Effects of Nitride Viscosity on the Stress Distribution in LOCOS Structure

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Introduction

Stress in oxidation of silicon causes reliability problems in VLSI device technology. It is important to evaluate an oxide shape and induced stress. The oxidation induced stress and the material shape during oxidation are strongly coupled each other through the stress dependent oxidation models of oxidation reaction, oxidant diffusion and oxide viscous flow. The role of stress dependent oxidation models have been well evaluated for the cylindrical oxidation system [1-3]. The local oxidation of silicon (LOCOS) structure, which additionally includes the silicon nitride mask, results in more nonuniform oxidant supply at the silicon/oxide interface and more complex stress distribution in the materials under consideration. Since nitride may greatly affects the overall stress distribution, proper modeling of nitride is also important for the LOCOS structure. However, there have been few approaches to nitride modeling other than simply treating it as an elastic material [4].

In this work, we have investigated the stress effect of the nitride viscosity in the LOCOS structure, by means of two-dimensional stress dependent oxidation simulation based on viscoelastic models. We have found that stress in the oxide depends heavily on the nitride viscosity, especially for the cases with higher stress values, which proves the importance of proper nitride modeling.

Modeling and simulation

The nitride is treated as viscoelasic material, with Maxwell's spring and dashpot. The stress dependent oxidation models for the oxidation reaction rate K, and the oxidant diffusivity D are taken into account [3]:

$$K=K_0\exp(\sigma_n V_r/kT) \tag{1}$$

$$D=D_0\exp(-PV_d/kT), \tag{2}$$

where K_0 and D_0 are corresponding stress-free values, respectively, σ_n is the normal stress at the silicon/oxide interface, P is the hydrostatic pressure, V_r and V_d are the corresponding activation volumes. The above equations describe the retarded oxide growth when σ_n and P is compressive ($\sigma_n<0, P>0$). The stress effect on viscosity of the oxide is also taken into account as the following Eyring model [5]

$$\mu=\mu_0(\sigma_s V_m/2kT)/\sinh(\sigma_s V_m/2kT), \tag{3}$$

where μ_0 is the low-stress viscosity, σ_s is the maximum shear stress, and V_m is the activation volume. Equation (3) indicates that the viscosity becomes smaller at higher stress levels. The viscoelastic deformation problem of all the three materials for the LOCOS structure is solved by a two-dimensional finite element method [6].

Results and discussion

The simulated LOCOS structure with the 10nm thick pad oxide and the 150nm thick nitride after wet oxidation at 1000°C for 10min is shown in Fig.1. A compressive component of the normal stress at the silicon/oxide interface is also shown in Fig.1. The peak position of the compressive normal stress corresponds to the nitride mask edge. The normal stress distribution induces the retarded oxidation reaction through the equation (1), leading to the curved oxide shape near the nitride mask edge. There is no significant lateral bird's beak growth under the nitride mask. This is because the stress caused by nitride bending, repulsion of the volume expansion of the oxide affects the oxide shape during relatively initial stage of oxidation.

The effects of the nitride behavior, that is whether the nitride behaves as a viscous material or as an elastic material, have been investigated. Figure 2 shows the plots of maximum normal stress at the silicon/oxide interface under the nitride mask edge versus the nitride viscosity with the pad oxide thickness as a parameter. It should be noticed that the nitride viscosity affects the normal stress, especially for thinner pad oxide case. As the nitride viscosity decreases, the stress relaxation time becomes short; as a result the stress levels are lowered. This indicates that the nitride treatment, that is viscous or elastic, is important to evaluate the stress levels. Thus, the modeling of materials particularly for the nitride is necessary for an accurate analysis of oxidation induced stress during LOCOS process.

References

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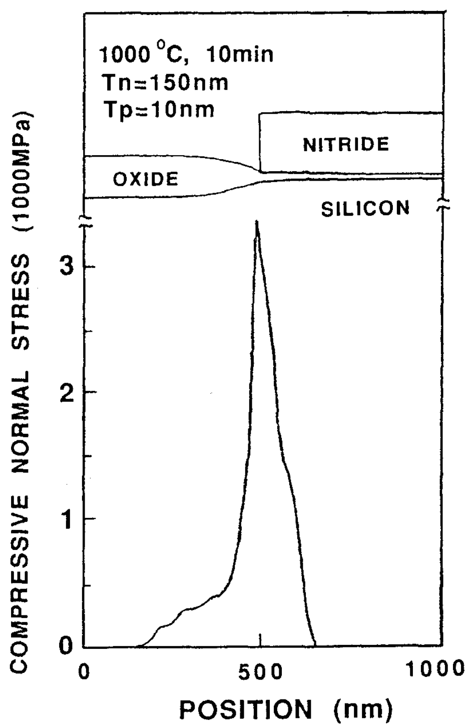

Fig.1: Simulated LOCOS Structure and compressive normal stress at the silicon/oxide interface.

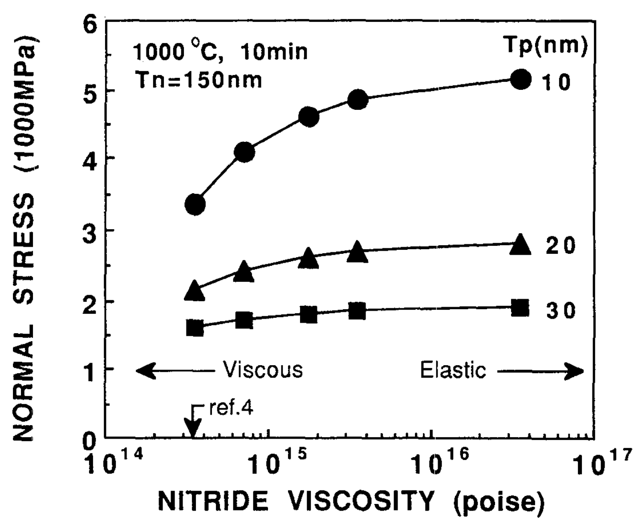

Fig.2: The maximum normal stress at the silicon/oxide interface versus the nitride viscosity, with the pad oxide thickness as a parameter. The nitride viscosity becomes large, the nitride changes from viscous to elastic. The smallest viscosity value is extracted from reference 4.