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The Study of Metal-GaN Interface of Schottky Contacts with Different Metals

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1. Introduction

Many important device, such as metal-semiconductor-metal (MSM) Photodiode, metal-semiconductor field effect transistors (MESFETs), high electron mobility transistors (HEMTs) employ a Schottky barrier for at least one electrode. So a good and stable Schottky barrier was essential.In this article we reported experiment results of Schottky barrier contact on n-type GaN. The detail of the growth and crystal properties had been previously reported.[1,2]We used Au, Pd, Ni, Pt and Ti to as Schottky dot and Al was used for ohmic contact. Measurements were carried out by using current-voltage(I-V), current-voltage-temperature(I-V-T) and capacitance-voltage(C-V) techniques. The barrier, ideality factors and effective Richardson constant are presented. Contact of Ti exhibited only slight rectifying characteristics and small barrier. These result showed that the barrier on n-type GaN increase with metal work function. This supported the prediction that Fermi level was not pinned at the GaN surface.

2. Results and Discussions

GaN was known to suffer from a usually high deep level defect density. In order to explain this phenomenon, we advocacy that the transport mechanism in GaN-based metal semiconductor contact is trap enhanced thermal field emission (TETFE).

We speculated that the existence of the allowing electrons to tunnel through the Schottky barrier to an available state (labeled process 1 in Fig.1), then to either subsequently tunnel through the remaining barrier (process 2 in Fig.1) or be thermally excited up to the ladder like set of state (process 3 in Fig.1). Upon completion of the voltage sweep, most of the states are filled. There are far fewer empty states available to support the tunneling electron. Some of the tunneling electron will fall back to Schottky metal (process 4 in Fig.1)[1].

For Au and Pd Schottky diode, during the annealing process, the effect barrier height changed with different annealing temperature. In Fig.2 and Fig.3, we observed an increase in the barrier height with annealing temperature. The value of effect barrier height reached a maximum, then fall down with annealing temperature. The change in barrier height suggests that change of structural occur at the interface. Auger electron spectroscopy indicated no appreciable characteristic between the Au film and GaN after 400°C. Changes during annealing at such low temperature could happen on a more microscopic scale. If microscopic interfacial reaction occur, it would be detected by high resolution transmission electron microscopy. Such studies are in progress to understand the underlying mechanisms leading to the changes in the Schottky barrier height. Additionally, we were interested in the barrier height fall down after some special temperature .We believed it was arisen from the fix charge in interfacial oxide between metal and GaN. During the high temperature annealing, the oxide layer form between the metal and GaN. And then some mobile charges were accelerated into the interface during I-V measurement. And we guess the fixed charges are positive. The image model is showed in Fig.4 In the simple depletion approximation for carriers in interfacial oxide, the change of Schottky barrier height (SBH) was given by

$$\Delta SBH = qNT_{oxide}^2 / 2\varepsilon_{oxide}$$

where N is the charge density in the interface oxide layer, ε_{oxide} and T_{oxide} were permittivity and thickness of the interface oxide layer, respectively .The interface charge may be fixed ionic or defect space charge in the interface layer[2].

For GaN, as seen in Fig.5, a monotonic increase inψ_B was observed as metal work function was increase . This dependent has been attributed to the ionic nature of GaN. The index of interface behavior,

$$S \equiv \Delta\psi_B / \Delta\psi_m$$

Where ψ_m was the metal work function, used to quantify the dependence of Schottky barrier height on the Schottky metal[3]. For several metal electron negativity, and the value of barrier height reported here, S was calculated to be 0.604. This large value of S indicated that the fermi level at the GaN surface was not pinned by surface state.

However, the increase did not scale with the work function as expected from the relation

$$\Phi_B=(\Phi_m-\chi_s).$$

This indicated that the Schottky height of n-GaN is also influenced by other factors besides metal work function.

References

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[3] S. M. Sze, *Semiconductor Device Physics and Technology*.

