Factors affecting stress-induced defect generation in trenched SOI for high-voltage applications

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Trench isolated fusion bonded silicon-on-insulator (SOI) is becoming an important commercial substrate for the fabrication of high-voltage electronic devices, used in areas such as telecommunications, displays and smart power. The technology gives a number of advantages over conventional substrates, including improved electrical performance, high quality and versatility of the silicon layer type, and substantial scope for die shrinkage. However, a major obstacle to extending the range of breakdown capability to higher voltages is the generation of slip dislocations in the SOI layer at filled trenches, which occurs as a result of increasing levels of stress in the silicon with increasing thickness of the sidewall oxide. This usually happens during thermal cycling of the structures at high temperature. We have recently reported (1) that the generation of slip is strongly dependent on the doping type and concentration of the silicon material. In addition, we found that the material is weakened by incorporation of a buried implanted layer of dopant at the bottom of the SOI layer, which is typically included to improve the electrical performance of high voltage devices. In this work, we have further examined the effect of buried implants, as well as investigating various structural and material aspects of slip generation in SOI.

Samples were prepared by joining polished silicon device wafers to oxidised polished silicon handles, bond annealing at high temperature, and thinning the device wafers by grinding and polishing. The SOI layers were then trenched to the buried oxide by inductively coupled plasma etching, lined with a thick LPCVD oxide layer, and the centres of the trenches filled with polysilicon. In some cases, a doped layer was diffused into the trench sidewall, and/or a buried doped layer was formed by blanket implanting into the surface of the device wafer before joining. The structures were thermally stressed at various stages of the refill process by high-temperature annealing cycles, in order to induce the propagation of slip dislocations from the trench corners. The degree of generated slip was analysed by phase sensitive Normarski optical microscopy, and by Secco etching of cross sections. In addition, TEM, AFM and SIMS were used to examine the structure and composition of the silicon-silicon oxide interfaces.

We found that the buried implant concentration had a large impact on the ease of slip generation from the corners of filled trenches. Thus, for the same oxide liner thickness, slip occurred in samples with an arsenic dose of $5x10^{15}$ atoms/cm^2, while no slip was seen in unimplanted SOI or with a $3x10^{13}$ atoms/cm^2 dose. The different slip behaviour appears related to the presence of a band of crystalline precipitates observed in the high-dose implanted SOI, running parallel to the bonded interface at a distance of about 50 nm above it, which is the region where the implanted atoms are expected to lie. This is shown in the TEM image of Fig. (a). In contrast, no precipitates were seen in a sample with a low arsenic implant dose, as shown in Fig. (b). The degree of generation of slip was found to be dependent on a number of other parameters, including the material composition, SOI thickness, trench density, trench shape and concentration of sidewall doping species.

In this paper we will discuss the nature and conditions of formation of the precipitates, as well as the influence of the other parameters on slip generation. By controlling the composition of the silicon material and the pre-bond processing conditions of the device wafer, we were able to achieve slip-free thick oxide refilled trenched structures capable of withstanding high-temperature cycling without slip generation, even with the incorporation of high-dose buried implanted layers.

(1) W.A. Nevin, K. Somasundram, S. Blackstone, S. Magee and A.T. Paxton, in *High Purity Silicon VI*, C.L. Claeys, P. Rai-Choudhury, M. Watanabe, P. Stallhofer and H.J. Dawson, Eds., PV2000-17, p. 524 (Electrochemical Society, 2000).

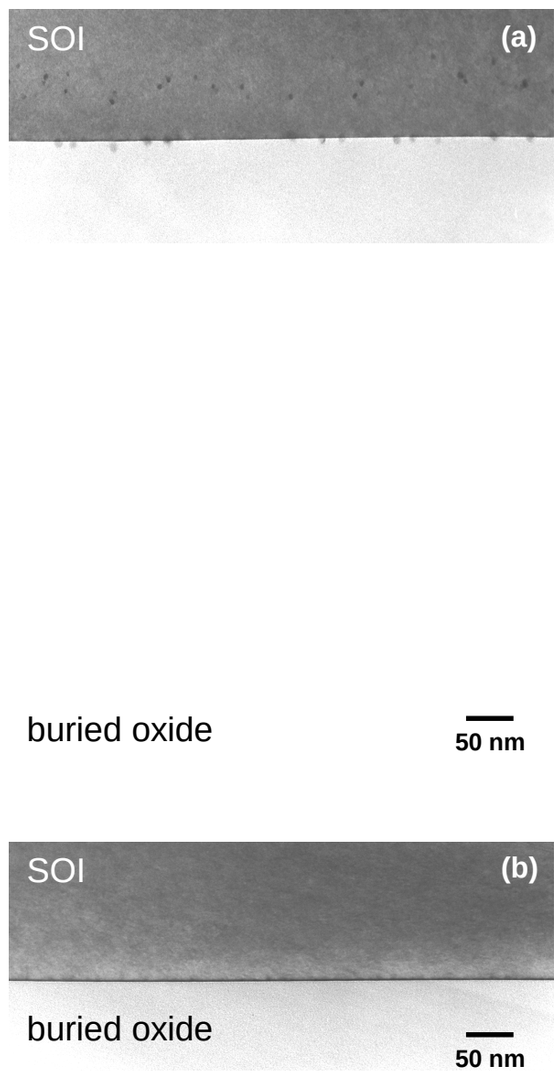

Figure 1. Cross-sectional TEM images of the interfaces of trenched SOI samples with (a) heavy-dose and (b) light-dose arsenic implants.