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Investigation of GaAs MOSFETs with Gate Oxide Grown Using Photoelectrochemical Oxidation Method

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Abstract- In this work, photoelectrochemical oxidation method was used to directly grown gate oxide of GaAs metal-oxide-semiconductor field effect transistor. The I_{DS}-V_{DS} and g_m-V_{GS} characteristics of the GaAs MOSFETs were measured. For biasing at V_{DS}=2.4V and V_{GS}=0V, an output current density of 101mA/mm was obtained. The associated extrinsic transconductance of the GaAs MOSFETs was 65mS/mm.

1. Introduction

Since there is no reliable oxide layer in the III-V compound semiconductors, the GaAs metal-oxide-semiconductor field effect transistors (MOSFETs) can not be fabricated and applied in systems. To reduce leakage current, increase high breakdown voltage, and operate at high temperature, metal-oxide-semiconductor (MOS) devices have been widely investigated. In previous reports, a number of dielectrics such as Al_2O_3[1], SiO_2[2] and $Ga_2O_3(Gd_2O_3)$[3] have been used in the MOS structures. However, these dielectrics were deposited by external deposited methods. Therefore, the properties of the external deposited oxide were inherently affected by the contaminant on the samples and the deposition conditions. In this work, we used photoelectrochemical (PEC) oxidation method to directly grow oxide layer on GaAs as the gate oxide of GaAs MOSFET. The resultant GaAs MOSFETs were fabricated and the electronic characteristics were measured.

2. Experimental procedure and results

PEC oxidation procedure and results

Recently, photo-enhance wet etching (photoelectrochemical etching) method was widely used to etch GaAs samples [4]. The PEC etching process includes two steps of oxidation and oxide dissolution. If the oxidation rate is faster than oxide dissolution rate, the oxide layer would be resulted. Therefore, oxide layer can directly be grown on the semiconductor surface. In this work, we used the system of the photoelectrochemical oxidation method to grow the oxide on the GaAs surface directly was shown in Fig. 1. In the PEC system, we used the He-Ne laser as the light source, and the pH meter to measure the pH value of the diluted HCl as the electrolytic solution. The intensity of laser and the pH value of the electrolytic solution were 5.1mW/cm^2 and 3.5, respectively. Figure 2 shows the GaAs oxide growth rate at pH=3.5 as a function of the oxide growth time. From the experimental result, we found that the growth rate of the oxide was decreased linearly with the growth time increased. It can be described that the reaction of electrolytic solution and GaAs at the bottom of the thick oxidation layer was hard to occur. This phenomenon was like the thermal oxidation of silicon.

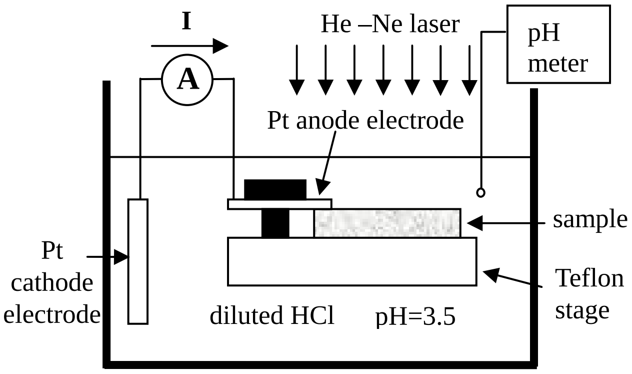

Fig. 1 The system of the photoelectrochemical oxidation method.

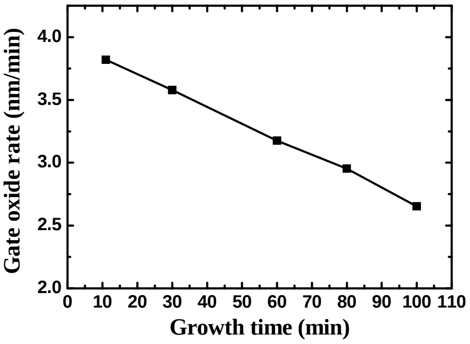

Fig. 2 The GaAs oxide growth rate at pH=3.5 as a function of the oxide growth time.

Experimental results of MOSFETs

Figure 3 shows the cross section of the GaAs MOSFETs structure. It consisted of a 400nm undoped GaAs buffer layer, a 100nm n-type GaAs (4×10^{17}cm^{-3}) as the channel layer, and finally a 40nm heavily Si-doped GaAs(2×10^{18}cm^{-3}) ohmic contact layer. After epitaxial growth, the GaAs MOSFETs were fabricated using a standard photolithography and lift-off technique. The MOSFET mesa regions ($30\times100\mu m^2$) were fabricated by using $NH_4OH:H_2O_2:H_2O$=1:1:50 to etch GaAs through the n$^+$-GaAs ohmic contact layer down to the undoped GaAs buffer layer. The patterns of the source and drain regions for MOSFETs were defined. The distance between the source and drain regions is 4μm. Prior to deposition of AuGeNi/Au (100/300nm) ohmic contact metals using electron beam evaporator, the samples were etched by using chemical solution of NH_4OH:H_2O=1:10 for 30sec to remove the native oxide on the n^+-GaAs surface. After the excess metals were removed using lift-off technique, the samples were thermally alloyed at 450°C for 3min in H_2 ambiance. By using an HP4145B semiconductor parameter analyzer to measure the transmission line patterns, the associated specific contact resistance of $4\times10^{-5}\Omega\text{-cm}^2$ was determined. The gate patterns with a length of 1.25μm and a width of 30μm was defined and aligned in the photoresist. We used the PEC oxidation method to directly grow the gate oxide on the patterning GaAs surface. The conditions of the grown gate oxide were shown in Table 1. After the gate oxide grown, the gate metal of Al/Au (100/200nm) was then evaporated and the excess metals were removed using lift-off technique.

