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Electroluminescence Measurement of n Self-Aligned GaAs MESFETs

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1. Introduction

It is very important to realize a high-breakdown-voltage GaAs FETs for power application. However, electroluminescence (EL) signal has been reported at the gate-drain region at a large drain voltage [1,2]. The impact ionization at the drain edge in the channel has been pointed out as the origin of these phenomena. In the recent study of InAlAs/InGaAs HEMTs, the EL due to electron-hole recombination comes from a region between the source and gate metals [3]. It has also been reported that high-energy luminescence came from drain region [4]. In the GaAs MESFET, however, there is no report which studies the spatial distribution of the EL with wide energy range of 1.4 - 2 eV.

In this report, we have successfully observed EL spatial distribution for luminescence energy of 1.4 - 2.4 eV. It has been found that the spatial distribution of the EL intensity is dependent on the luminescence energy.

2. Results

We measured the EL of the n^+ self-aligned GaAs MESFETs at room temperature. The spatial distribution was studied using microscopic luminescence measurement system with minimum spatial resolution of about 1 μm. The schematic cross section of the measured GaAs MESFETs fabricated by the ion implantation is shown in Fig. 1.

Figure 2 shows the EL spectrum at V_{DS}= 8.5 V and V_{GS} = 0 V. The luminescence was collected from all surface area of the MESFET by opening a spatial slit. Considering the GaAs band gap of 1.424 eV at 300 K, the peak at about 1.4 eV is attributed to the direct recombination of the holes generated by impact ionization with majority electrons in GaAs channel. The broad luminescence was also observed in the high-energy region between 1.6 and 2.6 eV.

Figure 3 shows the EL spatial distribution for various luminescence energies at V_{DS} = 8 V and V_{GS} = 0 V. The measurement was performed in the configuration that the source, gate, and drain metals cover regions $x < -1.5$ μm, -0.5 μm $< x < 0.5$ μm and 2 μm $< x$, respectively. The EL peak with band gap energy was observed at a region between the source and gate metals. This indicates that parts of holes generated by the impact ionization are distributed between the source and gate metals in the channel without plunging into gate electrode, and cause the luminescence by recombining the majority electrons. The luminescence observed under the gate electrode is probably due to the finite spatial resolution of about 1 μm. The EL with energy higher than the bandgap, on the other hand, was observed on the drain-side edge of the gate metal. It is well known that the high electric field exists on the drain-side edge of the gate metal and the impact ionization occurs there. The FWHM of high-energy peak is narrower than that of luminescence with band gap energy. This suggests that luminescence mechanism is different between the two luminescences at source-gate and gate-drain regions. Taking a fairly long recombination lifetime of about 1 ns into account, the high-energy EL is not probably due to the electron-hole recombination but due to the intraband transition of the single kind carrier [4,5].

Figure 4(a) shows the EL spatial distribution at 2.0 eV for the electrode arrangement that the source, gate, and drain metals cover regions $x < -1.5$ μm, -0.5 μm $< x < 0.5$ μm and 2 μm $< x$, respectively. The EL distribution shown in Fig. 4(b) was obtained after exchanging the source and drain positions with each other. The EL spatial distribution shows that the high-energy (2.0 eV) EL is observed on the drain-side edge of the gate metal for both arrangements. This means that the high-energy EL is not caused by the structural inhomogeneity but by the high field at the drain region.

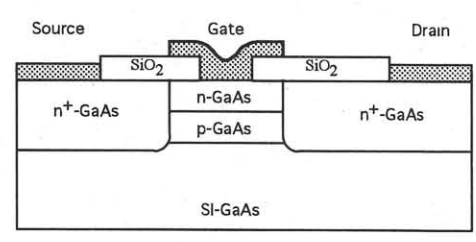

Fig. 1 The schematic cross section of the measured GaAs MESFETs.

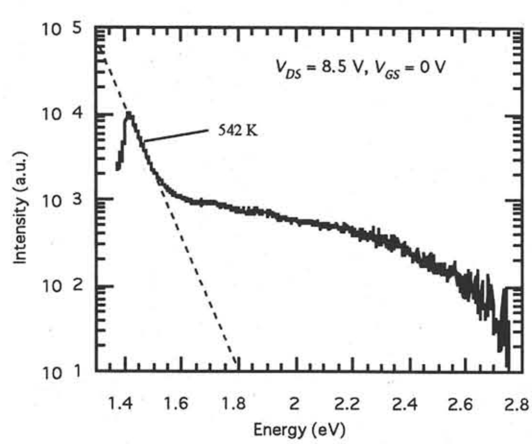

Fig. 2 The EL spectrum at V_{DS} = 8.5 V and V_{GS} = 0 V.

