Defects and Electrical Consequences in SOI Buried Oxides

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The buried oxide quality in SOI is a major parameter determining the quality of the SOI substrate, affecting both yield and reliability. In SIMOX, the BOX is Si rich, and can contain several types of defects. Amorphous Si clusters [1] with less than 10 nm diameter pervade the BOX relatively uniformly, leading to leakage and trapping effects [2] with large C-V shifts if the BOX is exposed to plasmas. Si crystalline precipitates [3] also occur in the BOX with lower densities than the clusters. These Si islands are 20 to 80 nm in diameter and occur in densities of 10^7 to 10^8 per cm2 for low dose SIMOX with >$4*10^{17}$ per cm2 implant doses, and decrease dramatically as the implant dose is reduced [3] until they are below the TEM detection limit. A further weakness in the BOX electrical characteristics is related to blocked implants where particles present on the surface during the implant result in thinner BOX regions which can rise closer to the surface. In the worst case, the blocked implants result in "short circuits," or "pinholes," through the BOX, but in any case, thinner BOX regions lower the breakdown voltage. A schematic of the BOX and its potential defects is shown in Figure 1. Bonded SOI material doesn't exhibit islands , clusters, or amorphous clusters, but particles present on the wafer surfaces during the bonding process can result in early breakdowns and short circuits.

The I-V characteristics of a SIMOX wafer are shown in Figure 2, plotted on a logarithmic scale. A wafer with $4*10^{17}$ cm-2 implant dose has been chosen to exaggerate the results of the defects. The various features of the I-V curve with increasing voltage include linear regions near the origin, space charge limited flow, multi-step tunneling, and Fowler-Nordheim tunneling . The most dramatic feature, however, is the spikes in current seen at various voltages. These spikes, or "mini-breakdowns," are caused by the Si precipitates which cause an enhancement of the field in their vicinity, resulting in premature breakdowns of the oxide. Once the oxide breaks down, current concentration and thermal runaway occur and the region around the defect vaporizes with a bright light flash, resulting in self-healing. The larger the Si precipitate is, the lower the early breakdown voltage will be. Thin BOX regions can also result in early breakdowns, but the self-healing process may not take place since the defect density within the thin BOX region leading to current concentration may be lower. The amorphous clusters are very likely <u>not</u> involved in the mini-breakdowns, but may enhance leakage currents.

Figure 3 shows the I-V data plotted on a linear scale using a fast response electrometer as the current sensor. Measurements using different current integration times show that the current during the thermal runaway rises by several orders of magnitude and the current spike lasts less than 500 microseconds, perhaps as short as several µsecs. These early breakdowns can occur during processing and damage areas of the SOI wafer. Changes in the SOI fabrication process, especially lowering the implant dose [3], can dramatically lower the density of these mini-breakdowns and raise the voltages at which they occur. Though the densities are too low to be observed by TEM. they can be determined by electrical measurements using a range of electrode areas, while the voltages at which they occur can be used to determine the size of the precipitates. Mini-breakdowns can also occur in bonded SOI material, although much less frequently, caused by particles trapped at the bonding interface.

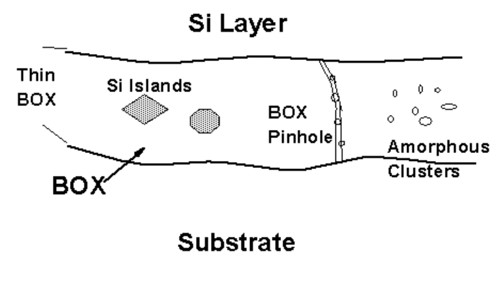

Figure 1. Defects in SIMOX buried oxides.

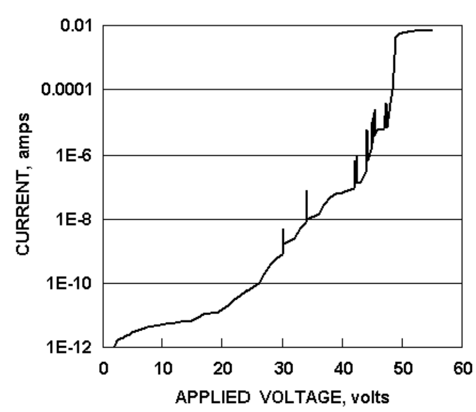

Figure 2. Electrical characteristics of the BOX in a 4E17 cm-2 low dose SIMOX wafer.

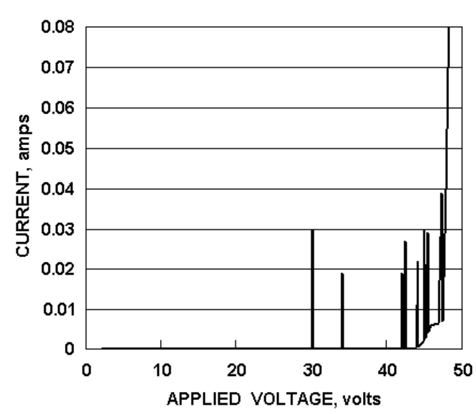

Figure 3. Linear I-V behavior of the BOX in 4E17 cm-2 low dose SIMOX wafer.

References.

1. A.G. Revesz, V.V. Afanas'ev, and H.L.H Hughes, Proc 1993 IEEE Intern. SOI Conference, pg. 24 (Oct. 1993).

2. S. Mayo, J.S. Suehle, and P. Roitman, Proc. 1992 IEEE Intern SOI Conf., pg 28 (Oct. 1992).

3. S. Nakashima, M. Harada, and T. Tsuchiya, Proc. 1992 IEEE Intern. SOI Conf., pg 14 (Oct. 1992).