Electrical characteristics of Al foil/Si junctions by surface activated bonding method

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***Abstract*—**We successfully fabricated Al-foil/p-Si junctions by surface activated bonding (SAB). We found that the junctions revealed Schottky properties by measuring their current-voltage characteristics. We also found that the reverse-bias current of the junctions was decreased, i.e., their electrical characteristics were improved by annealing at temperatures below 200 °C. These results demonstrate that the bonding of metal foils should be useful for fabricating several-ten-μm-thick electrodes.

Keywords- surface activated bonding; Si; Al foil; thick film electrode

Ⅰ. INTRODUCTION

Thick (low-resistance) elctrodes and wiring are essential for realizing low-loss operations of high-power devices and circuits with large-current and/or high-voltage capability. It is noteworthy, however, that a long period is required for fabricating thick metal films on semiconductor substrates by evaporation or sputtering due to the low rate of depostion. Furthermore we must note that a marked environmental burden occurs in processing wastes in electroplating although metal films are deposited with higher rates.

Junctions of dissimilar materials are fabricated by using a various kind of wafer bonding technologies, among which the surface activated bonding (SAB) [1] is advantageous since it is applicable for bonding samples with different lattice constants, thermal expansion coefficients, and crystal structures in a short period. The I-V characteristics of SAB based Si/Si, Si/GaN, and Si/InP junctions were reported[2-3]. Au/Au, Al/Al and Cu/Cu junctions were also made by using the SAB [4-6]. In the present study, we investigated the possibility of metal foils as thick electrodes on semiconductor substrates by applying the SAB for bonding Al foils and Si substrates.

Ⅱ. EXPERIMENTS

We prepared B-doped p-Si (100) substrates and commercially-available aluminum (Al) foils with a thickness of 38 μm. The resistivity and doping concentration of the Si substarates were estimated to be 0.1 $\Omega\cdot$cm and 2.4×10^{17} cm^{-3} respectively, by the Hall effect measurement at room temperature. Ohmic contacts on the back sides of the Si substrates were prepared by evaporating Al/Ni/Au multilayers and annealing for 1 minute at 400 °C in a nitrogen ambient. Then we fabricated Al/p-Si junctions by bonding the Si substrates and the Al foils. We prepared 1.5 mm × 1.5 mm electrodes by photolithography and ≈ 20-hour wet etching of the Al foils. We used a mixture of H_3PO_4, HNO_3, CH_3COOH, and H_2O with a volume ratio of H_3PO_4: HNO_3: CH_3COOH: H_2O = 16: 1: 2: 1 as etchant. Then we evaporated Ti/Au pads on the surfaces of Al foils. The electrical properties of the junctions were investigated by measuring their current-voltage (*I-V*) characteristics at room temperature after they are annealed in a nitrogen ambient. An Agilent B2902A Precision Source/Measure Unit was employed. The schematic cross section of Al/p-Si junctions as well as the diagram of measurement is shown on Fig. 1.

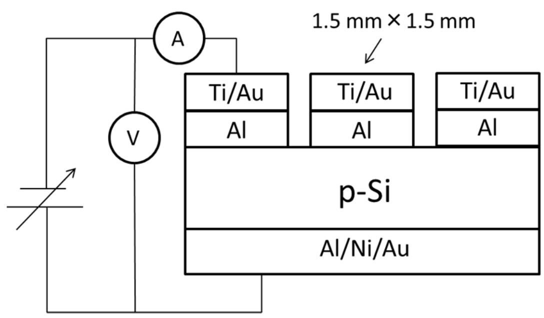

Fig.1 Schematic cross section of Al/p-Si junction and diagram of measurement.

Ⅲ. RESULTS AND DISCUSSION

Figure 2 shows the *I-V* characteristics of the Al/p-Si junctions annealed at 100 and 200 °C for 1 min. Results for junctions without being annealed are also shown for comparison. The respective curves revealed rectifying (Schottky) properties, which is consistent with the fact that the electron affinity of Si (4.05 eV) and the work function of Al (4.1 eV) are comparable to each other [7]. The reverse-bias current at -2.0 V was found to be 8.3×10^{-3}, 6.4×10^{-3}, and 3.1×10^{-4} A/cm^2 for the junctions without being annealed and those annealed at 100 and 200 °C, respectively. We also found that humps in the forward-bias characteristics at ~0.2 V disappeared due to the annealing. These results suggest that the electrical properties of the Al-

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foil/p-Si bonding interfaces were improved by the annealing and the SAB of metal foils is promising electrodes with a thickness of several-ten µm.

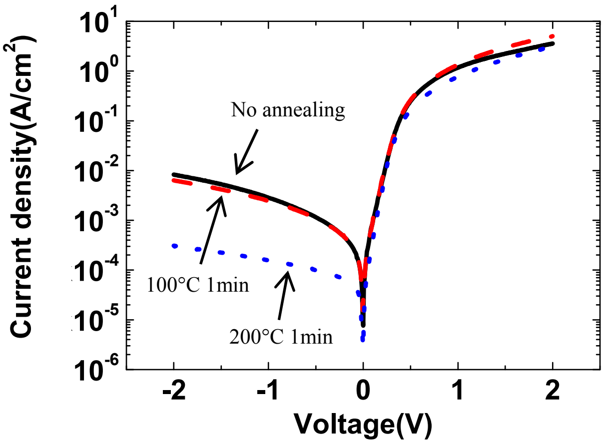

Fig.2 *I-V* characteristics of the Al foil/p-Si junctions at room temperature after annealings with the respective conditions.

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