Materials Science in Semiconductor Processing 35 (2015) 66–74

Contents lists available at ScienceDirect

Materials Science in Semiconductor Processing

journal homepage: www.elsevier.com/locate/mssp

Fabrication, structural and electrical characterization of $AlNi_2Si$ based heterojunction grown by LPE

A. Ashery [a], A.A.M. Farag [b,c,*]

[a] Physics Department, National Research Center, Dokki, Cairo, Egypt
[b] Department of Physics, Faculty of Science and Arts, Aljouf University, Aljouf, Saudi Arabia
[c] Thin Film Laboratory, Physics Department, Faculty of Education, Ain Shams University, Cairo, Egypt

ARTICLE INFO

Available online 19 March 2015

Keywords:
LPE
$AlNi_2Si$
I–V
C–V
Abrupt heterojunction

ABSTRACT

This work elucidates the applicability for Liquid-Phase Epitaxy (LPE) to grow epilayers of $AlNi_2Si$ on single crystalline Si with a good crystalline quality and low series resistance. Surface morphology and crystalline structural characteristics of the heterojunction were characterized by scanning electron microscopy (SEM) and X-ray diffraction (XRD), respectively. Temperature dependence of the current–voltage (*I–V*) characteristics is studied to elucidate the predominant conduction mechanism in the temperature range 305–370 K. Heterojunction parameters such as ideality factor, series resistance, barrier height show temperature dependence in the desired temperature range. Cheung functions are applied for determination the heterojunction parameters and compared with each other. Temperature dependence of capacitance–voltage (*C–V*) characteristics was considered. The built-in potential, net carrier concentration, maximum barrier height, maximum barrier field and the width of the depletion region obtained from the *C–V* measurements were studied as a function of temperature.

1. Introduction

Recently, there are many preceding technologies, particularly in electronic and optoelectronic devices need thin films of materials with particular optical and electrical characteristics [1]. Such characteristics are established by assembly combination of different physical parameters and the structural characteristics of selected materials and structures. Alloys are one of the prospective their layer materials [2] and a major role of this type of materials in the field of industry, medicine and scientific applications such as optoelectronics [3].

Moreover, there has been considerable interest in heterojunction devices. Heterojunction alloys have improved for device applications due to the lattice—mismatch to Si-substrate [4]. In addition, heterojunction devices have great increasingly role in optoelectronic applications [5]. Production of this type of materials is paid by using a combination of different band gap energies of semiconductors under condition of closely lattice parameters matching [5,6]. This achievement can be produced by epitaxial growth on single-crystalline substrates [6–8].

Various methods for epitaxial growth on crystalline substrates such as vapor phase epitaxy (VPE) [9], chemical vapor deposition(CVD) [10], metal organic chemical vapor deposition (MOCVD) [11], molecular-beam epitaxy (MBE) [12] and liquid-phase epitaxy (LPE) [13] are mainly used for semiconductor compounds.

In LPE, a substrate is brought into contact with a saturated solution of the film material at an appropriate temperature and the substrate is then cooled at a suitable

* Corresponding author at: Department of Physics, Faculty of Science and Arts, Aljouf University, Aljouf, Saudi Arabia. Tel.: +20 2 226979854; fax: +20 2 22581243.
E-mail addresses: alaafaragg@gmail.com, alaafaragg2014@hotmail.com (A.A.M.Farag).

http://dx.doi.org/10.1016/j.mssp.2015.02.052
1369-8001/

rate to lead to film growth [14]. The main advantage characteristics of LPE are the suitability for crystal growth for the preparation of a wide range of binary and ternary semiconductors as well as quaternary alloys semiconductors. Moreover, the introduction of impurities can be strongly reduced as well as doping can easily be achieved by the addition of dopants [14,2]. In addition, the other characteristics are less expensive method and higher deposition rates, low defect concentration and excellent control of stoichiometry [2,15].

In our series of publications [16–19], we have studied the structural and electrical characteristics of heterojunctions prepared by LPE. Indeed, we have determined various electrical parameters that control the heterojunction mechanism for the applicability for optoelectronics. To the best of our knowledge, there have been little reports in this regard.

