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ELECTROLUMINESCENCE STUDY OF InP/InGaAsP/InAs/InP P-I-N LASER HETEROSTRUCTURE

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ABSTRACT

MBE (Molecular Beam Epitaxy) grown p-i-n laser heterostructure, based on InAs/InP Quantum Dashes with quaternary InGaAsP Quantum Well, were investigated through electroluminescence (EL) measurements. Bipolar injection set on just of forward bias,V_F, ≅1.3 V, resulting an emission of long wavelength laser light, peaking of 1550 nm. This value was consistent with thermal energy band gap, deduced from current-voltage measurement in space charge limited regime where mobility of injected carriers followed Poole-Frenkel type conduction.
Keywords: EL, quantum dashes, and annihilation.

INP/INGAASP/INAS/INP LAZER HETROEKLEM P-I-N YAPININ ELEKTROLÜMINESANS ÇALIŞMASI

ÖZ

InAs/InP lazer heteroeklem p-I-n yapısı MBE yöntemiyle üretilmiş ve elektrolüminesans ölçümüyle incelenmiştir. Farkli iki tür yük taşıyıcısının rekombinasyonu yaklaşık olarak düz beslemenin 1.3 volt değerini aştığı gerilimde gerçeklemiş ve neticesinde dalga boyunun tepe noktası 1550 nm noktasında olan lazer ışığı emisyonu gözlenmiştir. Elde edilen değer, uzay yükü sınırlamalı akım-gerilim ölçümlerinden elde edilen aktivasyon enerji değeriyle örtüşmektedir. Ayrıca, bu bölgedeki yüklerin mobilitesi Poole-Frenkel türündendir.
Anahtar Sözcükler: EL, kuvantum noktası, rekombinasyon.

1. INTRODUCTION

Long wavelength (1.3 and 1.55 μm) semiconductor laser diodes in p-i-n heterostructure have attracted much attention in recent years. The semiconductor laser with p-i-n heterostructure consists of doped InP cladding layers and InGaAsP injector quantum well (QW) separated by a thin InP barrier from InAs elongated quantum dots (known as quantum dash, QDash). The structure is sandwiched in between cladding layers, forming p-i-n laser heterostructure. Overall,

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by designing InP/InGaAsP/InAs/InP structure, a laser light is seeking for emission of 1.55 µm at room temperature. The working principle of such tunnel injection (TI) structure is that injected carriers from the cladding layers are captured by a quantum well (injector) and subsequently tunnels from QW to QDash though a thin InP layer and finally radiatively recombine in QDash. As a consequence of that 1.55 µm (0.8 eV) laser emission is achieved [1-8]. Within this context, transportation of electrons and holes though QW and QDash and finally meeting in QDash where annihilation occurs can be studied though electro-optical system like electroluminescence (EL) measurement. Because in EL measurement, opposite kind charge carriers are injected from the contacts (front and back) into the active region of device in which recombination occurs and light is produced from radiative recombination.

In this work, InP/InGaAsP/InAs/InP p-i-n laser heterostructure was investigated though EL measurement to further verify the recombination issue in QDash by current-voltage measurement [9]. The onset of luminance was observed for the forward bias greater than 1.35 V and the emerged light had a peak wavelength at 1550 nm: the former corresponded to bandgap of InP film while the latter was attributed to bandgap energy of QDash layer (InAs film) where light electron-heavily hole transition took place by radiative recombination, hence produced a laser light operating at 1550 nm.

2. EXPERIMENT

The present InP/InGaAsP/InAs/InP structure was built though molecular beam epitaxy (MBE) system in form of p-I-n diode. Thickness of each layer was 165, 354 and 1000 nm, respectively. Details of the growth conditions is given elsewhere [9]. EL measurements were carried out by using Keithley 2400 voltage/current source meter, equipped with a Oriel Cornerstone 260 monochromator and InGaAs photodiode, produced by ThorLabs.

3. RESULT AND DISCUSSION

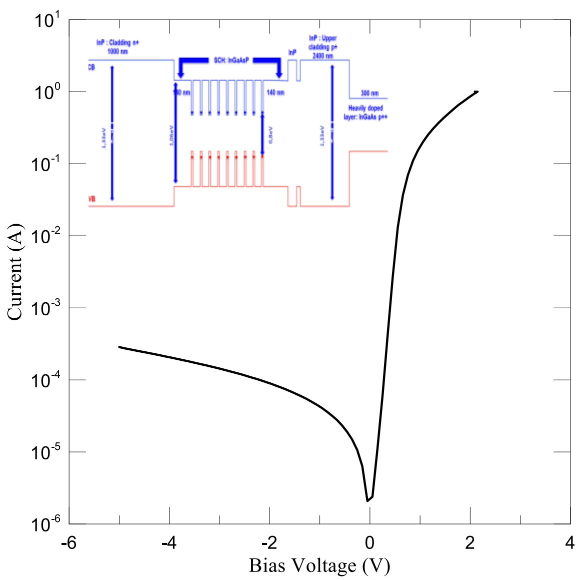

Figure 1. Current-voltage measurement on InP/InGaAsP/InAs/InP p-i-n laser heterostructure at room temperature. The inset shows the schematic band diagram of the structure.

