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Effects of annealing on the properties of Au–$Cd_{0.9}Zn_{0.1}Te$ contacts

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Abstract

Au–$Cd_{0.9}Zn_{0.1}Te$ contacts were annealed for 10 min at 100, 200 and 300 °C, respectively. The effects of annealing have been analyzed with photoluminescence (PL) spectra, leakage current-bias voltage (*I–V*) characteristic and leakage current–time (*I–t*) characteristic. PL spectra indicate that there are more Au-related complexes and Cd vacancies (Zn vacancies) produced in Au–$Cd_{0.9}Zn_{0.1}Te$ contacts during the annealing. These complexes and vacancies are responsible for the decrease of leakage current, which is revealed by *I–V* measurement, because they can trap free charge and improve the recombination rate of charge effectively. The *I–V* measurement also shows that the ohmic characteristic of Au–$Cd_{0.9}Zn_{0.1}Te$ contacts is improved obviously by the annealing at 100 and 200 °C and deteriorated seriously by the annealing at 300 °C. In addition, *I–t* curves suggest that annealing can improve the stability of leakage current remarkably.

Keywords: Annealing; Au–$Cd_{0.9}Zn_{0.1}Te$ contacts; PL spectra

1. Introduction

Compound semiconductor $Cd_{1-x}Zn_xTe$ ($x = 0.1$–0.2) has attracted an increasing interest recently. It is the most promising material for room temperature nuclear radiation detectors because of its unique physical properties. Some key properties of $Cd_{1-x}Zn_xTe$ are as follows: (1) high atomic number for efficient radiation-atomic interactions; (2) large enough bandgap for high resistivity and low leakage current; (3) high intrinsic $\mu\tau$ product for effective charge carrier collection, where μ is the carrier mobility and τ is the carrier life [1]. These advantages allow $Cd_{1-x}Zn_xTe$ nuclear radiation detector work at room temperature efficiently, which avoids complicated cooling systems and, therefore, enlarges the applications of nuclear radiation detectors.

The fabrication of $Cd_{1-x}Zn_xTe$ nuclear radiation detector involves a lot of important steps and the preparation of contact is a key one. Metal contact can influence the performance of $Cd_{1-x}Zn_xTe$ detector to a large degree [2,3]. Au is regarded as the most suitable contact material for $Cd_{1-x}Zn_xTe$ [2,4]. Unfortunately, the Au–$Cd_{1-x}Zn_xTe$ contacts prepared by normal methods such as sputtering and electroless deposition face some serious problems, which worsen the performance of $Cd_{1-x}Zn_xTe$ detector seriously. The leakage current in the as-prepared contacts, for example, is at microampere level [5]. This value is somewhat high for the fabrication of $Cd_{1-x}Zn_xTe$ nuclear radiation detector with good spectral resolution and high charge collecting efficiency. It still keeps a challenge to acquire Au–$Cd_{1-x}Zn_xTe$ contacts with excellent comprehensive properties until now.

In this paper we attempted to anneal Au–$Cd_{1-x}Zn_xTe$ ($x = 0.1$) contacts following the preparation of contacts. The effects of annealing have been investigated according to the results of PL spectra, *I–V* measurement and *I–t* measurement. It will be significant for exploring a new approach to improve the properties of Au–$Cd_{1-x}Zn_xTe$ contacts.

To avoid the complexity introduced by different contact configurations, our research is focused on Au–$Cd_{1-x}Zn_xTe$ planar contacts. It is mainly because that, since planar configuration of contacts is the basic one for nuclear radiation detectors, the understanding of the specific annealing mechanism to planar contacts is also meaningful to other contacts with different configurations.

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2. Experimental details

The $Cd_{0.9}Zn_{0.1}Te$ crystal investigated in this work was grown with the modified vertical Bridgman (MB) method in our laboratory. The ingot produced in this way was cut along (1 1 1) faces with the dimension of 5 mm × 5 mm × 2 mm. The bulk resistivities of $Cd_{0.9}Zn_{0.1}Te$ wafers are at the level of 10^9 Ω cm. Before the preparation of contacts, the wafers were mechanically polished with MgO suspension and rinsed in methanol. All samples were also chemically polished in 5% bromine in methanol (Br–MeOH) for 2 min in order to remove the mechanically-damaged layer. Next they were dried by pressured nitrogen gas. Following these treatments, both faces of each wafer were sputtered with Au in a KYKY SBC-12 coating system immediately to avoid surface oxidation.

Annealing experiments were carried out at 100, 200 and 300 °C separately in a specially-designed chamber of a JGP560C sputtering system. The vacuum in this chamber was 2×10^{-4} Pa. The annealing time was 10 min.

In photoluminescence (PL) measurement, the samples were attached to the cold copper finger of a closed-cycle cryostat with grease to keep the sample temperature at 10 K. An Argon ion laser with the wavelength of 488 nm was used to excite the samples. The signals were collected and analyzed with a Triax 550 tri-grating monochrometer whose spectral resolution was better than 0.3 nm. A thermal electric cooled photomultiplier tube (PMT) was employed to detect the luminescence emitted from the samples. *I–V* characteristic and *I–t* characteristic were measured with an Agilent 4339B high resistance meter controlled by an external computer. It could reflect the slight change of current at picoampere level.