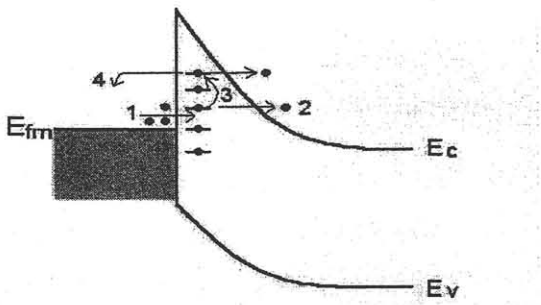

Fig.1 Schematic diagram showing one plausible explanation for the transport mechanism

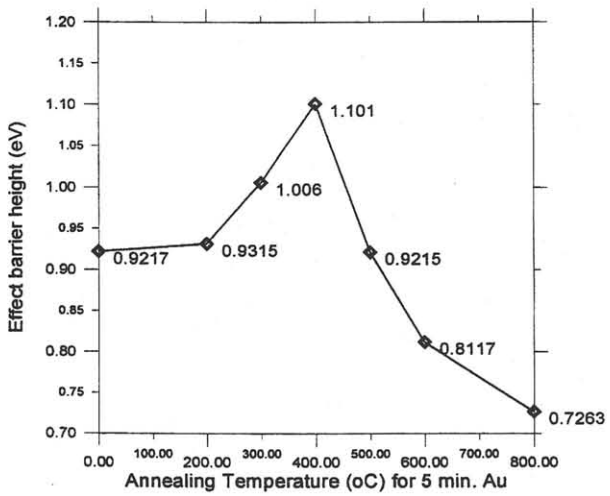

Fig.2 The change of barrier height after different annealing temperature for 5 min for Au

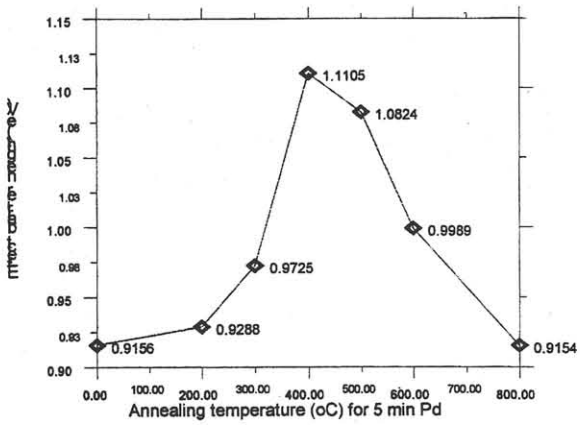

Fig.3 The change of barrier height after different annealing temperature for 5 min for Pd

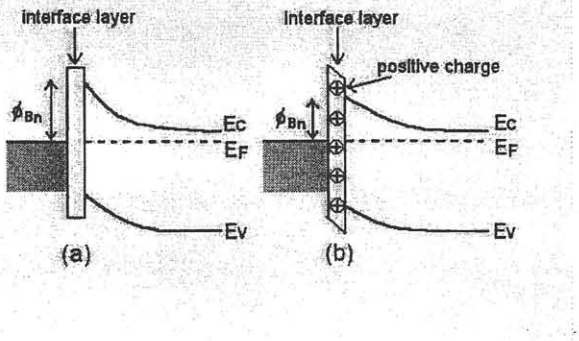

Fig.4 (a) The band structure of metal–oxide-semiconductor, (b)with positive charges in oxide

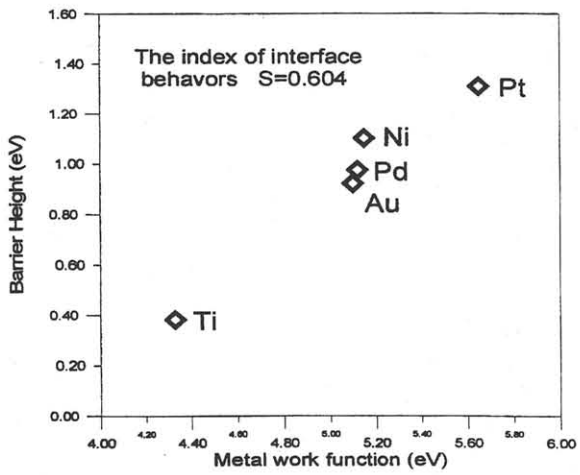

Fig.5 Relationship between barrier height and metal work-function