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Low resistivity V/Al/Mo/Au ohmic contacts on AlGaN/GaN annealed at low temperatures

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1. Introduction

AlGaN/GaN heterostructure field effect transistors (HFETs) are very attractive for high-power and high-frequency electronic devices. This is due to its unique material properties, including wide band gap, large saturation velocity, and polarization effects leading to high sheet charge density. In order to make the best use of these advantages, it is important to develop ohmic contact technology which provides low contact resistances.

Several metallization schemes, mostly Ti/Al-based, have been reported to form ohmic contacts on AlGaN/GaN heterostructures [1-6]. Due to the low melting temperature of Al, ohmic contacts are easy to be oxidized at high temperatures. Therefore it is desirable to get low-resistivity ohmic contacts with smooth surface morphology by low-temperature annealing. Schweitz et al. reported that V/Al-based metals are effective for AlGaN/GaN ohmic contact formation [5]. They pointed out the potential of low-temperature annealing below 700°C, but they reported minimum contact resistivities in the order of $10^{-6}\Omega cm^2$ after annealing at 700-750°C [5]. In this paper, we present experimental results of V/Al/Mo/Au ohmic contact, and report a minimum contact resistivity of low-$10^{-6}\Omega cm^2$ after low-temperature annealing at 600-650°C.

2. Experiments

AlGaN/GaN heterostructures used in this study were grown by metalorganic chemical vapor deposition (MOCVD) on a sapphire substrate. The structure consists of a 1µm unintentionally doped GaN and a 25nm unintentionally doped $Al_{0.25}Ga_{0.75}N$. Ohmic metals were successively deposited by electron-beam evaporation. Contact resistances were determined by circular transfer length measurement (C-TLM). The metallization schemes studied consist of V(15nm)/Al(60nm)/Mo(35nm)/Au(60nm). For comparison, we have also investigated other ohmic metallization systems, such as Ti/Al/Mo/Au, Hf/Al/Mo/Au, and Zr/Al/Mo/Au. These ohmic contacts were annealed at temperatures ranging from 550 to 900°C by rapid thermal annealing for 30s in a N_2 ambient. The effects of the thickness of V were also investigated for the V/Al/Mo/Au metal system. Figure 2 shows the top-view of C-TLM patterns. The distance between electrodes was varied from 2 to 20µm.

3. Results and discussion

Figure 3 shows the specific contact resistivity (ρc) as a function of annealing temperature for ohmic contacts with V/Al/Mo/Au and related metal systems. It is clearly seen that the optimum annealing temperature differs significantly depending on the ohmic metal system employed. Table I lists the minimum ρc and the optimum annealing temperature for each ohmic system. Note that V/Al/Mo/Au exhibited a lowest ohmic contact resistivity of $1.6\times10^{-6}\Omega cm^2$ at 550°C. These results suggest that V/Al/Mo/Au works as a low-resistivity ohmic contact metal after annealing at temperatures below 650°C.

Figure 4 shows ohmic contact resistance of V/Al/Mo/Au with various V thicknesses ranging from 0 to 22.5nm as a function of annealing temperature. The optimum annealing temperature moves toward higher temperatures as the thickness of V is increased. A minimum ohmic contact resistivity of $1.6\times10^{-6}\ \Omega cm^2$ was achieved at 550°C for a V thickness of 15nm. These results suggest that the second ohmic layer of Al reacts with the AlGaN layer to form N vacancies [6], and the first ohmic layer of V prevents Al from reacting excessively with the AlGaN layer.

Table II shows surface roughness (Ra) for V/Al/Mo/Au and Ti/Al/Mo/Au after annealing. V/Al/Mo/Au showed Ra of 87A at 550°C, while Ti/Al/Mo/Au exhibited Ra=213A after annealing at 800°C. The results indicate that V/Al/Mo/Au ohmic metal provides flatter surface morphology after annealing, which is important for securing good uniformity and reproducibility.

4. Conclusion

We investigated V/Al/Mo/Au ohmic contacts on AlGaN/GaN HFETs. A V/Al/Mo/Au ohmic contact exhibited a low resistivity of $1.6\times10^{-6}\ \Omega cm^2$ at a low annealing temperature of 550°C. It was found that the surface of V/Al/Mo/Au after annealing was very smooth (Ra=87A).

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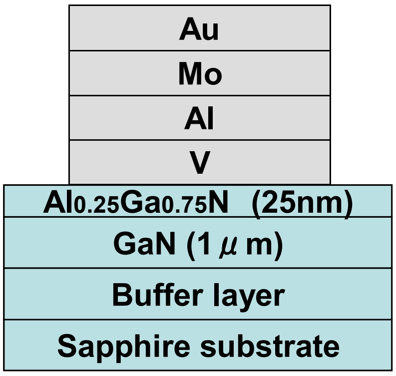

Fig. 1 Ohmic structure on $Al_{0.25}Ga_{0.75}N$/GaN.

