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 °C HCl on thermal oxide wafers annealed from 250 °C to 400 °C is shown in Fig. 1. As shown in Fig.1, Ni, in the conditions of low annealing temperatures such as 250 °C and 350 °C, 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 °C.

The sheet resistance of NiGe after annealing at several temperatures and before 65 °C HCl processing is shown in Fig. 2. As predicted from the result in Fig.2, RTP temperature needs to be more than 350 °C to achieve low contact resistance. As shown in Fig.3, NiGe, annealed at less than 300 °C, could be removed easily as predicted from the result that the sheet resistance increased; however, NiGe, with 350 °C annealing, could not be removed with 65 °C HCl according to the result from that there was no observed increase or decrease in sheet resistance. Although 400 °C annealed NiGe also showed no change in sheet resistance like the 350 °C condition, 400 °C 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.

NiGe is the dominant species under condition of 250 °C annealing; in contrast, NiGe composition with 1:1 ratio is the dominant species at 500 °C annealing [1]. Hence, Ni,Ge annealed at 250 °C 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 °C annealing condition was found to provide the best selective Ni etching, which means it can be achieved with a lower contact resistance using 65 °C HCl. It was confirmed that a narrow annealing process window from 350 °C to 400 °C is needed to provide a favorable etching selectivity.

Reference