Fig.1 shows dark current-voltage measurement on the structure at room temperature in both reverse and forward bias conditions. It is obvious that diode (rectifying) property is eventual. Moreover, in here and temperature dependent current -bias voltage measurement (not shown) approved that the bias greater than 1 V was attributed to space charge limited regime in which carrier transport within InP/InGaAsP/InAs/InP p-i-n laser heterostructure was Poole-Frenkel type hopping transport and recombination current mechanism that took place in QDash with a thermal energy gap as 0.8 eV (1.55 µm). In this respect, this study can be considered as complementary work to further verify the recombination issue in QDash by electroluminescence measurement (EL). Fig.2 displays the EL measurement performed at room temperature under forward bias voltage (2 V) condition. As shown in Fig. 2, the onset of light begins around 1.3 V and becomes sharper with increase in forward bias and finally saturates for the bias voltage around 4 V. The emerged light from p-i-n heterostructure was collected and directed to the entrance slit of monochromator by using lenses.

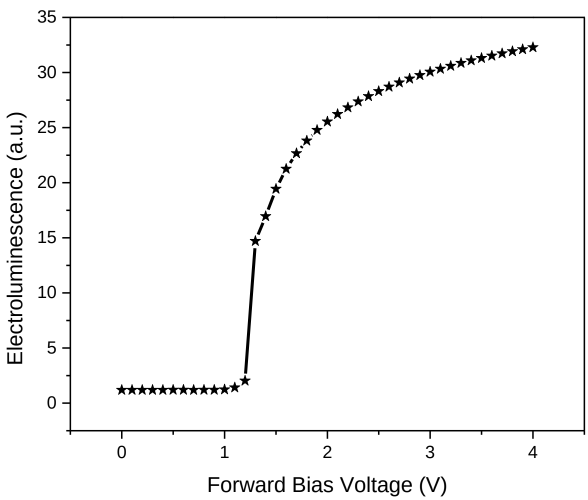

Figure 2. EL measurement on InP/InGaAsP/InAs/InP p-i-n laser heterostructure at room temperature.

At the exist slit, InGaAs photodiode is used to detect the wavelength dependence on light shines on the photodiode. Therefore, wavelength dependence of the light is characterized and illustrated in Fig. 3. Clearly, the light has a peak value of 1550 nm that corresponds to 0.8 eV energy. This value was attributed to radiative recombination of light electron-heavy hole transition and consistent with other values in literature [1-8], surveyed though photoluminescence, photoreflectance and PL excitations. Furthermore, it coincides with the previous work [9].

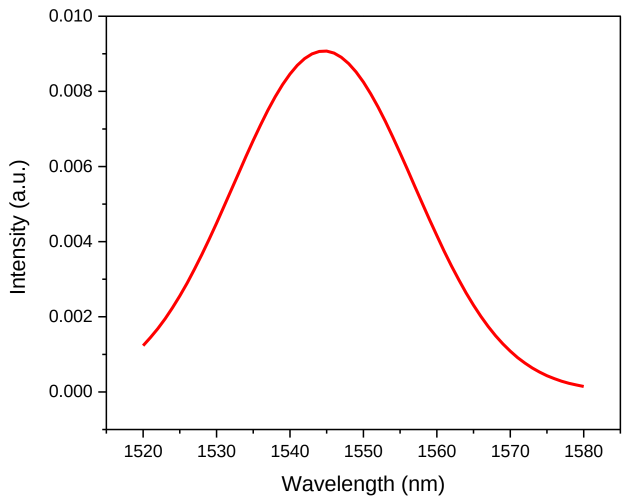

Figure 3. Wavelength dependence of light produced from InP/InGaAsP/InAs/InP p-i-n laser heterostructure.

4. CONCLUSION

Radiative recombination of electron hole carrier, injected from the cladding layers into active region in p-i-n laser heterostructure annihilated within QDash (InAs), yielding emission of laser light at 1550 nm and approved by electroluminescence measurement equipped with a monochromator.

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