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Selective Ni removal deposited on Ge at different annealing temperatures

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Introduction

The demand to reduce the power consumption of electronic devices continues to increase. To meet the need for reduced supply power to the transistor, the operating voltage of the transistor has been reduced by further miniaturization of the transistor; however, this has presented some problems e.g. the inability to obtain the necessary electrical current for transistor operation and the increase in leakage current from the shrinkage of the transistor. Ge devices, which have higher mobility than Si, are being investigated and developed. In this study, NiGe, which was made by reaction of Ni and Ge as source-drain electrode, was used in order to achieve low contact resistance between Ni and Ge. The choice of the appropriate chemistry for selective removal of excess Ni to NiGe after annealing is required.

Experiments

Ni was deposited on 300-mm thermal oxide wafers. The wafers were subsequently annealed at varying temperatures with a LEVITOR4300 provided by LEVITECK to observe the property of selective Ni etching. Experiments to evaluate Ni removability were done on a Dainippon Screen SU3100 single-wafer processing tool at varying HCl concentrations, chemical temperatures and processing times. Metal residue concentrations before and after HCl processing were measured by a Rigaku TXRF300. NiGe deposited wafers for observation of selective Ni removability were prepared by depositing 500 nm of Ge on Si, annealing with first RTP, followed by deposition of 8 nm of Ni, and annealed with second RTP. The residual volume of NiGe was obtained by difference measurement of sheet resistance values with KLA Tencor RS100.

Result and discussion

Ni removability using 65 ºC HCl on thermal oxide wafers annealed from 250 ºC to 400 ºC is shown in Fig. 1. As shown in Fig.1, Ni, in the conditions of low annealing temperatures such as 250 ºC and 350 ºC, was removed well upon increasing the processing time. On the other hand, it was impossible to remove the Ni completely at the higher annealing temperature of 400 ºC.

The sheet resistance of NiGe after annealing at several temperatures and before 65 ºC HCl processing is shown in Fig.2. In addition, the difference in resistance value before and after the HCl processing is shown in Fig. 3. As predicted from the result in Fig.2, RTP temperature needs to be more than 350 ºC to achieve low contact resistance. As shown in Fig.3, NiGe, annealed at less than 300 ºC, could be removed easily as predicted from the result that the sheet resistance increased; however, NiGe, with 350 ºC annealing, could not be removed with 65 ºC HCl according to the result from that there was no observed increase or decrease in sheet resistance. Although 400 ºC annealed NiGe also showed no change in sheet resistance like the 350 ºC condition, 400 ºC annealed NiGe was not regarded as an ideal condition for Ni removal selectivity against NiGe since there was no Ni removal as shown in Fig. 1.

Ni_2Ge is the dominant species under condition of 250 ºC annealing; in contrast, NiGe composition with 1:1 ratio is the dominant species at 500 ºC annealing [1]. Hence, Ni_2Ge annealed at 250 ºC has the possibility of the higher contact resistance and faster etching than others. Considering the result in change of NiGe etching property and sheet resistance upon annealing temperature, the annealing temperature is an important parameter to determine the composition of NiGe. NiGe composition would be expected to form NiGe close to 1:1 ratio, as the annealing temperature increases.

Summary

The chemical conditions for removal of excess Ni when NiGe was formed were evaluated. A 350 ºC annealing condition was found to provide the best selective Ni etching, which means it can be achieved with a lower contact resistance using 65 ºC HCl.
It was confirmed that a narrow annealing process window from 350 ºC to 400 ºC is needed to provide a favorable etching selectivity.

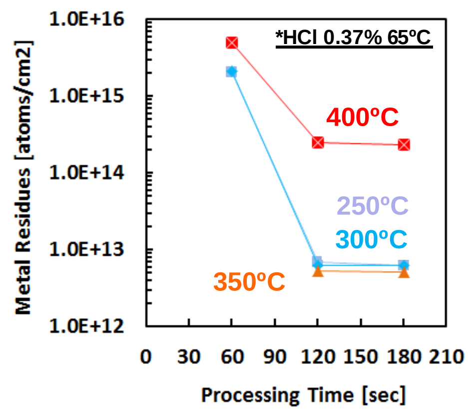

Fig.1 Metal residues as function of processing time

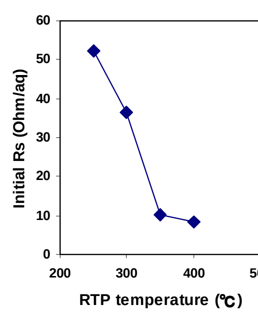

Fig.2 Sheet resistance related with annealing temperature

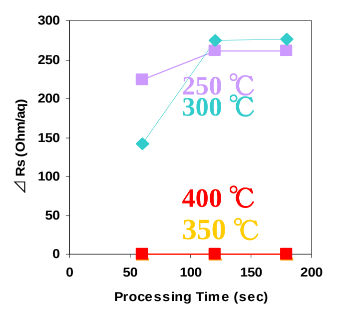

Fig.3 Difference in value of sheet resistance between pre and post wet process

Reference

[1] *Japanese Journal of Applied physics* Vol. 44, No. 45 2005, PP. L1389-L1391