

Investigation of the Au-Ge-Ni and Au-Ge-Pt system used for alloyed contacts to GaAs

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Widely used metallization schemes for alloyed contacts to *n*-type GaAs consist of a Au-Ge alloy with a cover layer of Ni or Pt. We have studied the interaction of these elements (Au-Ge and Ni, Au-Ge and Pt) upon heat treatment on an inert substrate. Our results show that Ni and Pt play an active role in contact formation. During heat treatment the Ge diffuses out of the Au into the Ni or Pt layer, respectively, where it forms stable compounds. Due to the fact that Ni and Pt act as a sink for Ge the composition and, as it is shown, the uniformity of the heat-treated layers depend on the ratio of the amount of evaporated Ge to Ni or to Pt.

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INTRODUCTION

Though the electrical properties of Au-Ge-Ni and Au-Ge-Pt contacts have been studied in the past, only little is known about the reaction mechanism of these contacts during the alloying process on GaAs.^{1,2} This is due to the fact that the five-element systems GaAs-Au-Ge-Ni and GaAs-Au-Ge-Pt are very complicated from a point of view of metallurgy. Therefore we simplified the situation and investigated the metallurgy of the Au-Ge-Ni and Au-Ge-Pt system without any interaction with GaAs by using an inert substrate. The results may help to understand what happens when these contact layers are alloyed to a GaAs substrate. In this communication we give a brief summary of our investigations. A detailed report of the Au-Ge-Ni system is published elsewhere.³ Our investigation on the Au-Ge-Pt system is part of a survey we are undertaking on similar triple-layer systems.

Successive films of Au-Ge-Ni in one case and Au-Ge-Pt in the other case were evaporated with an electron gun at pressures of 10^{-6} Torr (10^{-4} Pa) on SiO₂ substrates. Small samples were annealed in a vacuum of 5×10^{-7} Torr (6×10^{-5} Pa) at 450°C for 5 min. The samples were then investigated by 2-MeV ⁴He⁺ backscattering spectrometry and glancing-angle x-ray diffraction.

RESULTS

Au-Ge-Ni system

Figure 1(a) shows the backscattering spectrum of an as-deposited sample of the structure SiO₂/Ge/Au/Ni. For simplicity, the low-energy part of the spectrum containing the signal of the SiO₂ substrate has been omitted. The vertical arrows indicate the energy of ⁴He⁺ particles scattered from surface atoms of the corresponding element. The sample annealed at 450°C for 5 min has the backscattering spectrum shown in Fig. 1(b). The comparison with Fig. 1(a) shows that after annealing, the Ge signal at low energies has disappeared and that the spectrum shows a step at the energy corre-

sponding to the surface location of Ge, indicating that Ge has appeared in the surface layer. Therefore, we assume that Ge diffuses through the Au and mixes with the Ni to form compounds. The presence of these compounds was independently revealed by glancing-angle x-ray diffraction. This can also be established with backscattering spectrometry by etching off the top Ge-Ni layer in dilute HNO₃, which does not attack Au. Figure 1(c) shows the backscattering spectrum of the

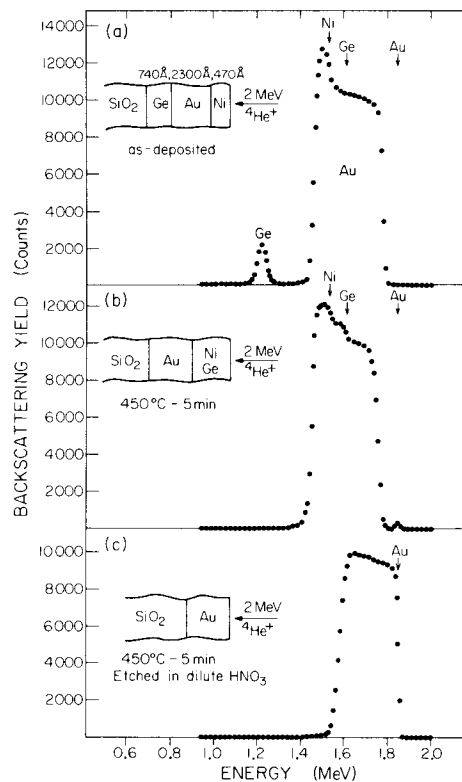


FIG. 1. 2-MeV ⁴He⁺ backscattering spectra of a SiO₂/Ge/Au/Ni sample. The spectra of the substrate has been omitted and the vertical arrows indicate the energy of He particles scattered from surface atoms of the corresponding elements. (a) as-deposited, (b) annealed at 450°C for 5 min., (c) same as (b) but Ge-Ni layer etched off in dilute HNO₃.

