Optik 168 (2018) 174–178

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Original research article

Incorporation of CdSe quantum dots (QDs) in KH_2PO_4 (KDP) crystalline host: Processes of elaboration and characterization

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ARTICLE INFO

Article history:
Received 11 March 2018
Accepted 11 April 2018

Keywords:
CdSe QDs
KDP
XRD
UV–visible
Photoluminescence

ABSTRACT

The aim of this work is to survey experimentally the effect of doping CdSe quantum dots (QDs) on structural and optical properties of Di-hydrogen phosphate KH_2PO_4 (KDP) single crystal, where we expose a simple and reproduced technic to obtain KDP:CdSe single crystal starting from aqueous solution phase. In order to characterize the samples comfortably, the obtained crystals were cleaved into pellets with suitable size each surface being parallel to the faces (100). The XRD results denote that the CdSe QDs inside KDP single crystal have only one preferred direction (110) and the estimated size as derived from Sheere's formula proved the nano-regime of guest material. On the other side, UV–vis absorption spectrums appear that a pure KDP crystal has transparence property in the visible range with a large window where E_g (KDP) ≈ 7.17 eV. However, KDP:CdSe sample exhibits two bands located at 425 nm and 625 nm attributed to the transition band to band and excitonic, respectively. As an accordance result, photoluminescence (PL) measurements indicate that the band gap of CdSe QDs inside KDP single crystal appears a significant amount of blue-shift (ΔEg = 0.284 eV) due to well recognized quantum confinement effect exerted by the CdSe QDs.

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1. Introduction

To date, QDs of semiconductors have received much attention because of an exceptional property where they appear the size-dependants on their properties such as structural, optical and optoelectronics properties which change dramatically compared to the bulk semiconductors. Commonly, these new behaviors of nanosemiconductors can be interpreted through the quantum confinement effect and a large surface-volume ratio [1]. The II—VI semiconductors occupy an important position; they have been widely used for different applications such as lasers, biomedical tags, and solar cells [2–4]. Among the II—VI semiconductors, CdSe is extensively used in different application devices [5]. As a bulk crystal, CdSe exhibits direct band gap energy (E_g≈ 1.75 eV) with exciton Bohr radius 3.67 nm [6,7]. Moreover, The CdSe QDs have amazing size-dependants emissions, due to this feature they have greatly interested in the pharmaceutical and biological science [8].

In order to use QDs in the optical experiments, their nano-size makes a big challenge. Therefor QDs need, in general, to support or matrix host. Recently, many investigations have been interested in the optical properties of nanosemiconductors dispersed in crystalline matrix, for example: KBr:CuO, NaCl:CdTe, KBr:AgBr, KCl:AgCl KCl:Sb_2O_3, NaCl:ZnO, and KDP:CdTe

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https://doi.org/10.1016/j.ijleo.2018.04.076
0030-4026/Published by Elsevier GmbH.

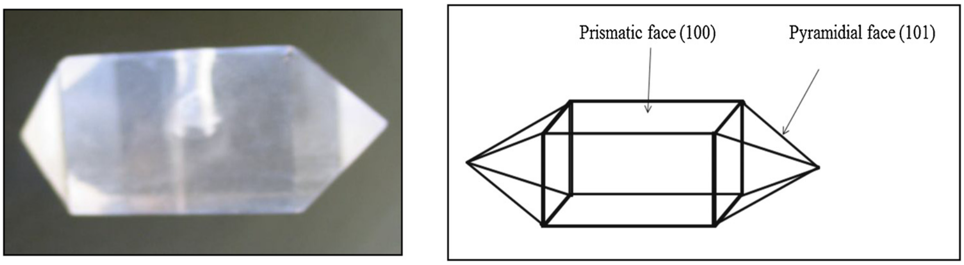

Fig. 1. Photograph of a KDP:CdSe single crystal.

