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Optimization of Overgrown Ex-Situ Processed GaAs Interfaces for a Resonant Tunneling PBT

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1. Introduction

Epitaxial overgrowth over metals is a key technology for the implementation of several advanced semiconductor devices, such as metal-semiconductor hybrid structures.[1,2,3] One problem with this kind of processing is the control of the regrown interface, where incorporated impurities may severely hamper the performance of the device. It has previously been shown [4] that the impurity concentration can be minimized by use of various chemical treatments prior to overgrowth. The effect of the chemical cleaning is however strongly dependant on the processing prior to the overgrowth. We have studied in a novel way how the regrown interface of *ex-situ* processed GaAs is affected by different chemical processing prior to overgrowth, using a RTD as a sensitive probe for potential fluctuations around the overgrown interface. Finally, we have used the optimized processing to fabricate a resonant tunneling permeable base transistor (RT-PBT).

2. Experiments

Interface Processing

The experimental work started by growing a base structure including a $GaAs_{0.22}P_{0.78}/GaAs$ double barrier resonant tunneling diode (RTD) on an n^+ GaAs substrate using metalorganic vapour phase epitaxy (MOVPE). The double barrier was placed 30 nm below the surface on which we later overgrow. After a standard lift-off procedure where mesas were defined using tungsten frames [2], the samples were etched using different standard chemical cleaning solutions, such as $HCl:H_2O$ and HF. The samples were subsequently overgrown using MOVPE, and annealed contacts were formed on the mesas and backside of the substrate. The IV-characteristics of the overgrown RTD:s were measured, and used as a measure of the quality of the overgrown interface. To see how the different etchants influenced the quality of the crystal, the surface morphology of similarly processed samples was studied with AFM both before and after overgrowth.

RT-PBT

In order to study the effects of the etching on the electrical properties of the overgrown metal, a fine tungsten grating (180 nm wide metal stripes, with a period of 380 nm) connected to a contactable gate pad were formed on the base structure. This PBT structure was subsequently processed and overgrown in a similar fashion as the RTD:s.

Results and Discussion

Interface cleaning

A clear dependence of the used etchant and the IV-characteristics were observed, as shown in fig 1. The $HCl:H_2O$ etched diode shows the best characteristics, with a peak-to-valley ratio and peak current density comparable to unprocessed reference diodes. The other diodes had highly asymmetric IV- characteristics with very low peak-to-valley ratios and high peak voltages. The AFM investigations correlated well with the electrical data, the $HCl:H_2O$ treated sample had a smooth surface with visible monolayer steps.

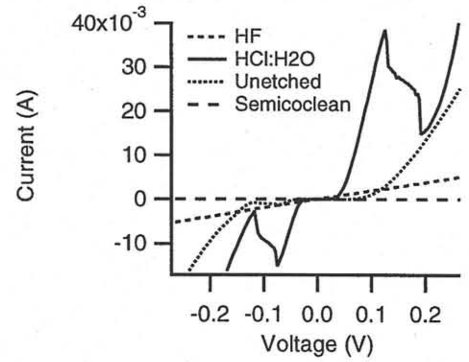

Fig.1 IV-Characteristics of processed diodes

RT-PBT

As expected, only the sample etched with $HCl:H_2O$ had clearly visible peaks in the current. By changing the gate voltage, the current through the device could be modulated, as shown in fig 2, as a result from the PBT operation of the transistor. Clear resonances in both directions where observed, indicating that the introduced metal wires and *ex-situ* processing did produce a uniform potential distribution over the entire area of the device.

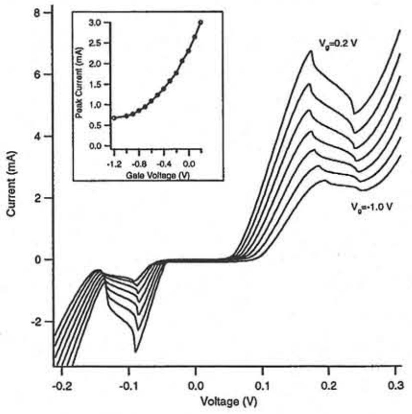

Fig.2 IV-Characteristics of RT-PBT, gate voltage is swept between 0V and –1V

Conclusions

By proper choice of processing parameters, especially etching steps, it is possible to achieve stable conditions for overgrowth of *ex-situ* processed GaAs. We have shown that it is possible to successfully integrate a PBT with a RTD, forming a novel resonant tunneling transistor.

References

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