An investigation into interfacial oxide in direct silicon bonding.

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Silicon–silicon bonding has its application in the manufacture of PIN diodes and IGBT transistors, using layers of single crystal silicon with different electrical characteristics. Deposited silicon (epitaxy) is currently used to make silicon layers of differing resistivity; however single crystal silicon has fewer defects, while thick epitaxial silicon can be expensive to produce. Silicon to silicon bonding allows layers of different electrical characteristics to be produced in one substrate, increasing the reliability of the product. Epitaxy requires a thermal cycle for deposition, which makes the production of diodes without an interfacial oxide difficult (1).

In this work we have used Transmission Electron Microscopy (TEM) to image the joined interface for both hydrophilic and hydrophobic direct silicon bonding. The factors investigated included annealing temperature, oxygen content in the silicon, and the doping level. Samples were prepared by joining polished silicon device wafers to polished silicon handles. The joined pairs were annealed at temperatures between 400°C and 1200°C, and the device wafers thinned by grinding and polishing. The interfaces were analyzed for interfacial oxide and crystalline defects using a high resolution TEM. SIMS was used to analyze the oxygen, carbon and dopant profiles along the interface. The electrical characteristics and movement of impurities across the bonded interface were investigated with a spreading resistance probe (SRP).

In this paper, direct silicon bonding with very low levels of interfacial oxide is presented. The mechanisms controlling the presence of oxide and the characteristics of the oxide after anneal are investigated. The interfacial oxide originates from the native oxide and begins to form islands at above 1100°C(2). Migration of the interfacial oxide as a function of temperature, and the formation of small oxide islands at the joined interface under high temperature annealing will be described. The non-symmetrical formation of oxide islands as a function of doping concentration and material type is also presented, as well as the effect of oxygen content in Cz and FZ material.

(1). G.R. Wolstenholme, N. Jorgensen, P. Ashburn, G.R. Booker. J. Appl. Phys. 61 91), Jan 1987.

(2) W.A. Nevin, D.L. Gay, V. Higgs, 5th int. Symp. Semiconductor Wafer bonding, Oct 1999.

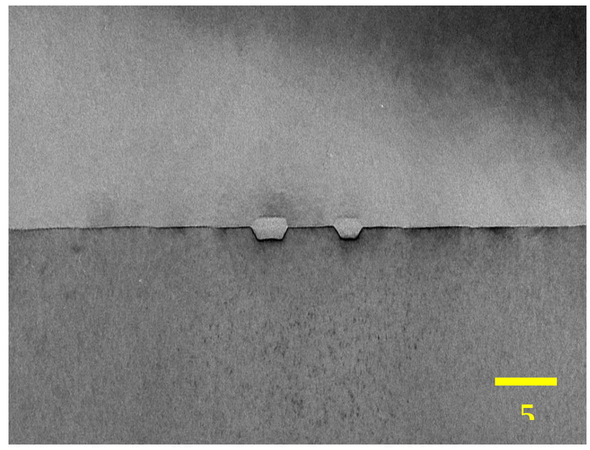

Figure 1 Oxide Islands between joined silicon layers. (5nm scale)

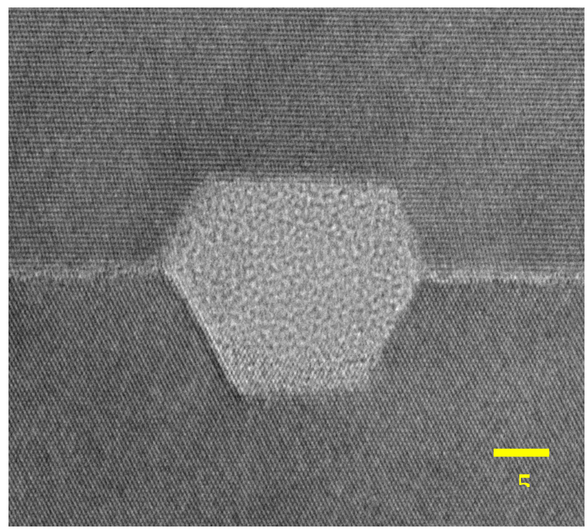

Figure 2 Oxide island showing preferential growth on highly doped Cz material. (5nm scale)