Simulation of Stress Redistribution on LOCOS Structure during Oxidation and Subsequent Cooling Down

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Simulation of silicon oxidation is a powerful tool to evaluate an oxide shape and stress induced during oxidation. Many approaches to modeling the oxidation process have been reported. Some of these approaches are based on a viscous flow model[1],[2], while the others are based on a viscoelastic model[3],[4]. For the LOCOS structure, various models including an elastic model[1], a viscoelastic model[3], and a viscous model[5] are used for nitride. Although the models are different from each other, the calculated boundary shapes show relatively good agreement with expermental results by SEM or TEM cross-sectional views. This indicates that as long as the oxide shape is concerned, we can have different values of nitride and/or oxide parameters to fit the actual oxide shape. The nitride parameters, however, may strictly affect on the calculated stress values. Therefore, a proper nitride modeling is very important for the oxidation-stress modeling of LOCOS structure.

Furthermore, a practical interest of stress distribution in the substrate is focuced not only on during oxidation but also on the following cooling down process in which temperature decreases to the room temperature. As the temperature of oxidation system is lowered to the room temperature, the stress may redistribute toward a new equilibrium condition. Various processes followed by oxidation determine the stress distribution of final device structure.

This work concerns with the stress redistribution of LOCOS structure after oxidation. One of the factors determining the stress state during cooling down after oxidation is the stress relaxation behavior of the oxide and nitride. A viscoelastic model is successfully applied to the oxide, nitride and silicon substrate for LOCOS structure. Finite element method (FEM) is used to solve the viscoelastic constitutive equation. Thermal stress is also taken into account during the cooling down process.

Simulations have been performed for LOCOS process at 950^{o}C in a wet ambient for 60min and the following cooling down process to room temperature in an inert ambient. The pad-oxide thickness and nitride thickness was 50nm and 100nm, respectively. The temperature cooling rate was 10^{o}C/min. The calculated principal stresses in oxide just after the oxidation and after cooling down are shown in Figure 1 (a) and (b), respectively. A compressive stress exists under the nitride edge and a tensile stress exists at the bird's beak after oxidation. This shows qualitative agreement with the results on LOCOS simulation[4]. The stress redistribution is evident during the cooling down process. In the pad-oxide region (right side in the figure) and the field oxide region (left side in the figure), the compressive stress becomes significant. In the latter region, the stress decreases toward the oxide surface which forms a free boundary for deformation. These are reasonable since the thermal expansion coefficient of nitride and silicon substrate is about five times lager than that of oxide. On the other hand, the stress at the nitride mask edge shows a relatively complex profile reflecting the deformed nitride shape. Thus, lowering the temperature produces the new stress state of the LOCOS structure, indicating that the wide temperature range modeling on the materials is necessary for a stress analysis of practical thermal processing after oxidation.

References

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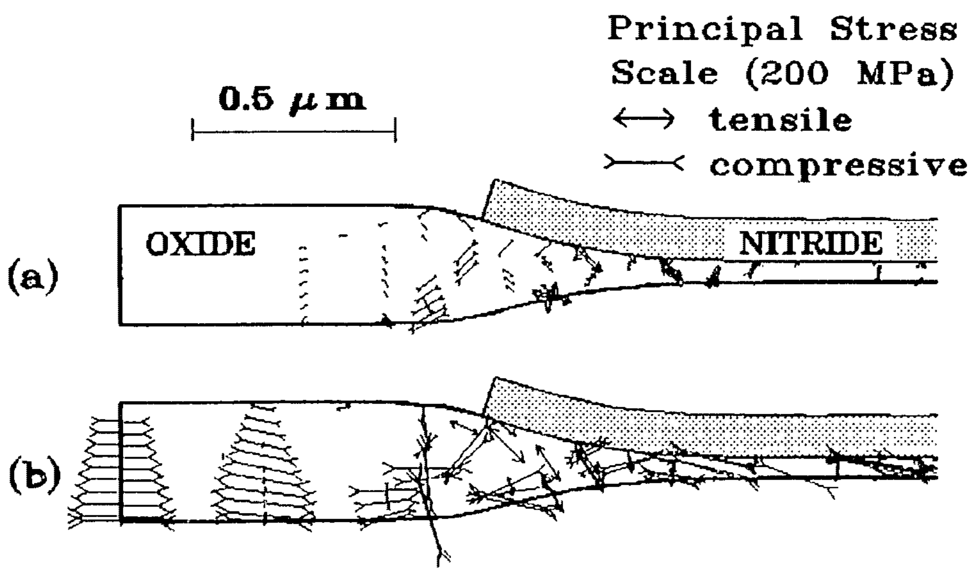

Figure 1: Stress distribution in a oxide for LOCOS structure.
(a)Just after wet oxidation at 950°C for 60min.
(b)After cooling down process to room temperature.