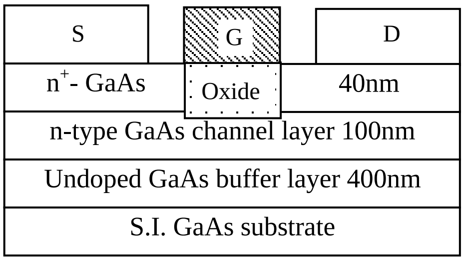

Fig. 3 The cross section of the GaAs MOSFETs structure.

Table 1 The conditions of the grown gate oxide by using PEC oxidation method.

laser intensity	pH value	growth time	thickness of the oxide
5.1mW/cm^2	3.5	11min	42nm

3. Results and Discussion

The MOSFETs performances were measured using an HP4145B semiconductor parameter analyzer. Figure 4 shows the drain-source current (I_{DS})-drain-source voltage (V_{DS}) with different gate-source voltage (V_{GS}) characteristics of the fabricated MOSFETs. For biasing at V_{DS}=2.4V, the output current was equal to 101mA/mm for the gate-source bias at V_{GS}=0V. At V_{GS}=-2.5V, the drain current was closed to zero. That is mean the MOSFETs were in a cut-off mode. Figure 5 shows the drain-source current-gate-source voltage and the associated extrinsic transconductance (g_m)-gate-source voltage characteristics of the GaAs MOSFETs. The maximum associated extrinsic transconductance is 65mS/mm at V_{GS}=-0.3V. We also measured the leakage current and the breakdown voltage of the MOSFETs, shown in Fig. 6. The leakage current was 10nA at V_{GS}=-21V. The breakdown voltage was 33.5V. From these experimental results, we can deduce that the gate oxide was grown by using PEC oxidation method have good performance.

4. Conclusions

We firstly and successfully fabricated the GaAs MOSFETs with gate oxide was directly grown by using photoelectrochemical oxidation method. Form the characteristics of I_{DS}-V_{DS}, I_{DS}-V_{GS}, g_m-V_{GS} and I_{GS}-V_{GS}, the high performance of gate oxide directly grown on the GaAs surface was obtained by using PEC oxidation method. High performances of the resultant GaAs MOSFETs were also measured and analyzed.

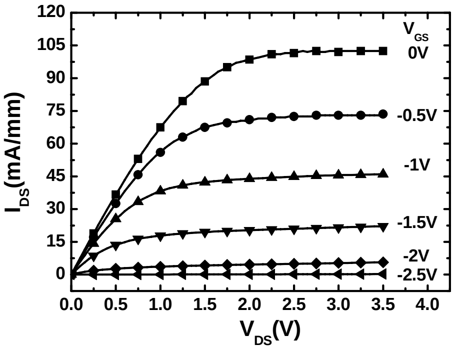

Fig.4 The I_{DS}-V_{DS} with different V_{GS} characteristics of the fabricated MOSFETs.

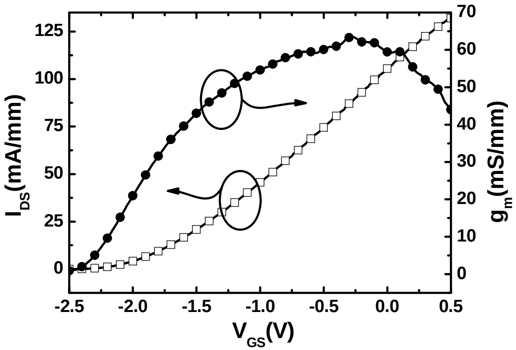

Fig. 5 The I_{DS}-V_{GS} and g_m-V_{GS} characteristics of the GaAs MOSFETs.

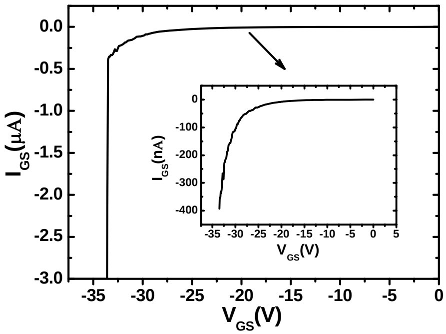

Fig. 6 The leakage current and the breakdown voltage of the MOSFETs.

Acknowledgements

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