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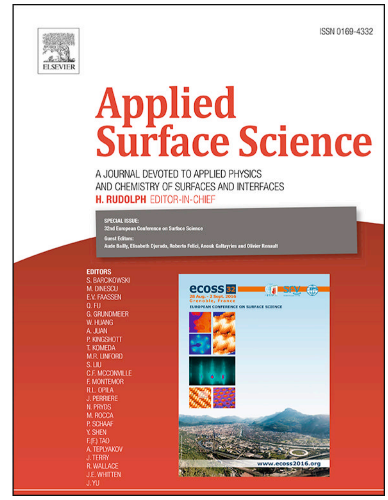

Full Length Article

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Influence of alloy engineering on structural and photo detection properties of $Sb_XSn_{1-X}Se_2$ ternary alloys

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In order to exploit effect of Sb incorporation on properties of $SnSe_2$, alloy engineering is performed in $Sb_xSn_{1-x}Se_2$ (x = 0, 0.1, 0.2, 0.3) ternary compounds. The single crystals are grown by direct vapour transport technique. The elemental composition and purity of as-grown compounds are characterized by EDAX. The optical microscopy and scanning electron microscopy show characteristic morphological features like helical spiral, layered structure, clean surface, etc. on surface of grown crystals. The powder X-ray diffraction shows that the pristine and Sb incorporated samples possess 2H-Hexahonal lattice structure. However, lattice parameters and unitcell volume are changed on incorporation of Sb in $SnSe_2$ structure due to increase in microstrain. The Raman spectroscopy reveals $SnSe_2$-type A_{1g} vibrational mode and the corresponding peak is shifted on lower wavenumber side on increasing Sb content. The results confirm substitution of Sb(+5) on Sn(+4) lattice site in host network. The influence of alloy engineering on photo response is studied. The highest photocurrent of 1.88 μA, responsivity of 43.45 mAW^{-1}, detectivity of 18.25 x 10^{11} Jones and EQE (%) of 47.28% are observed for X = 0.1 sample.

Keywords: Growth of single crystals; alloy engineering; ternary alloys;$Sb_xSn_{1-x}Se_2$; photodetector.

1. Introduction

In order to produce high performance opto-electronic devices, transition metal dichalcogenides (TMDCs) have captivated huge attention because of favourable material characteristics. Due to excellent chemical and environmental inertness, The IV-VI semiconductors having 1-2 eV band gap and strong light matter interaction are most appropriate candidates for fabrication of solar cells [1-6].One of the intensively exploited members, $SnSe_2$ has shown great potential for technical applications. In CdI_2 type hexagonal crystal structure of $SnSe_2$, Se-Sn-Se layers are stacked by weak van der Waal's interactions that allow separation of layers by exfoliation [7]. In single layer of $SnSe_2$, Sn layer is sandwiched between two Se layers that forms a stable hexagonal structure and unit cell contains planes of hexagonally close packed Se atom with the planes of Sn atoms giving the staking sequence Se-Sn-Se (X-M-X) along crystallographic c-direction of unit cell [8]. $SnSe_2$ has been identified as n-type semiconductor with high mobility of ~85$cm^2V^{-1}s^{-1}$ and current on-off ratio of 10^5, suitable for high performance field effect transistor (FET) [9].The properties can be tuned significantly by alloy engineering. This technique involves alloying of different semiconductors and doping of compound semiconductors [10-14].The electrical transport such as carrier concentration, carrier mobility, and electrical conductivity can be enhanced without altering/destroying the lattice structure [14-17]. Even semiconducting nature can be modified by substitutional doping, e.g. n-type $MoSe_2$ can be converted into p-semiconductor by doping with Nb [18] and p-WSe_2 can be converted into n-type semiconductor by doping of Sb [14].In context of layered compounds of TMDCs, intercalation can also play extensive role without altering the lattice structure. The photodetector based on TMDCs have formed strong base for intended opto-electronic devices. However, detectors based on binary alloys such as WSe_2, $MoSe_2$, $SnSe_2$, etc. are suffering from low photo response and slow switching response due to presence of deep-level-defect states (DLDS). Due to higher synthesis temperature of crystals of the binary compounds, chalcogen vacancies are created which in turn generates DLDS which act as carrier-recombination centres, which reduces the photocurrent. Due to larger concentration of defect states, response of device become slow [19].Therefore, high performance photodetector, offering significant photocurrent and fast switching action, demands the suitable material which can be produced by alloy engineering. The enhanced photo detection has been demonstrated in $Mo_{0.5}W_{0.5}S_2$ [19] and $V_{0.75}W_{0.25}Se_2$ternary alloy [10] due to suppression of DLDS and due to enhanced work function. Recently, improvement in photo-responsivity from 4.88 to 106.95 mAW^{-1} has been demonstrated for detector based on $V_XSn_{1-X}Se_2$ ternary alloys [20, 21]. Besides, the absorption of environmental oxygen on surface defects of TMDC plays crucial role in photo-detection properties. The defect concentration strongly depended on crystal growth conditions and doping concentration or alloy engineering and that substantially affects the photoresponse of the device [22].

Here in, we demonstrated the influence of cation site substitution in $SnSe_2$ on structural and photo detection properties of $Sb_XSn_{1-X}Se_2$(X = 0, 0.1, 0.2, 0.3) ternary alloys grown by direct vapour transport technique. As shown in Figure 1, the Sb (+5) (0.65 Å) can be well substituted on Sn(+4) (0.71 Å) lattice site because of their similar ionic size and Sb(+5) acts as electron donor in $SnSe_2$ unit cell [23]. To ensure the substitution of Sb(+5) in $SnSe_2$ lattice, the grown ternary alloys have been characterized by powder XRD, SEM, TEM, optical microstructure and Raman spectroscopy. The enhanced photo detection properties have been realised due to alloy engineering in $Sb_XSn_{1-X}Se_2$ (X = 0, 0.1, 0.2, 0.3) ternary alloys.