In this study, $AlNi_2Si$ epilayer is grown by LPE on single crystalline Si substrate to form $AlNi_2Si$/Si heterojunctions. In addition, *I–V* characteristics of Au/$AlNi_2Si$/Si/Al heterojunctions is investigated and attempted to determine the predominant conduction mechanism. The main heterojunction parameters such as barrier height, ideality factor and series resistance are also estimated. Various electrical parameters such as built-in potential, effective carrier concentration and others are also obtained from *C–V* characteristics.

2. Experimental procedures

2.1. Wafer etching and cleaning

Single crystalline wafers of p-type Si with resistivity of $\approx 10\ \Omega$ cm was obtained from Nippon Mining Co. Pieces of area $\approx 1\ cm^2$ for each and 500 μm thick were etched by using the CP4 solution ($HF:HNO_3:CH_3COOH$ in ratio 1:6:1) for 10 s to remove the native oxide [20]. After etching, the p-Si wafers were immersed and washed with distilled water followed by ethyl alcohol and finally dried.

2.2. LPE technique

To perform the LPE operation, a special hardness graphite slider boat was used to grow epitaxial layers of $AlNi_2Si$ on crystalline p-Si substrates. Cleaned p-Si substrates were placed inside the slider and the whole unit was transferred into the silica tube furnace. The silica tube has a purified argon gas and flow passed through the tube to prevent surface oxidation of the substrate and removing oxides from the surface during the operation [13]. Process of LPE technique is described in further detail elsewhere [6]. A thermocouple is fixed under the boat through the LPE process. Growth solution contained indium as a solvent for $AlNi_2Si$ pieces due to its low melting point and high solubility provided for beneficial electrical properties [16]. The loaded boat was heated up to 1073 K and kept at this temperature for 30 min to homogenize the solution. The surface of the substrate Si was smooth and contained no pores and then the probability for the mechanism of growth is outward diffusion of Si. Moreover, the outward grown coating provided a better resistance to oxide spallation [21]. The liquid cooled down with a slow cooling rate of 0.5 K/min for depositing $AlNi_2Si$ layers on Si and kept constant for 30 min to improve the growth quality.

The diffusion will always cause vacancy in the substrate, which will influence the electrical performance heavily. The vacancies induced defects that are so called as oxide charges ,could introduce new energy states in the oxide band gap similar to the hole doping which eventually act as leakage paths of charge carriers thus increasing the leakage current [22].

2.3. Characterization techniques

X-ray diffraction measurements have been taken by using analytical Philips PW/1710 diffractometer by using Ni filter and Co K_α radiation (1.78897 Å) with $2\theta = 30–90°$.

Scanning electron microscope model JOEL14775 was used to study the surface morphology of the $AlNi_2Si$/Si heterojunction.

Ohmic contacts of gold (Au) and Al were deposited on $AlNi_2Si$ and p-Si, respectively, by thermal evaporation under a vacuum of 10^{-4} Torr. The schematic diagram of the fabricated heterojunction is shown in Fig. 1.

To measure the electrical properties of the heterojunctions, electrical contacts were equipped with copper wires mechanically applied to the two metal electrodes using thermosetting silver paint. The current flowing through the sample was determined using a stabilized power supply and a high-impedance Keithley 617 electrometer. Electrical properties were performed in dark over the temperature range 305–375 K. The temperature was measured directly by means of chromel–alumel thermocouple connected to hand-held digital thermometer. Dark *C–V* measurements were performed at different temperatures using a computerized capacitance–voltage system consisting of *C–V* meter (model 4108, Solid State Measurement, Inc., Pittsburg).

3. Result and discussion

3.1. Morphology and crystalline structural characterizations

Surface morphology and microstructure of the AlNiSi/Si heterojunction prepared by LPE were analyzed by SEM and shown in Fig. 2(a) and (b) with two different magnifications of 2000× and 3500×, respectively. Grains of different sizes and shapes which inhomogeneously distributed over the entire surface of the sample are observed.

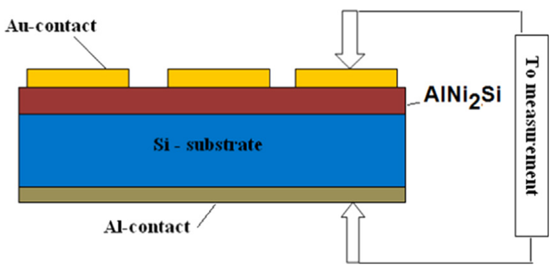

Fig. 1. Schematic diagram of Au/$AlNi_2Si$/Si/Al heterojunction.