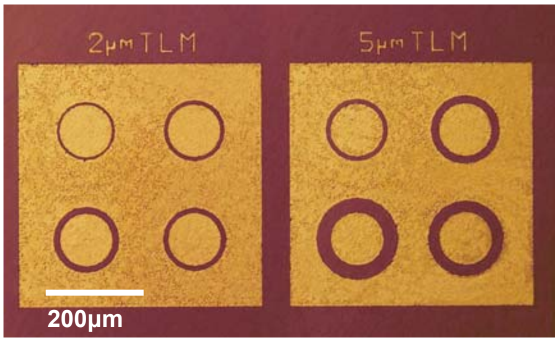

Fig. 2 Top-view of circular TLM patterns.

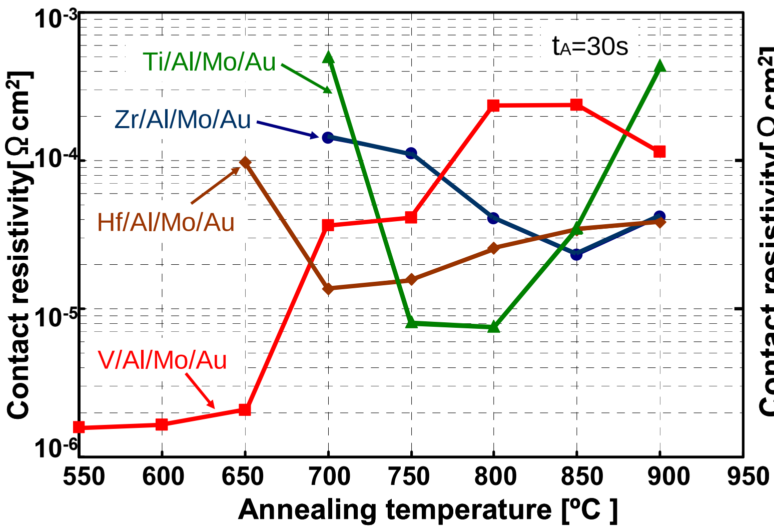

Fig. 3 Contact resistivity of X/Al/Mo/Au (X=Ti, Hf, Zr, and V) as a function of annealing temperature.

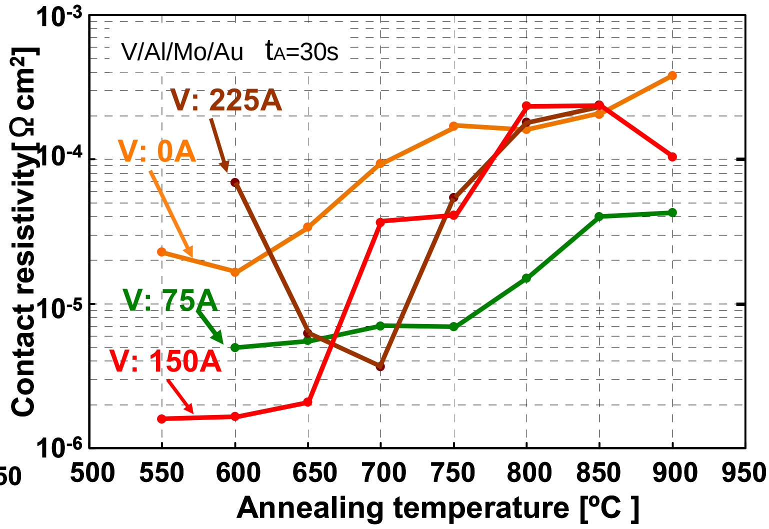

Fig. 4 Contact resistivity of V/Al/Mo/Au with V thickness from 0 to 300A as a function of annealing temperature.

Table I Summary of contact resistance of V/Al/Mo/Au and related metal systems.

	Annealing temperature (˚C)	Contact resistivity (Ωcm^2)
V/Al/Mo/Au	550	1.6×10^{-6}
Ti/Al/Mo/Au	800	7.7×10^{-6}
Hf/Al/Mo/Au	700	1.4×10^{-5}
Zr/Al/Mo/Au	850	3.3×10^{-5}

Table II Surface roughness Ra of V/Al/Mo/Au and Ti/Al/Mo/Au.

	Annealing temperature (˚C)	Surface roughness: Ra (A)
V/Al/Mo/Au	550	87
Ti/Al/Mo/Au	800	213