An Improved Mo/n-GaAs Contact by Interposition of a Thin Pd Layer

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Abstract—**The idea of limited reaction is employed to solve the adhesion and stability problems of Mo/n-GaAs and Pd/n-GaAs contacts by interposing a thin Pd layer between the Mo and GaAs. The structural and electrical properties of Mo/Pd/n-GaAs with different thicknesses of Pd layer, annealed at 300°C up to 500°C for 30 min, were investigated. Adhesion of Mo to GaAs has been improved with the interposition of a thin Pd layer. With increasing interposed Pd thickness, wider temperature ranges were achieved in which the contact showed rectifying Schottky behavior. The Schottky barrier heights kept nearly constant below 300°C and then dropped sharply at 450°C, except those of Mo(2000 Å)/Pd(200 Å)/n-GaAs diodes. The ideality factors converged to nearly unity at 300°C then increased sharply from 300 to 500°C, except those of Mo(2000 Å)/Pd(200 Å)/n-GaAs diodes, which maintained nearly a constant of 1.34 from 400 to 500°C.**

I. Introduction

It HAS BEEN shown [1]–[4] that Mo/n-GaAs contact has a large barrier height ($\phi_{bn} \simeq 0.9$ eV) and does not form any interfacial compound even at a temperature as high as 600°C. However, the Mo layer will begin to blister and peel off when the annealing temperature reaches 400°C. This phenomenon is attributed to the difference of the thermal expansion coefficients mismatch (Mo: 4.9×10^{-6}°C^{-1}, GaAs: 6.5×10^{-6}°C^{-1}). Hence, Mo may be used as a high-temperature Schottky barrier if the adhesion problem is solved.

On the other hand, Pd/n-GaAs contact also has a large barrier height ($\phi_{bn} \simeq 0.87$ eV) but interfacial reaction occurs when the annealing temperature is over 250°C [5]–[9]. The formation of interfacial compounds increases the adhesion but results in a degradation of the barrier at high temperature. In this study, the idea of limited reaction [10], [11] was employed by interposing a thin Pd layer between the Mo and GaAs. It is expected that the adhesion between Mo and GaAs can be improved by the limited amount of compounds formed and that the degradation of the barrier at higher temperature would not occur because of the incorporation of Mo.

The structural and electrical properties such as adhesion, surface morphology, ideality factor n, and barrier height ϕ_{bn} affected by annealing temperature and the thickness of interposing layer were studied.

II. Experimental

Si-doped n-GaAs HB wafers of (100) orientation and carrier concentrations of $4 \sim 5 \times 10^{16}$ cm^{-3} were used. Prior to metallization, the wafers were ultrasonically cleaned in trichloroethylene and acetone and then etched in the H_2SO_4:H_2O_2:H_2O (5:1:1) solution for 5 min at room temperature. Samples with five different combinations of thickness were prepared, namely Mo(2000 Å), Mo(2000 Å)/Pd(60 Å), Mo(2000 Å)/Pd(120 Å), Mo(2000 Å)/Pd(200 Å), and Pd(2000 Å), by using a multisource e-gun evaporator. All samples were annealed in a flow of purified hydrogen for 30 min and the annealing temperatures were varied from 300 up to 500°C. For study of electrical properties, Schottky diode dots with a diameter of 1 mm were formed by the lift-off technique. The backside ohmic contacts were formed by depositing Au:12-percent Ge:4-percent Ni, followed by annealing at 450°C for 3 min. An HP4145A Semiconductor Parameter Analyzer was used for I-V measurements. Adhesion was tested by using a tape peeling test. A SEM was used for the observation of the surface morphology.

III. Results and Discussions

Samples annealed at 400°C were tested for adhesion. Samples with Mo only were easily torn off while those interposed with Pd layers still showed good adhesion to the GaAs. The surfaces of samples with Mo or Mo/Pd began to crack after being annealed above 300°C, while those samples with Pd only began to wrinkle. The difference can be assumed to be a result of the large thermal expansion coefficient of Pd (11.76×10^{-6}°C^{-1}), compared with that of GaAs.