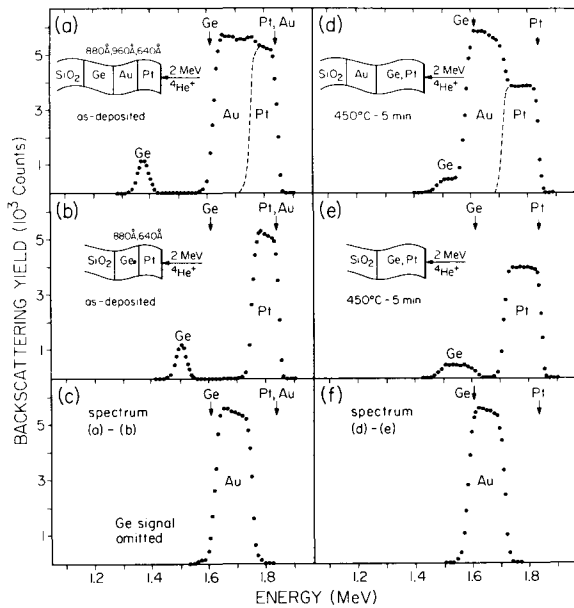


FIG. 2. 2-MeV $^4\text{He}^+$ backscattering spectra of two samples of the same wafer of composition $\text{SiO}_2/\text{Ge}/\text{Au}/\text{Pt}$. The $\text{SiO}_2/\text{Ge}/\text{Pt}$ sample was obtained by protecting part of the wafer with a shutter during the Au evaporation. The spectrum of the substrate has been omitted and the vertical arrows indicate the energy of He particles scattered from surface atoms of the corresponding elements. (a) $\text{SiO}_2/\text{Ge}/\text{Au}/\text{Pt}$ sample as-deposited, (b) $\text{SiO}_2/\text{Ge}/\text{Pt}$ sample as-deposited, (c) spectrum (b) subtracted from spectrum (a) to reveal the Au signal, (d) sample of (a) annealed at 450°C for 5 min., (e) sample of (b) annealed at 450°C for 5 min., (f) spectrum (e) subtracted from spectrum (d).

etched sample. Only the Au signal is left. The absence of any Ge signal demonstrates that there is no Ge dissolved in the Au within the resolution limit of better than 0.5%. Thus all the Ge has been absorbed in the Ni layer.

The investigation of a sample of the composition $\text{SiO}_2/\text{Ni}/\text{Au}/\text{Ge}$ showed that Ge diffuses also from a location at the surface of the triple layer through the Au to form compounds with a Ni film lying under the Au film on the SiO_2 substrate. The phases of the compounds were identified with glancing-angle x-ray diffraction as Ni_2Ge and NiGe .

As long as all the Ge can be accommodated by the Ni, the layer as a whole remains uniform. However, if more Ge is used than can be absorbed by the Ni in form of NiGe , the layer becomes laterally nonuniform.

Au-Ge-Pt system

In practice, the Ni top layer is sometimes replaced by Pt and it is interesting to know whether the same interactions take place with Pt during the heat treatment as are observed in the case of the Au-Ge-Ni system.

Figure 2(a) shows the backscattering spectrum of an as-deposited sample of the composition $\text{SiO}_2/\text{Ge}/\text{Au}/\text{Pt}$. During the Au evaporation, part of the wafer was protected with a

shutter. The backscattering spectrum of that part is shown in Fig. 2(b). From these two spectra the thickness of the Pt film can be calculated. This is not possible from Fig. 2(a) alone because Pt and Au can not be distinguished in a backscattering spectrum due to the similar mass of these two atoms. If we subtract the Pt signal of Fig. 2(b) from the Pt and Au signal of Fig. 2(a), we get the signal shown in Fig. 2(c), which is that of the Au contained in the spectrum of Fig. 2(a). From this signal we can calculate the exact thickness of the Au film. The annealed sample with the Au layer has the backscattering spectrum of Fig. 2(d). Again we see that the Ge signal has disappeared from its original position. The annealed sample without the Au layer has the backscattering spectrum given in Fig. 2(e). By comparing this spectrum against that of Fig. 2(b), it is readily seen that the Ge and Pt are uniformly mixed in this case. Glancing-angle x-ray diffraction reveals that platinum-germanides have been formed. If we subtract the spectrum of Fig. 2(e) from that of Fig. 2(d), the spectrum of Fig. 2(f) results. The signal obtained in this fashion has exactly the same shape as that of the Au in Fig. 2(c). This therefore indicates that the Au film remains essentially unaltered and that no appreciable amount of Ge is dissolved in the Au film. All the Ge formed compounds with the Pt as if the Au film was not present.

Laterally uniform Au-Ge-Pt contact layers are obtained after annealing if the atomic percentage of Ge is less than that of Pt. If more Ge is present initially than can be absorbed by the Pt, the layer becomes nonuniform.

CONCLUSION

In conclusion, we have shown that Ni and Pt behave in similar fashion as far as the present study is concerned. With limited amounts of Ge present, the Au plays a passive role during heat treatment. Ge diffuses through the Au and forms compounds with both the Ni or the Pt. The uniformity of the heat-treated layers depend on the ratio of the amount of evaporated Ge to Ni or Pt.

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