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Elmination of Kink Phenomena in InP-Based HEMTs by Forming Direct Ohmic Contacts in the Channel

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We eliminated the kink phenomena and Ids hysteresis in a double-doped InP HEMT by fabricating direct ohmic contacts in the InGaAs channel. InP HEMTs are used for high-speed integrated circuits due to their excellent high-frequency characteristics. There is, however, an unexpected drain current feature, called a "kink phenomenon", that limits their RF characteristics. We investigated the effect of the current paths in a device on this phenomenon.

We used a double-doped HEMT consisting of InGaAs cap layer/InP stopper layer/InAlAs supply layer/InGaAs channel layer/InAlAs supply layer on InP substrates. We used an alloyed ohmic structure for the direct contacts, which were fabricated by etching the n-InGaAs cap layer and evaporating the Ni/AuGe/Au layer and alloyed. Etching the cap layer reduced the contact resistance enough to prevent excess reaction between the Au and the n-InGaAs cap layer. We also fabricated a non-alloyed ohmic structure by evaporating Mo/Ti/Pt/Au onto an InGaAs cap layer.

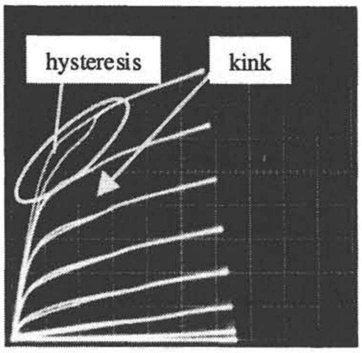
Kink phenomena around Vds=1V and Ids hysteresis (especially at Vg=0) were observed in the non-alloyed structure (Fig. 1(a)). The current path in a device with non-alloyed ohmic contacts is shown in Fig. 1(b). Because of the high resistance due to the band-gap discontinuity at the interface of InGaAs/InAlAs, electrons flow in the cap layer to the source edge of the gate recess, then flow into the channel layer and reach to the drain edge of the gate recess, and flow out to the drain cap layer. The kink generation mechanism was thus due to the excess carrier caused by the impact ionization due to the higher current density at the drain edge of the gate recess in the channel. The hysteresis consisted of two different Ids curves, both with a kink, at the same gate bias.

We proposed a device with forming direct ohmic contacts in the channel. Kink phenomena and Ids hysteresis were not observed in this structure (Fig. 2(a)). The current path in this device with alloyed ohmic contacts is shown in Fig. 2(b). Most of the electrons flow into the channel directly from the source electrode and flow out to the drain electrode, therefore the high current density at the drain edge of the gate recess is relaxed. The kinks are eliminated by this relaxation.

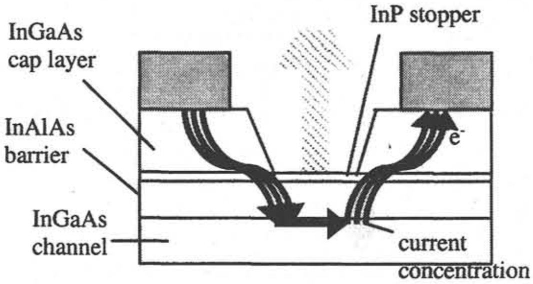
The elimination of the kink phenomena and Ids hysteresis in the device with alloyed ohmic contacts was apparently due to the change in the current path. In the direct ohmic structure, the main current path is away from the surface of the gate recess edges, which means the carrier density is low near the edges. This is shown by the high gate turn-on voltage (Vf) and low Cgs compared to those of the non alloyed ohmic structure.

And considering the reason of generating Ids hysteresis, we can suggest a hole trap mechanism at the recess surface between gate and drain region. Some hole generated by impact ionization are captured by traps in the InP layer between gate and drain region (Fig. 3(a)). In the case of direct ohmic structure, most electrons are not affected by these holes and Ids hysteresis is not observed. In the case of non-alloyed structure, these holes recombine electrons that flow near the recess edge region as a drain current. Therefore drain current decreases (Fig. 3(b)). When negative bias is added for Vg or drain bias increased, hole-electron recombination was decreased because of shielding a trap region by depletion layer expanding (Fig. 3(c)).

In conclusion, we eliminated the kink phenomena and Ids hysteresis in a double-doped InP HEMT without degrading its high-frequency performance by fabricating direct ohmic contacts in the InGaAs channel. And we suggest a hole trap mechanism at the recess surface between gate and drain region. From this consideration, abnormal drain current features like kink or hysteresis can overcome by controlling current paths in the device. Improvement of reliability, which is a key issue for commercial applications, is also expected.

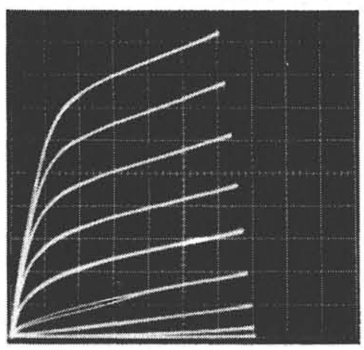


(a) Ids-Vds
(Vgmax=0 V, Vgstep= −0.1 V, 2 mA/div., 500 mV/div.)

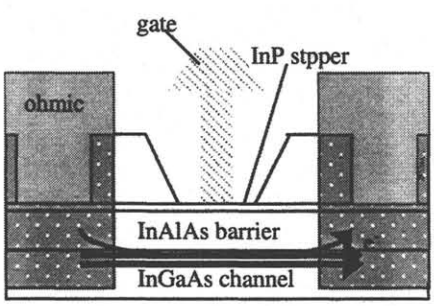


(b) Main current path

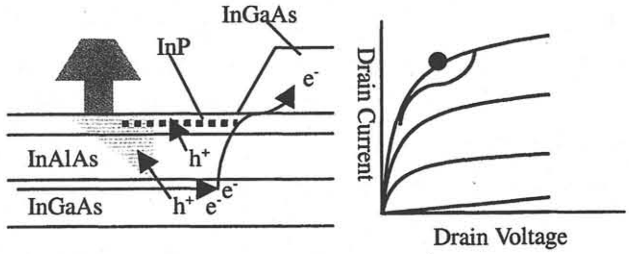
Fig. 1 InP HEMT with non alloyed ohmic contacts



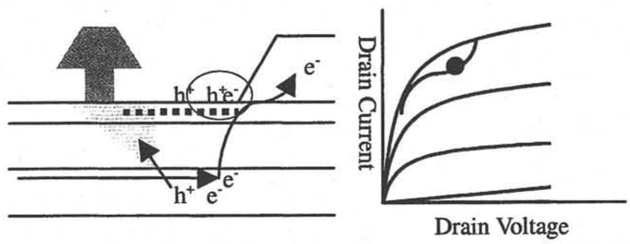
(a) Ids-Vds
(Vgmax=0 V, Vgstep=−0.1 V, 2 mA/div., 500 mV/div.)



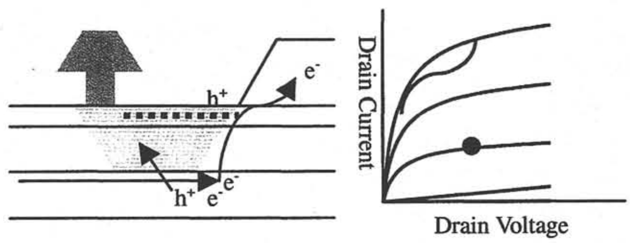
(b) Main current path
Fig. 2: InP HEMT with direct ohmic contacts



(a)



(b)



(c)

Fig. 3 Mechanism of Ids hysteresis by hole trap in InP layer