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Impacts of annealing on interfaces of Al foil/Si junctions by using surface activated bonding

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Abstract

We investigated impacts of annealing on Al foil/Si (100) junctions that were fabricated by using surface activated bonding. By performing X-ray photoelectron spectroscopy analyses as well as scanning electron microscope/energy dispersive X-ray spectrometry observations, we found that Al was diffused into the Si substrate and Si and Al reacted across the bonding interfaces when the junctions were annealed at temperatures higher than 800 °C.

1. Introduction

Thick (low-resistance) electrodes 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 with different lattice constants, thermal expansion coefficients, and crystal structures are fabricated by using the surface activated bonding (SAB) [1] since samples are bonded at low temperatures in the dry process. We previously reported on the possibility of metal foils as thick electrodes on semiconductor substrates by bonding Al foils and Si substrates using the SAB [2]. In this study, we investigated impacts of annealing on interfaces of Al foil/Si junctions.

2. Experiments

We prepared Al-foil/Si junctions by bonding 35-µm-thick Al foils and P-doped n^+-Si (100) substrates. We annealed the junctions at 400, 500, 600, 800 and 1000 °C for 1 min. in the N_2 ambient. We confirmed that the peeling of bonded Al foils was not observed although their surfaces got rougher due to the annealing at higher temperatures. After annealing, we removed Al foils by wet etching using a mixture of H_3PO_4, HNO_3, CH_3COOH, and H_2O (H_3PO_4: HNO_3: CH_3COOH: H_2O = 16: 1: 2: 1 in a volume ratio). We performed X-ray photoelectron spectroscopy (XPS) analyses on the surfaces of the Si substrates.

We also fabricated Si/17-µm-thick Al foil/Si junctions by bonding Al foils and Si substrates twice. The schematic cross section of the junctions is shown in Fig. 1. We annealed the junctions at 1000 °C for 1 min. in the N_2 ambient. The sides of the junctions before and after annealing were exposed by polishing. We characterized the interfaces by using the scanning electron microscope (SEM) and the energy dispersive X-ray spectrometry (EDS).

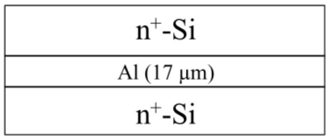

Fig. 1. Schematic cross section of n^+-Si/Al foil/n^+-Si junction.

3. Results and Discussion

Figure 2 shows XPS spectra around 76 eV, which corresponds to the binding energy of Al 2p level, of each Si substrate after removing the Al foil. Clear peaks were observed for samples annealed at 800 and 1000 °C.

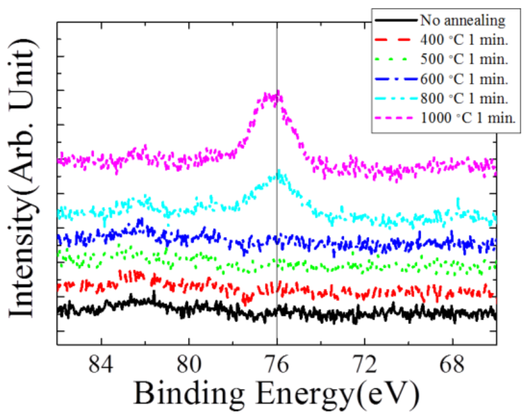

Fig. 2. Al 2p core-level spectra of Si substrates that were prepared by annealing Al-foil/Si junctions and removing Al foils.

Figure 3 shows SEM images of the Si/Al foil/Si junctions before and after the 1000 °C annealing. We find that the Al foils is swollen by 5 µm and the Al/Si interface is vague after the 1000 °C annealing. The EDS mapping images of Al and Si signals in the Si/Al foil/Si junction after the 1000 °C annealing are shown in Fig. 4, which indicates that the Al foil is partly replaced by Si grains.

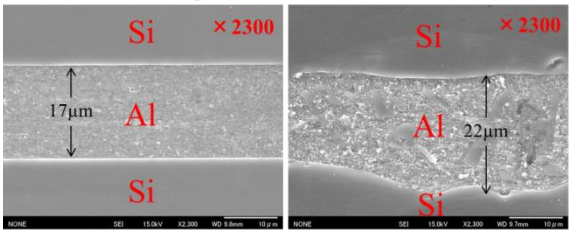

Fig. 3. SEM images of Si/17-μm Al foil/Si junctions before and after annealing at 1000 °C for 1 min.

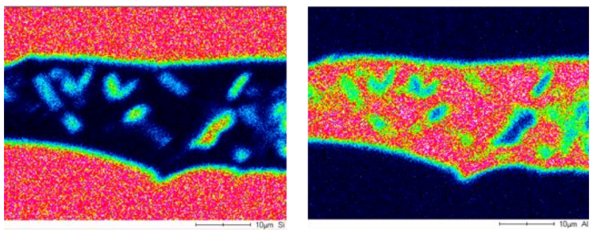

Fig. 4. EDS mapping images of Si and Al signals in the Si/Al foil/Si junctions after the 1000 °C annealing for 1 min.

These results suggest that Si substrates and Al foils react when the Al foil/Si junctions are annealed at temperatures higher than 800 °C. The interaction is likely to induce the rough surfaces of bonded Al foils.

4. Conclusion

The impacts of annealing on Al-foil/Si junctions that were prepared by using SAB were examined. The XPS analyses showed that Al atoms were diffused into Si substrates when the junctions were annealed at temperatures higher than 800 °C. The SEM/EDS observations indicated that Si grains were driven into the Al foils and the Al foils got swollen when the junctions were annealed. The interaction between Al foils and Si substrates is likely to induce the rough surfaces of bonded Al foils.

Acknowledgements

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References

[1] J. Liang, et al. Appl. Phys. Lett. **110** (2017) 111603.
[2] J. Liang, et al. ECS Transaction. **75** (2016) 25.