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Materials Today: Proceedings 3 (2016) 1271 – 1276

International Semiconductor Science and Technology Conference 2015 (ISSTC 2015)

Temperature dependence of current-voltage characteristics of Al/rubrene/n-GaAs (100) Schottky barrier diodes

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Abstract

5,6,11,12-tetraphenylnaphthacene (rubrene) is fabricated by spin coating technique on n type GaAs (100) substrate. The current-voltage (I–V) characteristics of Al/rubrene/n-GaAs (100) Schottky diode have been measured in the temperature range of 100–300 K. The experimental values of saturation current (I_0), ideality factor (n) and barrier height (Φ_B) are calculated as 2.749 pA, 6.051 and 0.297 eV at 100 K and 57.54 pA, 1.918 and 0.870 eV at 300 K, respectively. The values of series resistance (R_S) are calculated using Cheung functions at all temperatures. The R_S values are found as 1276.4 Ω and 119.7 Ω for 100 K and 300 K, respectively. It is found that barrier heights increased while ideality factors and series resistances decrease with the increasing temperature.

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Keywords: Schottky diode; rubrene thin film; spin coating; series resistance.

1. Introduction

Gallium arsenide (GaAs) is a direct band gap semiconductor and used in solar cells, laser diodes, field effect transistors (FETs), light emitting diodes, lower power and high frequency applications [1-10]. The explosive growth of present day technologies owes much to GaAs based devices. For the past years, much interest has been focused on

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doi:10.1016/j.matpr.2016.03.070

the modified GaAs Schottky diodes by reducing the interaction between metals and GaAs by organic interlayers such as copper phthalocynanine [11], rhodamine 101 [12], pyronine G(Y) [13], perylene monoimide [14], pentancene [15] and MEH-PPV [16].

The interface quality between metal and semiconductor surface has considerable influence on performance and reliability of Schottky barrier diodes [17-21]. The current–voltage (*I-V*) characteristics of Schottky diodes deviate significantly from linearity at high voltages and low temperatures due to the effect of the density of surface states and series resistance (R_S). It was also observed that an increase of barrier height (Φ_B) and a decrease in the ideality factor (n) with the increasing temperature for Schottky diodes in literature [12-17, 19, 21]. Furthermore, the presence of the interfacial layers (such as SiO_2, SnO_2, organic compound) strongly influence the electrical characteristics of Schottky structures [1, 17, 19, 21, 22]. Determination of barrier height (Φ_B) ideality factor (n) and series resistance (R_S) parameters according to temperature changes give us more detailed information about current conduction mechanisms of the Schottky structures. Although many studies have been performed on organic layer/n-GaAs Schottky diodes by means of current–voltage measurements [11-16], the detail information on main electrical parameters of organic layer/n-GaAs Schottky diodes has not been clarified yet. The organic layer/GaAs Schottky barrier diodes may have an important role in the semiconductor technology in recent years. Therefore, the study of the electrical properties of organic layer/n-GaAs is of great interest.

Because there are no reports dealing with the electrical characteristics of rubrene/n-GaAs structure, the present study deals with the design and characterization of the new type Schottky diode having configuration of Al/rubrene/n-GaAs. For this purpose, analysis of the *I-V* characteristics of Al/rubrene/n-GaAs Schottky diode has been performed between 100 and 300 K to clarify the origin of the anomalous behaviour of temperature dependence of the Schottky diode parameters such as the n, Φ_B and R_S.

2. Experimental procedure

The n-type GaAs (100) substrate used in this study has a 500 μm thickness and 20 Ω cm resistivity. Initally, the substrate has been cleaned in methanol and acetone using ultrasonic agitation for 3 min. and rinsed in deionized water (18 MΩ). First, the GaAs substrate was cleaned using the RCA cleaning method [14]. Ohmic contact with low resistance is made by evaporation of indium (In, 99.99%) metal with thickness of 150 nm in 5×10^{-6} Torr on the backside of the GaAs substrate and then by thermal annealing at 400 ºC for 2 min in vacuum. A rubrene organic film is prepared on the GaAs substrate by the spin coating technique with a Laurell Spin Coater. The chemical structure of rubrene is given in Fig. 1a. Later, Schottky contacts are prepared on rubrene organic film with a diameter of 2 mm by a metal shadow mask by evaporating aluminium (Al, 99.999%) metal with thickness of 150 nm in 5×10^{-6} Torr. The schematic representation of the device is shown in Fig.1b. The preparation of sample has been done in MBraun glovebox maintained nitrogen inert gas. The rubrene layer thickness is determined as 116.1 nm from measurement of the interfacial layer capacitance in the accumulation region. The current-voltage (*I-V*) measurements were performed by a Keithley 2410 SourceMeter at temperature range from 100 to 300 K using an ARS Closed Cycle Cryostat Model DE202 AI and a Lake Shore model 331 temperature controller.

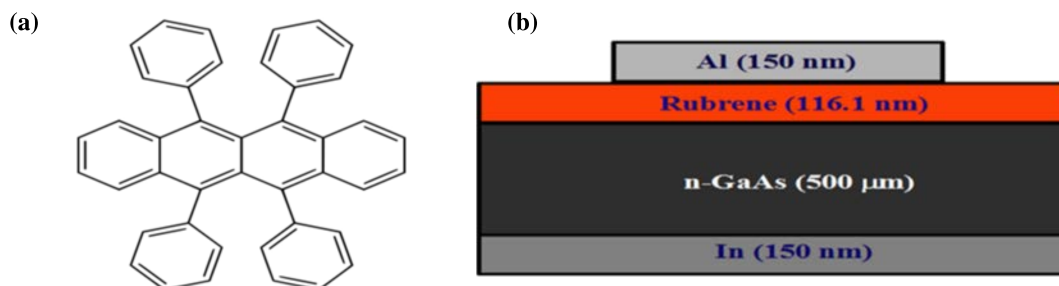

Fig. 1. **(a)** Molecular structure of rubrene organic compound, **(b)** Cross-sectional view of Al/rubrene/n-GaAs Schottky diode.

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