Growth Technology for 200 mm Antimony Heavily Doped Silicon Single Crystals

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With the development new types of electronic power devices, the demand has increased for large diameter heavily antimony doped silicon. The atom diameter of antimony is 15% larger than that of silicon, resulting large lattice mismatch. The segregation coefficient of antimony in silicon is low, making it very difficult to obtain crystal with required resistivity. Crystal growth 200 mm heavily doped antimony silicon with low resistivity and high yield remains one of the toughest challenges for the industry. This paper investigated crystal growth process of 200 mm heavily antimony doped silicon crystals. A new doping method was developed. Argon flow pattern and pressure control was modified for better process conditions.

Experimental

KX-150 crystal puller with 22" hot zone was used in the development. Silicon charge sizes of 90-100 kg were used. Graphite heat shield was applied.

This work designed a new quartz tool to steadily add vapor phase antimony into silicon melt. Antimony vapor created under high temperature flow directly onto silicon melt surface through a specially designed quartz mouth piece. Antimony was absorbed by silicon melt surface and diffused into bulk melt. By controlling the inside temperature of the quartz tool and furnace pressure, all antimony is smoothly doped into silicon melt without any splash. Six 9 pure antimony of 350-500 grams were doped.

Results and Discussion

Under the same power level, different furnace pressures resulted in different amount time needed for the same amount dopant to evaporate. Doping completed faster with lower furnace pressure.

Different heat shields were constructed. Under same doping and crystal pulling conditions, heat shield I produced crystals with increasing resistivity along crystal growth direction. The resistivity profile was different from that of a normal segregation coefficient of 0.023 for antimony. Heat shield II produced crystals with decreasing resistivity along crystal growth direction. The resistivity profile followed a pattern resulted from a segregation coefficient of less than 1.0. Heat shield I forced all argon gas to flow by the silicon melt surface while heat shield II allowed only partial argon flow to pass by the silicon melt surface. Heat shield II greatly reduced the impact of argon flow on antimony evaporation. More dopant was able to incorporated into crystal rather than evaporated.

Heat shield II produced crystals with resistivity decreasing along growth direction. However, the resistivity profile suggested more control over antimony evaporation is needed even with better argon flow pattern. Different furnace pressures were tested in efforts to lower crystal resistivity even further. Figure 1 shows the resistivity profile with 4 kinds of growth process. Results showed deceleration rate of resistivity along growth direction are different with different pressure. With higher furnace pressure, resistivity of most portion of the crystal was controlled under 0.02 Ωcm, achieving requirement from most device manufacturers.

Conclusions

Vapor doping technique was feasible and effective for heavily antimony doped silicon crystal growth. It created better growth environment and resulted better yield. With better hot zone design including heat shields, along with pressure control and other optimized growth parameters, heavily antimony doped 200 mm silicon with resistivity less than 0.02 Ωcm can be produced with high efficiency.

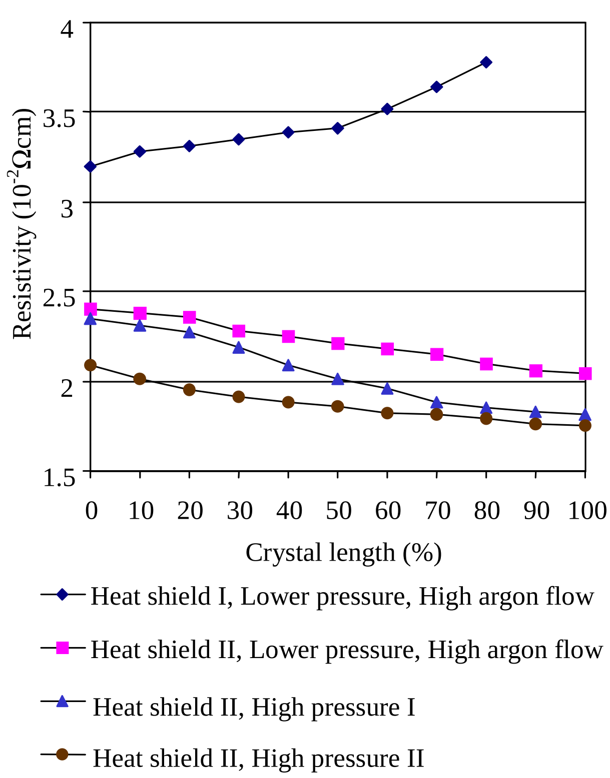

Figure 1 Resistivity profiles along with the crystal growth direction