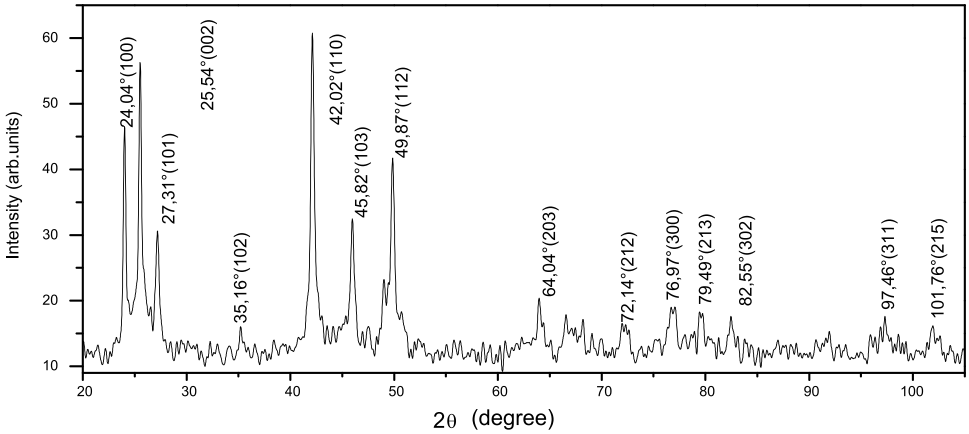

Fig. 2. XRD pattern of the CdSe nanopowder.

[9–15]. On the other hand, KDP crystal is one of the first inorganic materials with nonlinear optical properties [16–18]. It was already used in various laser systems for the generation of the second harmonic, the manufacture of the guide waves, optoelectronic commutations [19,20] In addition, KDP is a dielectric material, where it offers a large window in the UV–vis region with $E_g = 7.8$ eV and it has a wide range of possible doping impurities [21–25], these properties encourage us to investigate the structural and optical properties of CdSe QDs as bulk defects inside the KDP crystalline matrix.

2. Experimental details

The pure and 1.0 mol % CdSe doped KDP single crystals were grown from aqueous solution by the lowering temperature technique. The homogenous saturated solutions were prepared by mixing the KDP with pure water obtained from bidistillation. The KDP seeds were obtained from the slow evaporation method. To make the solution supersaturated, the temperature of the solutions was raised to 50 °C. At this temperature, the solutions were stirred for 4–5 h to get the homogenous mixture of supersaturated solution. After getting the homogeneous solution, the temperature was slowly decreased to ambient conditions. The obtained KDP single crystals have sizes around 15 × 15 × 60 mm and they display a simple morphology formed by a combination of the prismatic (100) and pyramidal (101) faces (Fig.1). The samples are cut parallel to the faces (100) as pellets with a 3 mm thickness. The faces of these pellets are polished for optical measurements. In order to obtain KDP:CdSe single crystal, the same experimental protocol was used. However, in this time the CdSe QDs were added to the homogenous saturated solutions during the growth process of KDP single crystal.

XRD data were obtained using BRUKER-AXSD8 diffractometer withe Cu radiation (35 kV, 30 mA) and a graphite filter. All the samples were analyzed under the same experimental conditions at room temperature (RT) in the angular range of 20–110° of 2θ, with the scan rate of 0.001°/s. The optical properties were studied using a UV–vis spectrophotometer (Shimadzu, UV-3101). Furthermore, the PL was measured at RT and the samples were excited by an argon laser (ionized light λ_{exc} = 313 nm).

3. Results and discussion

The XRD spectrum of CdSe QDs was presented in Fig. 2. It offers a remarkable broadening of the diffraction peaks due to nano-size of CdSe powder. Furthermore, it is easy to conclude that the CdSe QDs crystallize in hexagonal (wurtzite) with lattice parameters a = 0.4299 nm and c = 0.701 nm, and they have a symmetry of space group ($P6_3mc$) as reported in the JCPDS (08-0459) card. The significant intensities of these peaks indicate the high crystalline quality surface of these crystallites.