Barrier heights ϕ_{bn} of the diodes varying as a function of annealing temperatures are shown in Fig. 1. It can be found that the ϕ_{bn} of Pd/n-GaAs diodes has a large drop from 0.81 to 0.57 eV when the annealing temperature increases from 300 to 400°C, while ϕ_{bn} of Mo/Pd/n-GaAs diodes does not drop significantly, especially for Mo/Pd(120 Å)/n-GaAs diodes which still kept a large ϕ_{bn} of 0.82 eV. Up to 500°C, ϕ_{bn} of Pd/n-GaAs and Mo/n-GaAs diodes dropped to 0.46 eV, while ϕ_{bn} of Mo/Pd(200 Å)/n-GaAs diodes kept values as high as 0.78 eV. It is obvious that Mo/Pd/n-GaAs diodes, on average, showed less deterioration than Pd/n-GaAs diodes. Of course, the selection of optimum thickness is very critical. A thickness of 200 Å has shown the best result in this experiment.

Fig. 2 shows the variation of ideality factor n of diodes over a range of annealing temperatures. At 300°C, n converged to nearly unity, then increased sharply from 300 to 500°C, except those of Mo/Pd(200 Å)/n-GaAs diodes, which main-

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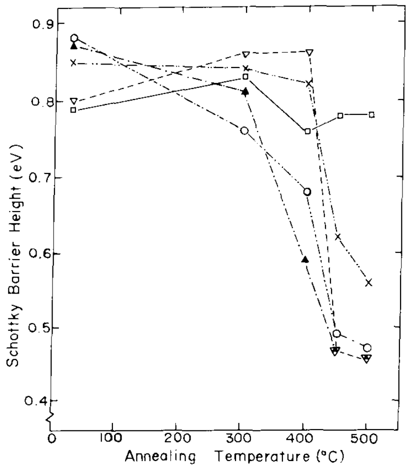

Fig. 1. Schottky barrier height ϕ_{bn} measured from I-V curves for diodes annealed at different temperatures. ∇: Mo(2000 Å)/n-GaAs; ○: Mo(2000 Å)/Pd(60 Å)/n-GaAs; ×: Mo(2000 Å)/Pd(120 Å)/n-GaAs; ▲: Pd(2000 Å)/n-GaAs; □: Mo(2000 Å)/Pd(200 Å)/n-GaAs.

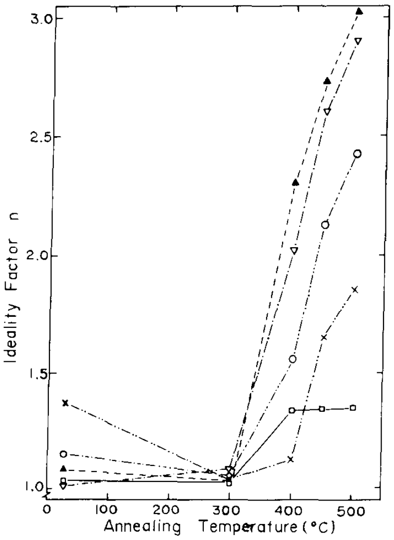

Fig. 2. Ideality factor n measured from I-V curves for diodes annealed at different temperatures. ∇: Mo(2000 Å)/n-GaAs; ○: Mo(2000 Å)/Pd(60 Å)/n-GaAs; ×: Mo(2000 Å)/Pd(120 Å)/n-GaAs; ▲: Pd(2000 Å)/n-GaAs; □: Mo(2000 Å)/Pd(200 Å)/n-GaAs.

tained nearly a constant n of 1.34 from 400 to 500°C. The convergence of n to nearly unity at 300°C may be due to the dispersion of native oxide by in-diffusion of Pd and consequently less defects and surface states at the interface after annealing [8], [12]. Above 300°C the deviation of n from 1.0 is attributed to the formation of compounds and the increase of defects due to interfacial reactions and stress. These mechanisms, which correlate the electrical and the structural properties, are very complex and more extensive studies are in progress [13], [14]. These studies, at annealing temperatures beyond 500°C, are much more complicated.

IV. Conclusion

A new Mo/n-GaAs contact with interposition of a thin Pd layer between Mo and GaAs was successfully fabricated to improve the adhesion and stability problems of Mo/n-GaAs and Pd/n-GaAs contacts. Mo/Pd(200 Å)/n-GaAs diodes operated with good electrical properties after 500°C annealing. The concept of limited reaction looks promising, and so various combinations of metals for metal GaAs contacts are under extensive study.

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