Nd-YAG laser alloying of ohmic contacts on P-InP

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Good ohmic contacts of P-InP/AuSb + AuZn + Au have been prepared by Nd-YAG pulse laser irradiation instead of thermal alloying. The best results of the specific contact resistance ($8.6\times10^{-5}\ \Omega\cdot cm^2$) achieved by laser irradiation are better than ($1.6\times10^{-4}\ \Omega\cdot cm^2$) by thermal alloying. The interface morphology is also improved by the laser irradiation. A peak of Zn distribution near the interface is discovered by AES analysis. Low contact resistance can be explained by the increase of the probability of carrier tunneling through the whole barrier.

I. INTRODUCTION

The qualities of ohmic contacts are of great importance in determining the characteristics of III-V semiconductor devices. Among the III-V semiconductors, it is very difficult to obtain ohmic contacts of low resistance for P-InP because of the relatively high potential barriers and the relatively low concentrations of activation by Zn. Hence the research and development of better P-InP ohmic contacts is of great importance with many practical applications. In laser alloying, the samples are treated by laser beams for short periods of time. The heating is localized to only a thin layer under irradiation. There is no effect on other parts of the devices. Furthermore, the process also improves the contact between the metal and the semiconductor and prevents the fusion of the metal into spherules. There is also less diffusion between the metal and the semiconductor. Recently, there have been many reports on the successful uses of laser light irradiations for fabrications of ohmic contacts.[1,2] However, there have been very few studies on the fabrications of ohmic contacts for P-InP materials. In our present work, we report on the experimental results for the fabrications of superior ohmic contacts on P-InP by alloying with Nd-YAG laser light pulses.

II. EXPERIMENTAL PROCEDURES

The sample materials are *n*-InP single crystals (doped with Sn) along the (100) direction. *P* layers are formed by Zn diffusion. The carrier concentration is $1–2\times10^{18}\ cm^{-3}$ as measured by the Van der Pauw method. After chemical cleaning and etching by 1% bromine in methanol solution, the samples are placed in the vacuum system. Using three sources of evaporation, the layers are 200 Å of AuSb alloy (1 wt% Sb), 800 Å of AuZn alloy (10 wt% Zn) and 1000 Å of Au. The pressure of the vacuum system is 5×10^{-6} torr before evaporation. The substrate temperature is 100 °C.

The samples are divided into two groups. Conventional thermal alloying is used for one group. The samples are quickly heated to 420 °C in a N_2-H_2 (3:1 ratio) gas mixture and then quickly cooled.

For the other group, the samples are alloyed by irradiation with focused beams from an Nd-YAG pulsed laser. The pulse width is less than 20 ns. The wavelength is 1.06 μm. The beam spot size is controlled by a lens. The diameter is 0.26 cm. The laser light energy density is 0.8–1.3 J/cm^2. The pulse rate is two per second.

The samples are fixed on the sample mount. Horizontal sweeps are by electric motors. The motor speeds are controlled by variable voltage transformers. The sweep rate is 0.012 cm/s. The manual vertical sweep is 0.038 cm each time. The overlap is greater than 85% between adjacent sweeps.

The Kuphal method[3] is used to measure the contact resistivity p_c for samples irradiated at different laser-light energy densities. Auger electron spectroscopy (AES) is used to analyze the compositions at cross sections of samples before alloying and after irradiation at optimum laser-light energy density.

III. EXPERIMENTAL RESULT AND DISCUSSION

The vapor pressure of Zn is relatively high and the evaporation temperature is relatively low. In contrast, the vapor pressure of Au is relatively low and the evaporation temperature is relatively high. During the vacuum deposition of the AuZn alloy, there is preferential evaporation of Zn initially, and there is poor adhesion between the metal and the substrate. In our present work, we have first deposited a ~200 Å layer of AuSb alloy before the 800 Å layer of AuZn alloy. There are improvements in the adhesions of the metallic layers as well as substantial decreases in the contact resistivities.

The variation of the contact resistivities of our samples with laser light energy densities is shown in Fig. 1. After laser light irradiations, the contact resistivity p_c would decrease initially as the energy density n(J/cm^2) increases. After reaching the minimum, the resistivity would again increase as the energy density increases. Initially, at very low levels of laser light irradiation, the energies are not sufficient to form the transition layers of the mixed crystals of metals and semiconductors. Hence the contacts are similar to mechanical contacts and the values of p_c are very large. As the laser light-energy density increases, there would be gradual melting of InP. When the energy density reaches ~1 J/cm^2, then a re-crystallized layer would form in the process of melting and re-crystallization. The value of p_c would reach the minimum of 8.6×10^{-5} $\Omega\cdot cm^2$. On further increases of laser-light energy densities, the sample temperatures would be too high such that InP near the boundary surface would decompose and there would be significant mutual diffusions among the various layers. The temperature may be so high that the InP surface may be destroyed and the contact resistivity would increase. In Figs. 2 and 3, AES analysis results are shown for samples before alloying and after optimum alloying by laser-light irradiation. It may be seen that for the sample irradiated by laser light, the time of heating is very short and the high-temperature region is only limited to the boundary between the metal and the semiconductor. At the boundary, the reaction layer is very thin and there is no obvious diffusion. Near the metal-semiconductor boundary, there is a distribution peak for Zn concen-

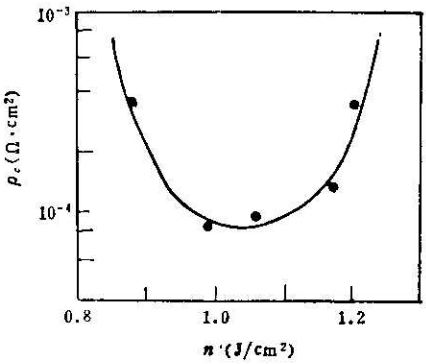

FIG. 1. The variation of contact resistivity p_c with the laser-light energy density. n(J/cm^2) P-InP/AuSb + AuZn + Au.

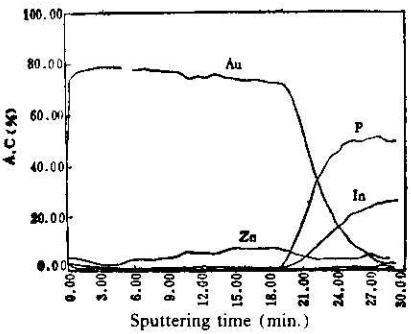

FIG. 2. Auger electron spectroscopic analysis for sample before alloying. P-InP/AuSb + AuZn + Au.

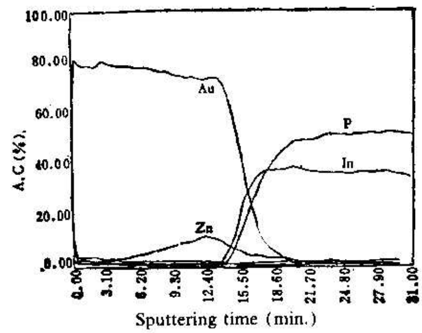

FIG. 3. Auger electron spectroscopic analysis for sample after optimum alloying using the Nd-YAG laser light. P-InP/AuSb + AuZn + Au.

tration which corresponds to the re-crystallization layer with large dopant concentrations and higher probabilities of carrier tunneling through the barrier. Hence we have superior ohmic contact characteristics. Further improvements on the uniformities and reproducibilities of alloying can be made by increasing the overlapping areas between adjacent sweeps with the concomitant lowering of laser-light energy densities.

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