Abstract

High-resistivity silicon (HRS) substrates are important for low-loss, high-performance microwave and millimeter wave devices in high-frequency telecommunication systems. The highest resistivity of up to ~10,000 ohm.cm is Float Zone (FZ) grown Si which is produced in small quantities and moderate wafer diameter. The more common Czochralski (CZ) Si can achieve resistivities of around 1000 ohm.cm, but the wafers contain oxygen that can lead to thermal donor formation with donor concentration significantly higher (~$10^{15}$ cm$^{-3}$) than the dopant concentration (~$10^{12}$-$10^{13}$ cm$^{-3}$) of such high-resistivity Si leading to resistivity changes and possible type conversion of high-resistivity p-type silicon. In this research capacitance–voltage (C–V) characterization is employed to study the donor formation and type conversion of p-type High-resistivity Silicon-On-Insulator (HRSOI) wafers and the challenges involved in C-V characterization of HRSOI wafers using a Schottky contact are highlighted. The maximum capacitance of bulk or Silicon-On-Insulator (SOI) wafers is governed by the gate/contact area. During C-V characterization of high resistivity SOI wafers with
aluminum contacts directly on the Si film (Schottky contact); it was observed that the maximum capacitance is much higher than that due to the contact area, suggesting bias spreading due to the distributed transmission line of the film resistance and the buried oxide capacitance. In addition, an “S”-shape C–V plot was observed in the accumulation region. The effects of various factors, such as: frequency, contact and substrate sizes, gate oxide, SOI film thickness, film and substrate doping, carrier lifetime, contact work-function, temperature, light, annealing temperature and radiation on the C-V characteristics of HRSOI wafers are studied.

HRSOI wafers have the best crosstalk prevention capability compared to other types of wafers, which plays a major role in system on chip configuration to prevent coupling between high frequency digital and sensitive analog circuits. Substrate crosstalk effect in HRSOI and various factors affecting the crosstalk, such as: substrate resistivity, separation between devices, buried oxide (BOX) thickness, radiation, temperature, annealing, light, and device types are discussed. Also various ways to minimize substrate crosstalk are studied and a new method is proposed.

Owing to their very low doping densities and the presence of oxygen in CZ wafers, HRS wafers pose a challenge in resistivity measurement using the conventional techniques such as Four-Point Probe and Hall measurement methods. In this research the challenges in accurate resistivity measurement using four-point probe, Hall method, and C-V profile are highlighted and a novel approach to extract resistivity of HRS wafers based on Impedance Spectroscopy method using polymer dielectrics such as Polystyrene and Poly Methyl Methacrylate (PMMA) is proposed.