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Enhanced f_{max} and low base resistance in Ni silicided SiGe HBT

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1. Introduction

The SiGe hetero-junction bipolar transistor (HBT) and HBTs with CMOS transistors (BiCMOS) technologies play an important role in optical transmission and wireless communication systems[1]. As the SiGe dense technology advances to deep sub-micron, Ti silicidation has a problem of the resistance increase as the line width reaches the lower sub-micron range. Thus, the Ni silicidation process is appeared to be a suitable candidate to replace Ti silicidation[2,3]. The SiGe HBT base is composed of a thick cap Si layer, a SiGe layer, and a seed layer. The extrinsic base is formed during Si/SiGe/Si epitaxy, and then nickel is deposited and silicided on the Si/SiGe/Si layer as an interconnection process for the sake of the reduction of contact resistance. Nickel silicide exhibits a superior sheet resistance than that of nickel germanosilicide[4]. Ni silicidation has several advantages over Ti silicidation when used in the SiGe HBT fabrication. The merits are low temperature silicidation process, low sheet resistance, and one step silicidation process[4]. Purpose of this work is to obtain a low base resistance of SiGe HBT and enhancement of f_{max} with Ni silicidation compared to Ti silicidation.

2. Device fabrication and Measurements

SiO_2 layers of 100 nm thick were formed on P-type Si <100> wafers which were used as starting substrates. In-situ heavily doped Si/SiGe/Si base layers and other Si epitaxial layers were grown in reduced pressure chemical vapor deposition (RPCVD) system. Self-aligned Ni silicide on Si/SiGe/Si base was formed in a rapid thermal annealing (RTA) chamber by one step annealing. A 50 nm thick nickel film which had the lowest value of sheet resistance was then deposited by M2i sputtering system at room temperature. The silicidation reactions were then performed in the RTA system in As ambient for 30 s with different annealing temperatures. The nickel layers not reacted on the base were removed by wet etch process after annealing. Ni silicide layers on all electrodes of the emitter, base, and collector of the SiGe HBT were formed simultaneously in a self-aligned manner instead of Ti silicidation[5]. Fig. 1 shows the cross sectional view of the SiGe HBT and the plane view of the intrinsic and extrinsic base region. The sheet resistance of the Ni silicide films and that of extrinsic base were measured by four-point probe and HP4145B semiconductor parameter analyzer systems, respectively. f_T and f_{max} were obtained using an HP8510B network analyzer and UTMOST3 parameter extraction software. The microstructures were examined by scanning electron microscopy (SEM), transmission electron microscopy (TEM) and their crystal phases were identified by x-ray diffraction (XRD) in the Bragg-Brentano geometry.

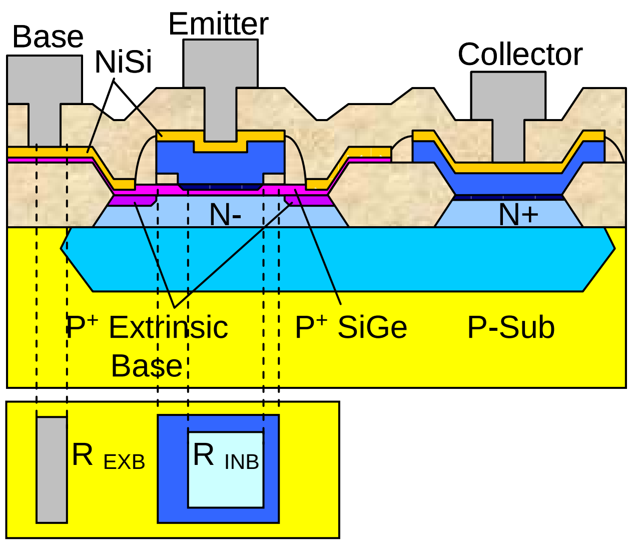

Fig. 1 Cross-sectional and plane views of the base, emitter and collector region of the SiGe HBT

3. Results and Discussion

Figures 2 (a) and (b) show the sheet resistances (R_s) of the Ni silicidation on Si/SiGe/Si base with given annealing temperatures and the XRD patterns, respectively.

