Two-terminal device based on white-light emitting in GaAs single layer

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1. Introduction

In recent years much attention has been given to the theory of the abrupt first-order metal-insulator transition. The LED (Light Emitting Diode) is notice begin to next generation by light source in the industrial world. Its materials are semiconductor materials contain to inorganic and organic matters. The Red, Blue, and Green LEDs make to multi-layer structure of GaP systems, GaAsP systems [1-3], and GaN systems [4-5]. A GaAsP system's LED is known to the yellow or red light emitting by junction with GaP, ZnO and a GaN system's LED is blue [6-8]. Since, GaAs p-n junction diodes reported on MESFET (Metal Epitaxial Semiconductor Field Effect Transistor) [9] which is caused by electronhole recombination and MOSFET (Metal Oxide Semiconductor Field Effect Transistor) [10] can be controlled by the bias applied to the n-, p-type GaAs layers and oxide layer. However, it efficient electroluminescence diodes and transistors have many questions about growth method, light emitting time, and temperature dependence of light emitting length. We reported on electrical and structural properties of epitaxial p-type GaAs thin film using MBE (molecular beam epitaxy) [11]. It shows control of abrupt current-jump induced by voltage, temperature, and light based on the first-order Mott metal-insulator transition (MIT) not accompanied with a structural phase transition (SPT) [12-14]. In I-V measurement on a two-terminal device, we observed a white-light emission (WLE) at junction section (or boundary) by metal-electrode and thin film. A WLE in GaAs material was reported on p-n junction diode status by Zn-doped GaAs (p-type) with Si-doped GaAs (ntype) layers [15-16]. It shows general I-V characteristic at room temperature and the WLE by the electron drift induced by free electrons in conduction band. However, a white-light emitting device (WLED) based on p-type GaAs single layer has different mechanism about light emitting as previous p-n junction diodes and transistors. First, it is just a single layer of p-type GaAs thin film on semi-insulating GaAs substrate, and a two-terminal device consist of metal-electrode and localizationthin film based on Ohmic contact. A WLE begins observe before MIT, it is apparent to the naked eye after MIT as metallic region. Thus, a WLED is electron-electron collision in metal-electrode and

localization thin film boundary induced by the abrupt current-jump. Above all, the emission is observing forward bias boundary then spreading to reverse bias boundary in applied electron field, and it is dependence of film thickness and hole concentration. As film thickness and carrier density increases as light intensity increases. In this paper, we demonstrate a WLE in p-type GaAs thin films and relationship with the MIT. The MIT characteristics can be control by temperature, voltage, and light intensity. While, a WLE is control by isolation thin film sizes, thickness, and carrier concentrations. A WLED's practical application is quantum dot laser source, various light fixtures, and photo-diodes.

2. Experiments and Results

We grew epitaxial Be-doped GaAs thin films on Semi-insulating GaAs (001) wafers at a substrate temperature of $T_s=560$ °C by MBE (RIVER, compact21). The growth velocity was 3 Å/s. The film thickness was approximately 300 nm. The hole concentrations doped in the Be-doped GaAs films were $\sim 3.0 \times 10^{16} \sim 2.0 \times 10^{18}$ cm⁻³. This was estimated by Hall measurements at room temperature. Through RHEED (reflection high energy electron an diffraction) and an X-ray diffraction analysis, it was found that GaAs film had an epitaxial growth and a zinc-blend structure. For the device fabrication, the film was selectively etched by the RF ion milling technique and wet-etching using HNO₃:H₂O =1:2 in order to isolate the current channel. Using the lift-off method and the RF magnetron sputtering technique, ITO (Indium-Tin-Oxide) transparent electrodes were patterned and formed on the etched film. Figure 1 shows a light intensity measurement of a WLED as applied constant currents based on I-V curve (Vmode) with a hole concentration of 2.0×10^{18} cm⁻³. We compared to association with metal-insulator transition (MIT) and a WLE. It shows the first-order Mott MIT at room temperature and when the current of 4 mA flows on thin flim, MIT is observe. However, an emission is beginning around 2 mA as shown in Fig 1(a). As shown in Figs. 1(b) and 1(c), a light intensity is abrupt increases after MIT and apparent to the naked eye from 4 mA. The hole-driven MIT induced is caused by the hole density excited by electric field [11, 17-18], while a WLE is caused by the electron(1)-electron(2) collision within injunction electron(1) by applied electric field and metalelectrode electron(2). We reported on the MIT of ptype GaAs with low-doping level [11], the current jump is observed micro-ampere region, so a WLE can't be observation. While, in this case of highdoping level, the current jump width are increases and a WLE observation simultaneously.



Fig. 1 The *I-V* measurement at room temperature vs a WLE of intensity of p-type GaAs thin film with a hole concentration of 2.0×10^{18} cm⁻³. (a) Intensity at 2 mA before MIT, (b) Intensity at 4 mA just before MIT, (c) Intensity at 15 mA after MIT.



Fig. 2.(a) A wavelength measurement of a white-light emitting with a diameter 300 $\mu m.$ A GaAs thin film of hole concentration is $2.0{\times}10^{18}\,{\rm cm}^{-3}.$

Figure 2 shows a WLED of wavelength measurement using spectrometer in a light intensity of 500 nW. It shows a wavelength of widely a white light region. A LED of white light is known to a mixture of red-LED and green-LED or change of color by phosphor. Recently, a white LED reported on n-type ZnSe/ZnCdSe multilayer structures. However, the ZnSe-based a white LED utilizes a phenomenon unique to ZnSe homoepitaxial structures grown to on conductive ZnSe substrates, and the multilayer's thickness control is difficult processor. Thus, ZnSe-based a white LED is consist of the greenish-blue emission (480~490 nm) from the active layer of a p-n junction diode and the selfactivated emission from the substrate near 585 nm [19-20]. A WLED shows a white-light emission of a wavelength of 500~800 nm from the p-type GaAs single layer without junction and heterosturcture.

3. Conclusions

The two-terminal based on p-type GaAs single layer shows a white-light emission (WLE) with a wavelength of 500~800 nm in visible ray. The light intensity can be control by isolation size of film, thickness of film, and carrier concentration. Furthermore, a WLED can be applied as quantum dot laser source, various light fixtures, and photo-diodes.

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