The Effect of Ni Content on Lateral Diffusion of Alloyed Au-Ni-AuGe Ohmic Contacts in GaAs-AlGaAs pHEMT Structures

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The quality of source and drain ohmic contacts in GaAs-AlGaAs-InGaAs pseudomorphic high electron mobility transistor (pHEMT) structures is critical to the performance and reliability of the devices. Since the introduction of the Ni-AuGe ohmic contact to GaAs by Braslau [1], it has become the most widely used because low contact resistance can be achieved by controlled vertical diffusion of the contact metals into the active channel of the device during the alloying cycle. Langer et al. [2] first reported on the phenomenon of lateral diffusion in Ni-AuGe contacts at the GaAs/AlGaAs interface in HEMT devices. In some reported cases, the lateral encroachment of the contact metal was significant enough (0.2 to 0.25 µm) to result in source-drain shorts in TLM measurement structures, due to the close spacing of the contacts [3]. Attempts to mitigate the effect of contact metal lateral diffusion by increasing the alloy temperature [4], transient thermal annealing [5], lowering the alloy temperature [6], utilization of a hypoeutectic AuGe composition [7], rapid thermal annealing [8] and various approaches that employ alternative ohmic contact metals have met with limited success. In this study we investigated the effect of *in situ* ion milling of the GaAs surface prior to deposition, optimization of the Au to Ge compositional ratio and control of the volume fraction of the Ni in the metal stack on lateral diffusion (which we refer to as “ohmic runout”) of the alloyed Au-Ni-AuGe contact.

The nominal ohmic contact metallization structure in this investigation was fabricated by sequential e-beam evaporation of Au (300 Å), Ge (400 Å), Au (600 Å), Ni (260 Å), Au (2000 Å) and Ti (200 Å) on top of the n^+ GaAs contact layer of an AlGaAs-InGaAs pHEMT structure. Ohmic contacts were alloyed at 426° C for 30 seconds under a nitrogen blanket. Figure 1a shows a dual beam FIB/SEM cross section of an as deposited ohmic structure, while Figure 1b shows the ohmic structure after the alloy sequence. The ohmic runout after alloy at the periphery of the contact in Figure 1b extends over 0.2 microns from the edge.

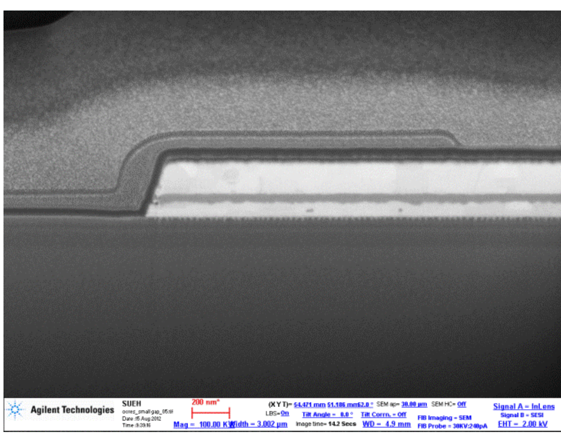

Figure 1a – SEM micrograph of as deposited contact

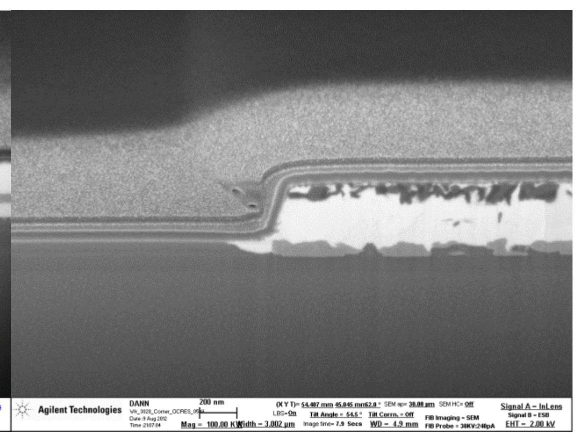

Figure 1b – SEM micrograph of alloyed contact

One set of experiments studied the effect of *in situ* ion milling of the semiconductor surface prior to ohmic contact deposition. The nominal ion mill etch rate was 8 Å/min for a total of 3 minutes. In this study, the ohmic runout was significantly more severe for wafers that did not receive the ion milling step, but modest ohmic runout was still observed in the ion milled wafers. In another set of experiments, the relative Ge content was varied from 8 wt. % (hypoeutectic composition) to 20 wt. % (hypereutectic composition) to study the effect of Ge composition on ohmic runout. It was found that the hypoeutectic compositions (8% and 11% Ge), the eutectic composition (88%Au-12%Ge) and a slightly hypereutectic composition (13% Ge) did not display evidence of ohmic runout. By contrast, wafers with a hypereutectic composition of 80%Au-20%Ge consistently displayed moderate to severe ohmic runout after the alloy sequence.

