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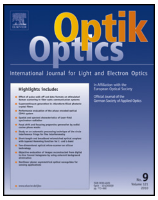

Full length article

Effect of gamma and neutron irradiation on structural and optical properties of ammonium dihydrogen phospate single crystals

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ABSTRACT

The nonlinear optical single crystals of ammonium dihydrogen phosphate (ADP) were grown by slow evaporation solution growth technique at ambient temperature. The grown crystals were exposed to neutron beam of energy 4.44 MeV and flux 2.2×10^7 $ncm^{-2}s^{-1}$ irradiated for 3hr and 5hr and Co–60 gamma radiation of doses 50 kGy and 100 kGy separately. The structural, optical, and nonlinear optical properties (second harmonic generation) of the crystals were investigated before and after irradiation. X-ray diffraction studies reveal that the compressive strains are generated in the irradiated crystals. The UV–visible spectra shows that the optical absorption increases with increase in radiation dose. The R.I of the crystal was found to decrease after neutron irradiation, whereas it increases with the increase in the gamma dose rate. Except at high dose rate, SHG efficiency of ADP is unaffected by either gamma or neutron irradiation.

1. Introduction

Ammonium Dihydrogen Phosphate is well known for their second order nonlinearity and piezoelectric properties. In fact, the tremendous feature is observed in phase transition i.e., anti-ferroelectric behavior of the material at low temperature (transition temp $T_c = 148$ K). The anti-ferroelectric interaction between protons was considered from the effect of N—H···O hydrogen bonding, and these hydrogen bonds creates a network and connecting to the phosphate groups in ADP crystal [1]. The second harmonic frequency generating materials play a major role in the field of optoelectronics and photonics. Device applications need a crystal possessing good nonlinear optical (NLO) properties with high conversion efficiencies for second harmonic generation (SHG) and transparency in the visible and ultraviolet ranges [2]. NLO materials have been used for optical switching, data storage, remote sensing, optical bi-table devices, optical-parametric oscillations, electro-optical devices, holography, frequency mixing medical diagnosis, and underwater monitoring and signal transmission because of its high optical nonlinearity [3,4]. Inorganic materials are of great interest because they have large thermal and mechanical stability, compared with organic materials. In order to obtain second-order NLO response in materials, one has to select the material in such a manner that it should have non-centrosymmetric behavior. Irradiation induced changes in structural and optical properties of the material would helped us in exploring suitability of such crystals for various applications. However, very few investigations on the irradiation on organic and inorganic single crystals has been reported in the literature

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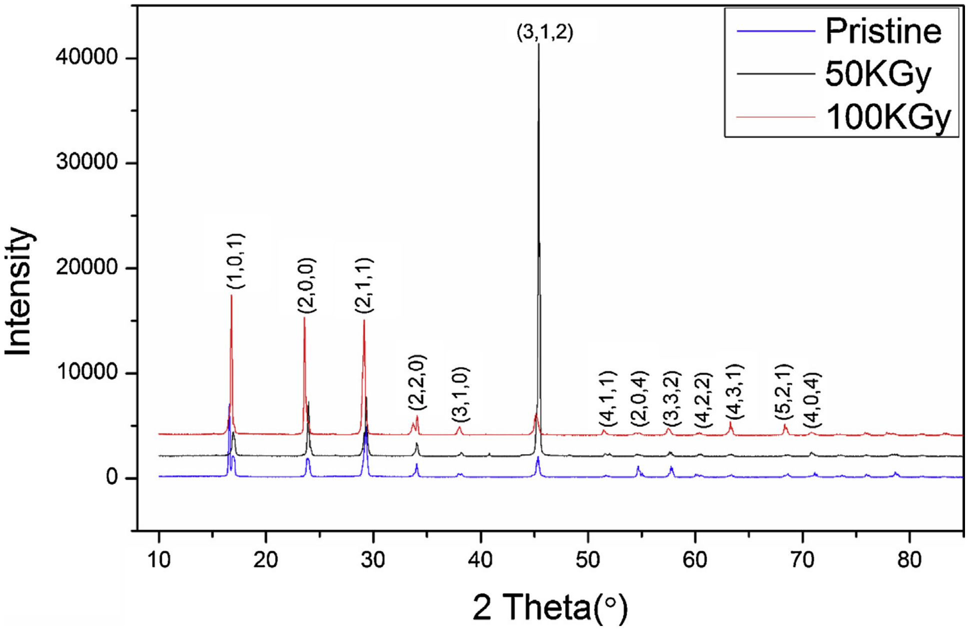

Fig. 1. powder XRD pattern of unirradiated, gamma irradiated ADP crystals.

[5–12]. Irradiation causes disorder in the crystal lattice, which in turn produces changes in electrical conductivity and optical properties depending upon the extent of damage caused. The lattice defects are the responsible for the optical absorption over the spectral ranges of UV–vis region. It is well known that irradiation caused lattice defects, among these defects the free radicals OPO_3H^- stable at a low temperature and at high temperature lattice defects due to anion and cation vacancies and involved in the interstitial atoms [13,14].

The SHG has increased with the increase in the irradiated current [15]. Introduction of stress is a powerful technique to change nonlinear optical susceptibility, in particular SHG efficiency in the irradiation sensitive materials [16]. These findings motivated us to study the effect of gamma and neutron irradiation on the characterizations of the samples by employing UV–visible and X-ray diffraction spectroscopy. Moreover, effect of irradiation on optical band gap energy, crystallinity, refractive index and SHG measurement was studied.

2. Experimental procedure

Good quality single crystals of ADP were grown by slow evaporation solution growth method at room temperature using water solvent [17]. The crystals were irradiated using Co–60 gamma chamber-5000, which is a compact, portable, self-shielded type of a Co–60 gamma radiation. A neutron beam of energy, 4.44 MeV and flux, 2.2×10^7 n cm^{-2} s^{-1} was used to irradiate samples in air at the atmospheric pressure. The pristine and irradiated crystals were subjected to powder X-ray diffraction (XRD) by using a Rigaku- Miniflex X-ray diffractometer with a scan speed of 5°/min with Cu-Kα radiations. The absorption spectrum was recorded using Varian (Cary 5000) UV–vis–NIR scanning spectrophotometer in the range of 200–1100 nm covering the UV, visible and near IR regions. The R.I was determined by the Brewster's angle method using homemade long arm spectrophotometer. The SHG conversion efficiency was tested using Kurtz and Perry technique.

3. Result and discussion

3.1. X-ray diffraction analysis

The lattice parameters and crystallographic structure of the ADP single crystals were determined using X-ray diffractometer. The powder XRD patterns of un-irradiated and gamma irradiated crystals were shown in Fig. 1. The crystallite size has been calculated using a relation,

$$L = K\lambda/\beta\cos\theta \quad (1)$$

Where $K = 1$, $\lambda = 1.5406$Å and β is the full width at half maximum, called Scherer equation. The XRD patterns of un-irradiated and neutron irradiated ADP crystals were shown in Fig. 2. The Bragg reflections at specific 2θ angles in the diffraction pattern confirm the crystalline nature of the sample. Further, in order to understand structural variation of ADP crystal