Student Paper

Contact Potential Measurements on Nano-particle embedded AlGaN/Metal Interface Using Kelvin Force Microscopy

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AlGaN/GaN Schottky barrier diodes (SBDs) have received much attention for high power and high-frequency applications because of the high breakdown field in the wide band gap semiconductor. Schottky contacts with tunable barrier height (ΦB) between the AlGaN and the metal contact can be used to determine the performance of AlGaN/GaN devices [1,2]. Recent studies have shown that the barrier height can be modified and the fundamental device properties tuned by incorporating metal nano-particles (NPs) at the metal-semiconductor interfaces in Si, GaAs, and SiC [3,4]. The effect of size reduction of NPs on the characteristics of diode structures with embedded NPs has been experimentally demonstrated the change the transport properties of metal/semiconductor interfaces [5].

The Kelvin Force Microscopy (KFM) has shown its capabilities in dopant profiling and potential variation analysis of semiconductors, such as Si, GaAs, and ZnO[6,7]. The tool can measure and image the potential differences of between the tip and sample which can be converted to the band bending and the charge states in the sample surface.

In this work, we have measured potential variation of Au-/Ag-NPs embedded at the metal/AlGaN interface in AlGaN/GaN SBDs using KFM. The nano-scale contact potential difference (CPD) distribution of an electrical contact with embedded NPs has been investigated, which effectively demonstrates the change in the barrier height between the electrical contacts and the NPs embedded AlGaN/GaN interface. Our results show that incorporating NPs with different work function can improve the barrier lowering effect and results in changing the Schottky contact characteristics of AlGaN/Ni intereface.

Fig. 1 (a) and (b) shows FE-SEM surface images of Au- and Ag-NPs formed on AlGaN/GaN substrate. Each NPs were formed after annealing at 400 °C in N_2. Fig. 1 (c) shows the distribution of relative amounts of the NPs in the samples sorted according to size. The barrier height was compared with the physical size distributions of NPs in each sample as determined by field emission scanning electron microscopy (FE-SEM).

Fig. 2 shows a 3D-image of CPD (fig. 2 (a)) and the CPD distribution in Ni contact on AlGaN/GaN without NPs (fig. 2 (b)). While scanning the surface, there is the possibility that the work function of the AFM-tip (Φ_{tip}) can be changed due to physical and electrical diminution of the tip-coated metal (Pt/Ir). Hence, we optimized the Φ_{tip} by scanning an Au (111)-plate (Φ_{Au}: 5.31 eV) before the measurement of the contacts. The Φ_{tip} extracted from the CPD value between tip and Au was 5.1 V. During the measurements, AC-amplitude to the tip has been fixed at 2000 mV to reduce the effect from electrical interferences of surface. As shown in fig. 2 (b), the CPD value of Ni-contact without NPs is 10.4 mV which has larger CPD values compared to AlGaN surface, -157.3 mV.

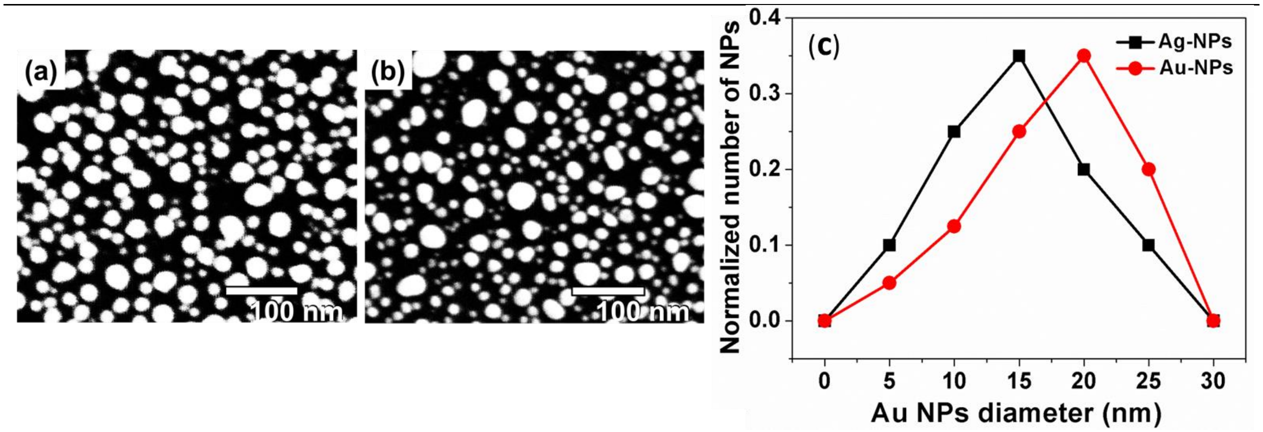

Fig.1 Representative FE-SEM images of (a) Au-NPs and (b) Ag-NPs on AlGaN/GaN substrate after annealing at 400 °C for 20 min. (b) Distribution of Au and Ag-NPs diameter relatively samples, sorted from the FE-SEM images.

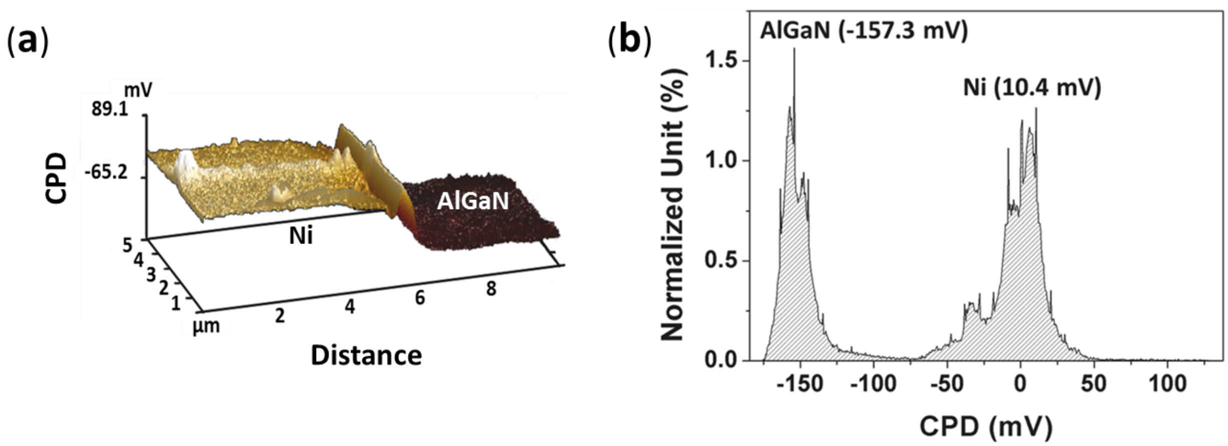

Fig.2 (a) 3D-image of CPD at Ni electrode without NPs and (b) Distribution of CPD in AlGaN and Ni electrode.

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