Figure 2a-2d shows a series of FIB/SEM cross sections, after alloying, where the Ni to Au-Ge volume fraction of the ohmic metallization stack was varied from 0.18 to 0.25. It is clear that the lower Ni volume fractions (0.18 and 0.20) which correspond respectively to 230 Å and 260 Å of Ni in the ohmic metallization stack, show no evidence of ohmic runout. Conversely, the ohmic runout for the sample with a Ni volume fraction of 0.22 (290 Å Ni) in Figure 2c is modest, whereas the ohmic runout for the sample with a Ni volume fraction of 0.25 (320 Å Ni) in Figure 2d is more significant.

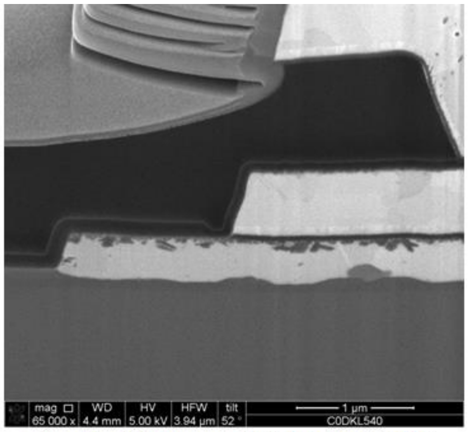

Figure 2a – SEM micrograph of 0.18 Ni fraction (230 Å Ni)

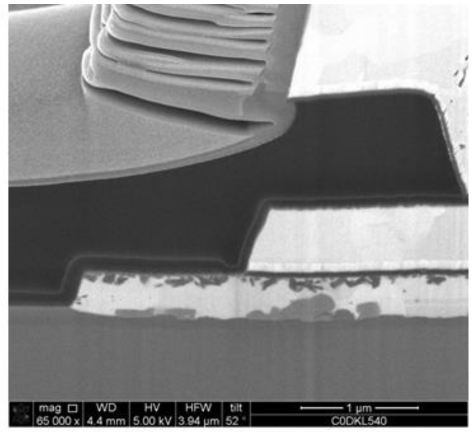

Figure 2b – SEM micrograph of 0.20 Ni fraction (260 Å Ni)

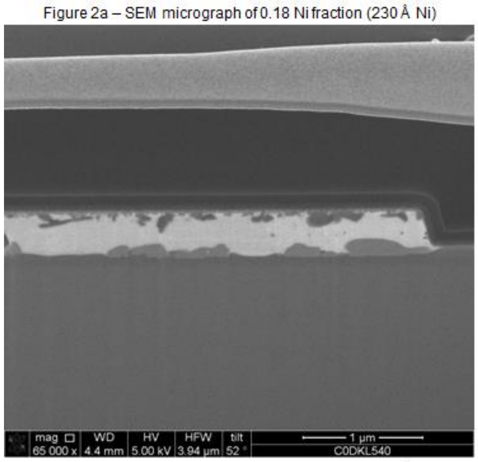

Figure 2c – SEM micrograph of 0.22 Ni fraction (290 Å Ni)

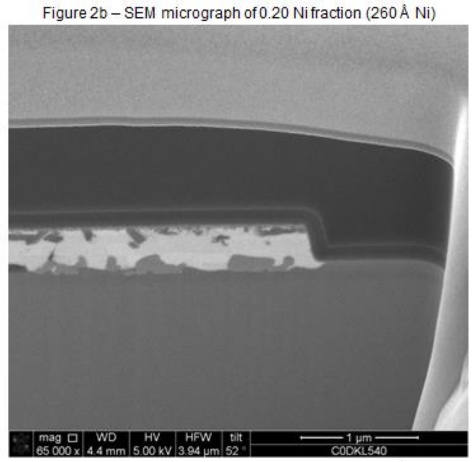

Figure 2d – SEM micrograph of 0.25 Ni fraction (320 Å Ni)

In situ ion milling of the GaAs surface prior to contact metal deposition and utilization of lower Ge composition partially mitigated the effect of ohmic runout. However, the key result of this investigation is the critical sensitivity of ohmic runout on the Ni content in the ohmic metal stack. We have found that a higher volume fraction of Ni to Au-Ge (0.22 – 0.25) in the ohmic deposition layer stack exacerbates ohmic runout and increases contact resistance to unacceptable values, whereas a lower volume fraction of Ni (0.15 – 0.20) eliminates ohmic runout without compromising the contact resistance of the ohmic contact. The final manuscript will provide complete details of this investigation, including associated contact resistance data.

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