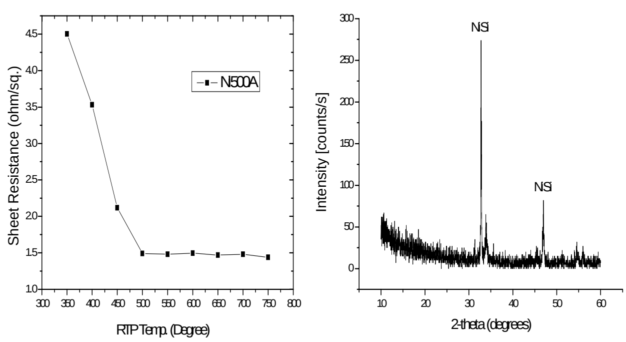

Fig. 2 (a) Sheet resistances versus varying annealing temperature (b) X-ray diffraction pattern

Comparing to Ti silicide, the Ni silicide exhibits a lower sheet resistance of under 2 Ω/☐[6]. In the fabrication of the

SiGe HBT, Ni silicide is formed after patterning of the emitter layer. The region below the emitter and of the rest of base are defined the intrinsic base and the extrinsic base, respectively. The measured sheet resistances of Ti and Ni silicide and of the each extrinsic base, are included in Table I. Ti silicide is formed in the RTP chamber by two step annealing. The first and second annealings are performed at 830 °C for 10 sec, and 850 °C for 30 sec, respectively. But, Ni silicide is formed just one step annealing that is performed at 600 °C for 30 sec. R_{EXB} of the Ni silicided is below 30% of Ti silicided.

Table. I The comparison of the Resistance values between Ti silicided and Ni silicided

Sample	Sheet resistance R_S [Ω/□]	R_{EXB} [Ω/□]
Ti silicidation	15.6	35
Ni silicidation	1.5	9

Figure 3 indicates that the f_T and the f_{max} versus collector current of the Ti silicided and Ni silicided SiGe HBTs. The Ni silicided SiGe HBT showed increased f_T and f_{max} values. This means that Ni silicided SiGe HBT has a decreased R_B. In terms of the two parameters, the f_{max} is more sensitively varied with R_B. Principally, f_T is inversely proportional to the sum of the base transit time, which is influenced by R_B, and f_{max} is significantly increased with the affected factors of f_T and R_B[7]. The SiGe HBT with Ni silicide reveals about 10% improvement in f_T and f_{max} with respect to the sheet resistance and $R_{EXB,}$ that were reduced about 90% and 70%, respectively. Therefore, the base resistance of devices should be reduced to improve f_{max}. In case of our system, the Ni silicide layer with very low sheet resistance was deposited on the Si/SiGe/Si base with 50 nm thickness, and formed at the annealing temperature of 600°C.

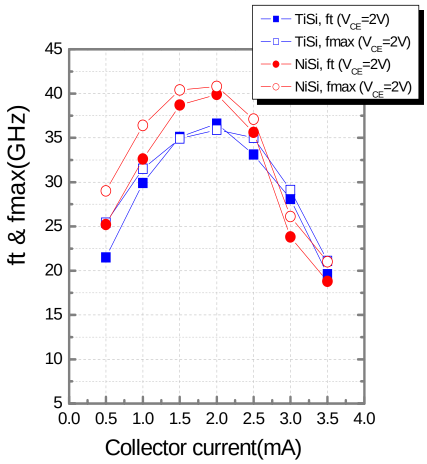

Fig. 3 f_T and f_{max} characteristics of the each fabricated SiGe HBTs with Ti silicidation and Ni silicidation

Cross sectional SEM image of the fabricated SiGe HBT was showed in Figures 4, the contact resistance is reduced because the interface between metal and Ni silicided Si/SiGe/Si layer becomes the low resistive conductive paths which are reduced at the contact region.

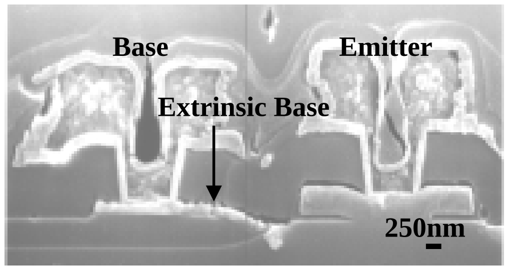

Fig. 4 Cross-sectional SEM image of a silicided region between the base and emitter of SiGe HBT

3. Conclusions

We have fabricated SiGe HBT with Ni silicidation instead of Ti silicidation in order to improve the sheet resistance, specific contact resistivity on Si/SiGe/Si base. As a result, we obtained a HBT with low sheet resistance and $R_{EXB,}$ which enhanced f_{max} and f_T about 10%. Also, the developed Ni silicide contact technology is suitable for the SiGe BiCMOS process, especially in sub-micron devices. In conclusion, RPCVD grown SiGe HBT with enhanced f_{max} and low base resistance has been developed and investigated.

Acknowledgements

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