4.86202	5.00844	4.5418
Bi	0.13932	0.07718	-2.56395	-0.39931	0.030819	-0.8497
Ci	0.04592	0.05931	1.17185	0.87726	0.18342	0.99966
Di	-0.06248	0.10762	5.31969	2.50406	0.12496	3.11717

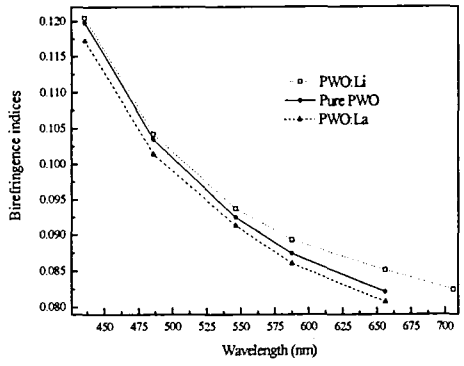

Fig. 1. Dispersion curves $\Delta n(\lambda)$ of pure PWO and doped samples.

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