Dopant activation by UV laser annealing to form non-alloy ohmic contact on n+ GaN

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The fabrication process for making ohmic contact on GaN always remains a challenge. For N-type GaN, the traditional alloy type ohmic contact requires high temperature annealing which may introduce material surface roughening [1]. While to form the non-alloy type ohmic contact needs epitaxial regrowth of the heavily N-doped layer, which is time-consuming and costly [2]. Therefore, it is of great interest to explore new process to realize low resistivity ohmic contact for GaN devices [3]. In this paper, we report the formation of non-alloy N-type ohmic contact on GaN achieved by ion implantation and laser annealing. The successful activation of the ion implanted Si dopants (concentration in the order of $10^{20}/cm^3$) in GaN enables the low contact resistivity in the order of 10^{-6} ohm-cm^2.

The experiment is carried out on 6-inch GaN wafers grown by MOCVD. 4 µm of GaN has been grown on Si (111) substrate with an AlN buffer layer. Then a capping layer of 5 nm AlN/40 nm SiN is deposited on GaN for surface protection. Si dopants are implanted at 500°C, with a dose of 4 x10^{15} /cm^2 and a targeted project range of 50 nm. The whole wafer is then annealed by the UV nanosecond laser tool (SCREEN-LASSE LT-3100, 308 nm wavelength, pulse 100-200 ns) at room temperature under air ambient. To characterize the annealed samples, the 4-point probe measurement of sheet resistance (R_s) is firstly performed after removing the AlN/SiN capping. The non-annealed as-implanted reference sample gives unmeasurable R_s. While the R_s of laser annealed samples demonstrate significant reduction. Fig 1 plots the R_s of 7 samples on the same wafer processed using 7 different annealing conditions. We can see that by increasing total laser annealing duration, the R_s of the targeted material decreases to as low as several hundreds of ohm/sq. Both reference sample and the annealed samples were also characterized by AFM after SiN capping removal. Fig 2 presents the surface morphology of the reference sample and the sample A marked in Fig 1 (Rs = 547 ohm/sq) for comparison. The sample A has received the maximum thermal budget in this study, and there is no drastic material surface change caused by laser annealing process. The sample B marked in Fig 1 (Rs = 665 ohm/sq) has been further processed to fabricate an ohmic contact transmission line (TLM) test structure with metal pad spacings of 5 µm, 10 µm, 20 µm and 36 µm. Cl_2-based inductively coupled plasma (ICP) mesa etching of GaN was performed to isolate the TLM test structure, Ti/Al/Ni/Au (20 nm/120 nm/25 nm/100 nm) was deposited by electron beam evaporation to form the metallic ohmic contact. In Fig 3, the linear characteristic of resistance values with respective to different metal pad spacings indicates that a good ohmic contact has been formed between metal and semiconductor. Contact resistance is then extracted by Least Square Method. As shown in Fig 4, the contact resistance is 4.16 ohm-mm with a transfer length of 1.16 µm. The contact resistivity is finally evaluated as 7.48 x10^{-6} ohm-cm^2.

Though more analysis is needed to deepen the understanding, we may conclude that by employing the UV laser annealing of implanted Si dopants to achieve highly N-type doped GaN is a viable technique to form low-resistivity metallic ohmic contact.

References

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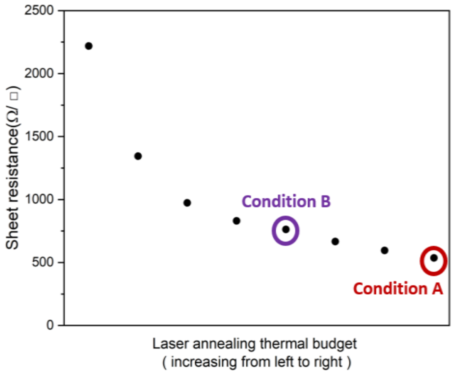

Fig 1. The sheet resistance of laser annealed samples decreases monotonically with the increasing thermal budget applied by laser.

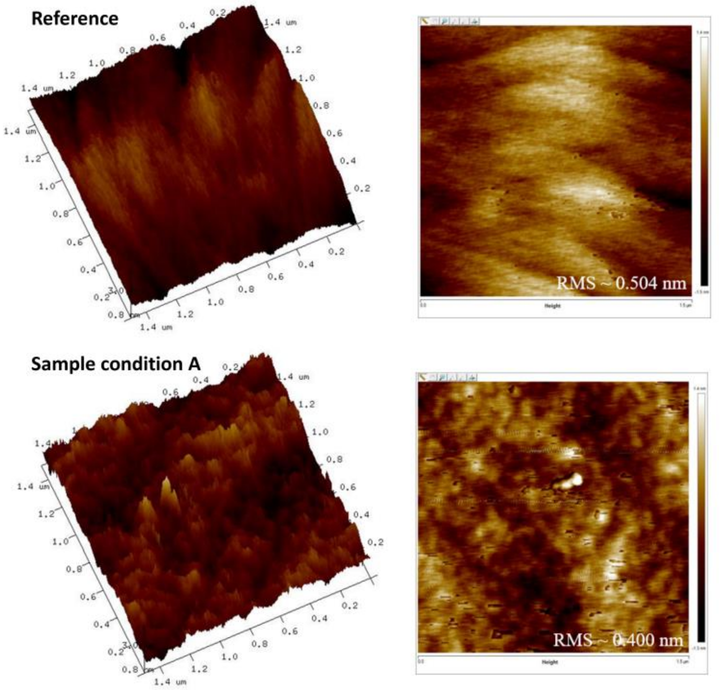

Fig 2. AFM characterization of the reference sample (as-grown without laser annealing) and the sample A marked in Fig 1. It is confirmed that the proposed laser annealing process will not damage the material.

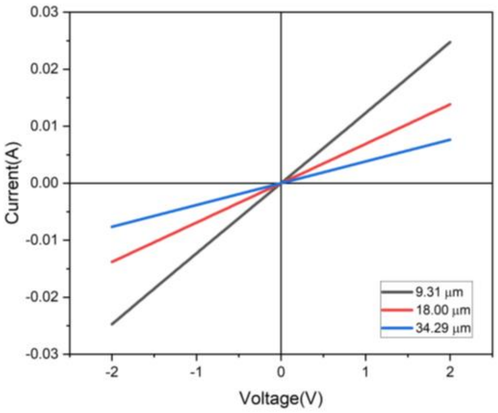

Fig 3. I-V characteristics of TLM structures as metal stack deposited.

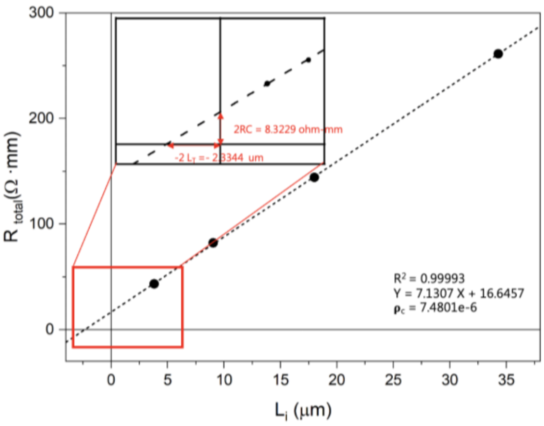

Fig 4. Contact resistance from TLM (Sample condition B). Resistance versus distance between contact pads, L_i, is plotted.