3. Results and discussions

3.1. Photoluminescence analysis of Au–$Cd_{0.9}Zn_{0.1}Te$ contacts before and after annealing

Photoluminescence (PL) measurement is used to clarify the effects of annealing on Au–$Cd_{0.9}Zn_{0.1}Te$ contacts because this technique is sensitive to perceive the energy levels of defects and impurities. The changes of energy states in the Au–$Cd_{0.9}Zn_{0.1}Te$ interfacial layer after annealing can be reflected by PL measurements effectively. Several obvious transitions are observed in the typical PL spectra, given in Fig. 1. Here, the peak centered at 746 nm, due to an exciton bound to the neutral donor, is labeled as (D^0,*X*) peak. The peak centered at 766 nm is ascribed to the donor–acceptor pair recombination (*D*,*A*) emission. With regard to the band centered at 816 nm, named as $D_{complex}$ peak, we think it is associated with some impurity-related complexes. In the Au–$Cd_{0.9}Zn_{0.1}Te$ interfacial layer, two $[Au]^{3+}$ ions can attract three Cd vacancy ions ($[V_{Cd}]^{2-}$) and compose a complex, $2[Au]^{3+}$–$3[V_{Cd}]^{2-}$. In our opinion, this Au-related complex is responsible for $D_{complex}$ peak. The broad structure of $D_{complex}$ peak is due to overlapping orders of photon replicas. As shown in Table 1, $I_{D_{complex}}/I_{(D^0,X)}$, the intensity ratio of $D_{complex}$ peak to (D^0,*X*) peak, increases obviously following annealing. It indicates that the diffusion of Au in the annealing augments the amount of $[Au]^{3+}$ ions and, therefore, the amount of the $[Au]^{3+}$-related complex, $2[Au]^{3+}$–$3[V_{Cd}]^{2-}$. In fact, the $[Au]^{3+}$-related complex can act as the trapping center, which increases the recombination rate of charges. Accordingly, annealing is beneficial to the reduction of the leakage current. *I–V* measurement in Section 3.2 supports this viewpoint strongly. In addition, $I_{(D,A)}/I_{(D^0,X)}$, the intensity ratio of $D_{(D,A)}$ peak to (D^0,*X*) peak, is also improved by annealing. We think that $D_{(D,A)}$ peak is closely related to Cd or Zn vacancy ($[V_{Cd}]^{2-}$ or $[V_{Zn}]^{2-}$), which is a shallow energy level and possibly acts as an acceptor of DAP in the Au–$Cd_{0.9}Zn_{0.1}Te$ interfacial layer. Actually, annealing can augment the amount of $[V_{Cd}]^{2-}$ or $[V_{Zn}]^{2-}$ distinctly, which is analyzed in detail in Section 3.2. Hence it is the increasing $[V_{Cd}]^{2-}$ or $[V_{Zn}]^{2-}$ that brings the improvement of the intensity of $D_{(D,A)}$ peak. More evidences are required to validate this viewpoint.

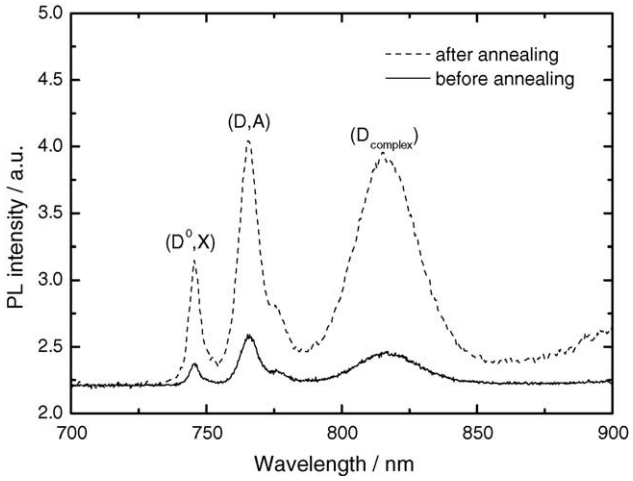

Fig. 1. Typical PL spectra of Au–$Cd_{0.9}Zn_{0.1}Te$ contacts.

3.2. Effect of annealing on I–V characteristic of Au–$Cd_{0.9}Zn_{0.1}Te$ contacts

In our research, the leakage current was measured in the bias voltage domain of 0–600 V. The corresponding *I–V* curves before and after annealing are given in Fig. 2. As shown in this figure, annealing reduces the leakage current

Table 1
Intensity ratios of $D_{complex}/(D^0,X)$ and $D_{(D,A)}/(D^0,X)$ in the PL spectra after the annealing at different temperatures

Annealing temperature	$D_{complex}/(D^0,X)$	$D_{(D,A)}/(D^0,X)$
Non-annealing	1.043	1.080
100 °C	1.196	1.210
200 °C	1.256	1.284
300 °C	1.279	1.305