Evaluation for the Influence of Impurities in Graphite Parts on Single Crystal Silicon

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Introduction

Heavy metals strongly influence the electrical characteristics of devices. With further increases in integration density, the device fabrication area is one of high activity with the aim of reducing contamination levels still further. However, at higher levels of device integration, the contribution of impurities incorporated during the Czochralski (CZ) growth process itself may play a more significant role in determining the final device quality.

Graphite parts, which were crucibles, heaters and insulators, were used in the CZ furnaces for producing single crystal silicon. The quality of CZ grown single crystal silicon was influenced with metal impurities. One origin of metal impurities is graphite parts in the CZ furnaces (Figure 1). It is known that out-gassing of contaminants from the graphite parts influences the silicon crystal. However, it was not confirmed the evaluation method for the influence of impurities in graphite materials on single crystal silicon.

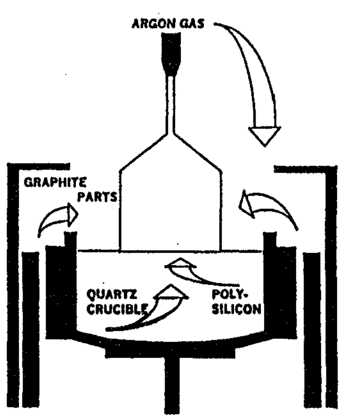

Figure 1. Origins of metallic impurities in CZ-silicon.

In this research, the experimental evaluation technique for the contamination of the single crystal silicon by metal impurities in graphite materials was developed and it was confirmed the relationship between the minority carrier recombination life time in single crystal silicon and metal impurity levels in graphite materials.

Experimental

4" graphite discs, 1mm in thickness, were manufactured with different metallic impurities concentrations. Impurity concentration of typical graphite materials (A:conventional high pure grade, B:super high pure grade) in this research was shown in Table1. These different graphite materials were evaluated by the developed method.

Table 1. Impurity concentration of typical graphite samples by neutron activation analysis.

Sample		A	B
Content (ppm)	Al	<0.1	<0.04
	Fe	0.19	<0.03
	Ni	<0.1	<0.1
	Cr	0.007	<0.0005
	Cu	<0.03	<0.0007
	Na	0.24	<0.007
	K	<0.02	<0.003

A graphite disc, along with a pre-oxidized monitor wafer, was placed in a special quartz boat (Figure2). The contents of a boat were isolated by means of a quartz cover. Here were then annealed at 400~1200℃ for 2hours in a argon ambient. The heat-treatment was carried out in a horizontal diffusion furnace. After heat-treatment, the monitor wafer's minority carrier lifetime was measured. This procedure was carried out for each of 5 test-pieces in each disc category.

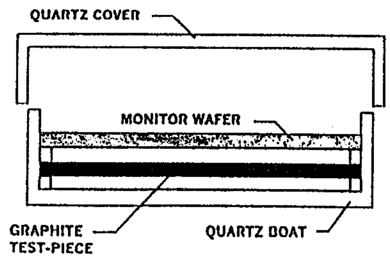

Figure 2. Quartz boat used in graphite's high temperature evaluation process.

The average lifetime value for each disc category was obtained and this was then used in the analysis of results. Monitor wafers were 4", N type, resistivity of 8-10 Ω cm and (100) in orientation.

Post heat-treatment analysis of the monitor wafer's oxide layer was also carried out using atomic absorption spectroscopy methods, to evaluate the incorporated impurity content. In addition, the monitor wafer without pre-oxidation analyzed by total reflection X-ray fluorescence analysis and secondary ion mass spectroscopy (SIMS).

Results and Discussion

In the evaluation method by using the special quartz boat within a graphite disc and a monitor wafer, it was also simulated that silicon monitor wafers were polluted by graphite materials like in CZ-furnace. The change lifetime of wafer was confirmed with the different metallic impurities concentration levels in graphite materials (Figure3).

As the result of the temperature dependence of lifetime with the conventional pure graphite parts material, lifetime decreased gradually over 1000 ℃ (Figure 4). It indicated that impurities in graphite parts which were used over 1000 ℃ polluted silicon single crystal. Therefore, it is necessary to be used higher purity graphite parts at high temperature region.

The carbon penetration into the silicon wafer by graphite materials and CVD coated graphite material was confirmed by SIMS. Although the penetration with CVD coated material was less than that with graphite materials, it was founded that the carbon penetration was also influenced with the purity in graphite materials.

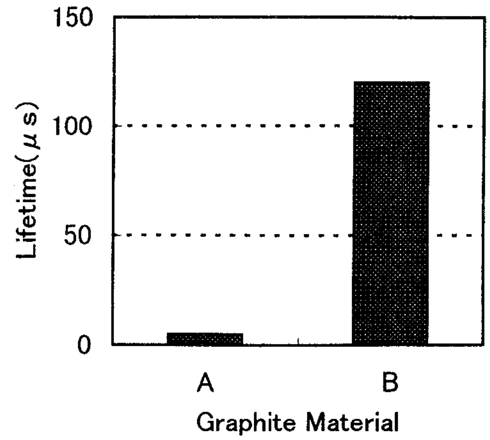

Figure 3. Results of lifetime measurement of monitor wafers heat-treated with graphite discs at 1200℃.

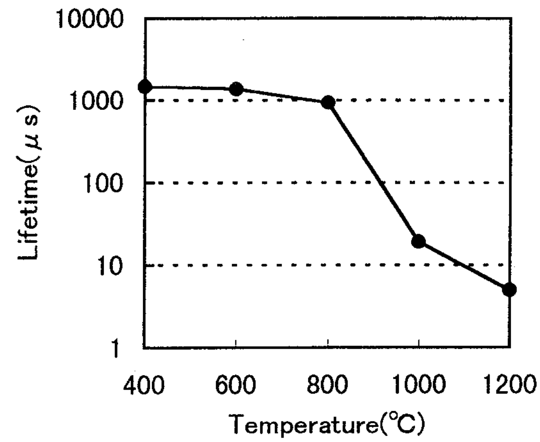

Figure 4. Results of lifetime measurements in monitor wafers heat-treated with graphite sample A at high temperature .

Conclusions

It was possible to evaluate the influence of impurities in graphite materials on single crystal silicon by using special quartz boat with graphite disc and a monitor wafer. It was concluded that single crystal silicon was influenced with the purity in graphite materials over 1000℃ and the purity of graphite parts for CZ-furnaces was very important factor especially at high temperature.