Figure 5 shows the micro-EL spectra obtained by collecting the luminescence from small area of 1 μm diameter between source-gate and drain-gate metals. It is possible to minimize the effects of luminescence from other region by the micro-EL. The measurement was performed at V_{DS} = 8.5 V and V_{GS} = 0 V. The two spectrum shows completely different shape. The EL from the source side has only the low-energy component. On the other hand, the EL from the drain side has a wide range spectrum from 1.4 to 2.0 eV. It is necessary to consider the spatial distribution when we discuss the carrier behavior using EL spectrum. When the carrier temperature is derived using luminescence intensity integrated on the whole device surface, for instance, it may have some error when the EL spectrum is dependent on the device position. The carrier temperature obtained from the integrated intensity is 542 K as shown in Fig. 2, which is higher about 100 K than that obtained from the luminescence spectrum at region between the source and gate (Fig. 5).

3. Conclusions

We have measured the electroluminescence of n^+ self-aligned GaAs MESFETs. It has been found that the spatial distribution of the EL intensity is dependent on the luminescence energy. The low-energy luminescence which is caused by electron-hole recombination was observed on the source side, whereas the high-energy one was observed on the drain-side edge of the gate metal. It is necessary to consider the position-dependent EL spectrum when we discuss the carrier behavior using the EL spectrum.

References

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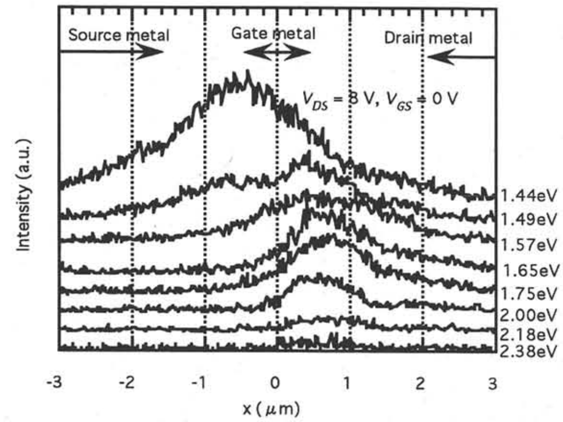

Fig. 3 The EL spatial distribution for various luminescence energies at V_{DS} = 8 V and V_{GS} = 0 V. The measurement was performed in the configuration that the source, gate, and drain metals cover regions $x < -1.5$ μm, -0.5 μm $< x < 0.5$ μm and 2 μm $< x$, respectively.

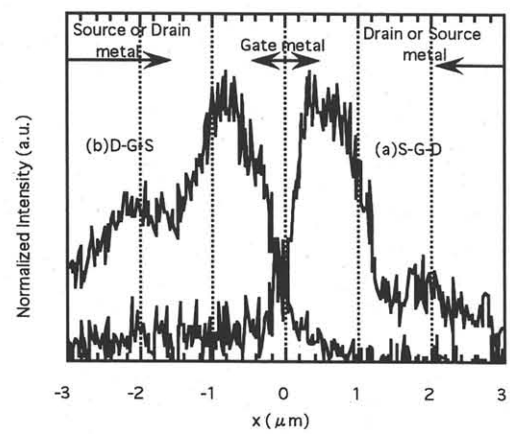

Fig. 4 The spatial distribution of 2.0 eV luminescence measured for two different arrangements that the source, gate, and drain metals cover regions (a)$x < -1.5$ μm, -0.5 μm $< x < 0.5$ μm and 2 μm $< x$, and (b)2μm $< x$, -0.5 μm $< x < 0.5$ μm and $x < -1.5$ μm, respectively.

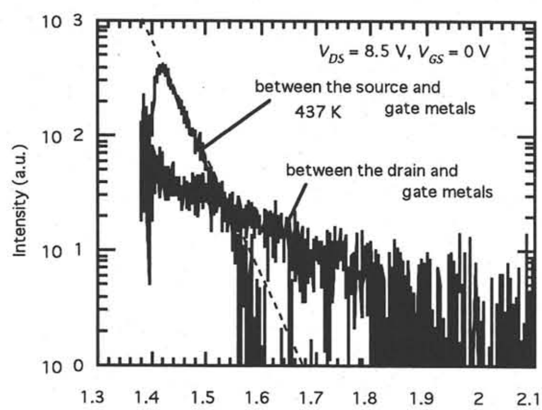

Fig. 5 Micro-EL spectra for regions between the source and gate metals, and between the gate and drain metals at V_{DS} = 8.5 V and V_{GS} = 0 V.