P-2

Elasto-Viscoplastic Modeling for Three-Dimensional Oxidation Process Simulation

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With continued minimization of the device structure and the development of new semiconductor process, the characteristics of submicron transistors in ULSI or GSI technologies are strongly affected by multi-dimensional device structure. Process simulations have contributed to a better understanding of device physics and to the development of new processing techniques. Device isolation has been most commonly achieved through the use of LOCOS(LOCal Oxidation of Silicon) or LOCOS derivatives due to its process simplicity and excellent isolation characteristics[1]. Viscous[2], elastic[3], viscoelastic[4], and plastic[5] models have proposed for oxidation simulation in two-dimensions and stress-dependent parameters have been widely used in the oxidant diffusion and the reaction mechanism. With device sizes shrinking, three-dimensional oxidation process simulations are required to predict the accurate shape of the oxide, the stress distribution and the three-dimensional effects, such as corner effect and mask lifting effect [6]. Therefore more accurate and robust oxidation model is needed in order to ensure optimal control of the technological oxidation process. In this paper, we developed the three-dimensional process simulator of oxidation with a newly proposed elasto-viscoplastic model. In this model, the oxidant diffusion is solved by BEM(Boundary Element Method) which is suitable for moving boundary condition and surface mesh. The stress factor is incorporated into oxidant diffusivity and reaction rate. The nitride mask is treated as elastic beam, which is bent when the window region is large enough to compare the thickness of the final oxide thickness, but when small geometry is used, it is just lifted rather than bent. The oxide deformation is treated as elasto-viscoplastic behavior. The result of this study is presented next page. Figure 1 shows schematically the initial hole or contact structure. A square nitride mask is defined in the hole structure in which the width of the nitride is same as the length. Figure 2 shows the 1/4 cutting part of simulation result bccause of the easy to understand the three-dimensional oxide shape. The process condition is: 1400Ånitride, 200Åpad-oxide, 5900Åthickness of grown oxide. In figure 3 and 4, by decreasing the size of the nitride mask on same process condition, the oxide shape of the LOCOS structure can be obtained and characterized both from the experiments and use of simulations. They show the cross-sectional simulated field oxide shapes and SEM photography, respectively. The patterned nitride mask sizes were from 1.0㎛ square to 0.3㎛ square. At the under of mask center position, the mask is bent until mask size is 0.5um, but when mask size is decreased to 0.3㎛ the mask is lifted and the bird's beak is much increased that is the reason of small oxidant diffusion and growth due to the mask pressure. Bird's beak punchthrough is clearly seen to have occurred when the Bird's beaks have met under the nitride mask resulting in less stress caused by lifting of the mask rather than bending at the size is small as below 0.5㎛ square. This effect arises even if the mask is relatively thick, of course it can be easily happened when mask is thin, because mask is just lifted and can not sustain its original position. This is a kind of narrow width effects in two-dimensions, but difference with two-dimensional cases, it has strong behavior in the submicron region. It can be understood that the bird's beak punchthrough occurs where the bird's beak length approaches approximately 50% of the nitride size and there is “bird’s neck” shape is formed.

References

[1] S. Wolf, *Silicon Processing for the VLSI Era - Volume 3*, Lattice Press, California, 1995

[2] D.J. Chin et al., "A General Solution Method for Two-Dimensional Nonplanar Oxidation", *IEEE Trans. on Electron Devices*, Vol. Ed-30, No.9, pp.993-998, Sep. 1983

[3] H. Matsumoto and M. Fukuma, "Numerical Modeling of Nonuniform Si Thermal Oxidation," *IEEE Trans. on Electron Devices*, Vol. Ed-32, No.2, pp.132-140, Feb. 1985

[4] S. Cea et al., "Multidimensional Nonlinear Viscoelastic Oxidation Modeling", *SISDEP'95*

[5] C.S. Rafferty, L. Borucki and R.W. Dutton, "Plastic Flow During Thermal Oxidation of Silicon," *Appl. Phys. Lett.* 54(16), pp.1516-1518, April 1989

[6] H. Umimoto et al., "Three-Dimensional Numerical Simulation of Local Oxidation of Silicon", *IEEE Trans. on Electron Devices*, Vol. 38, No.3, pp.505-511, March 1991

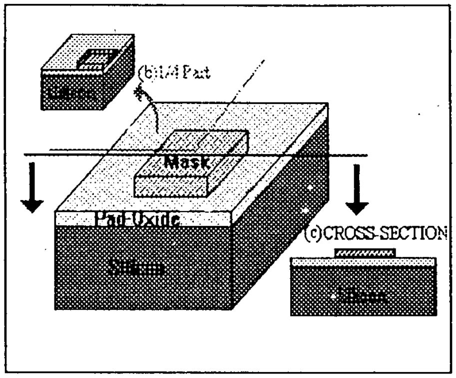

Figure 1. Initial Hole Structure for Simulation

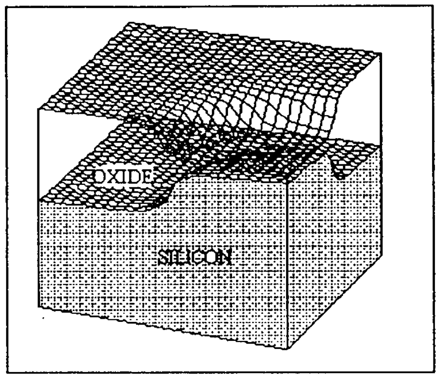

Figure 2. Simulation Result of 1/4 Part

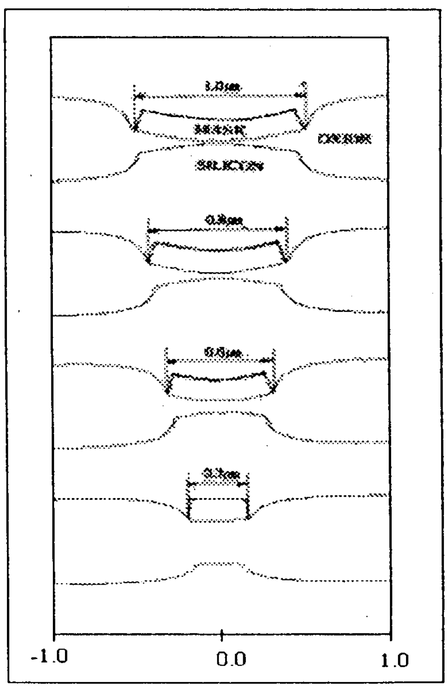

Figure 3. Cross-sectional View

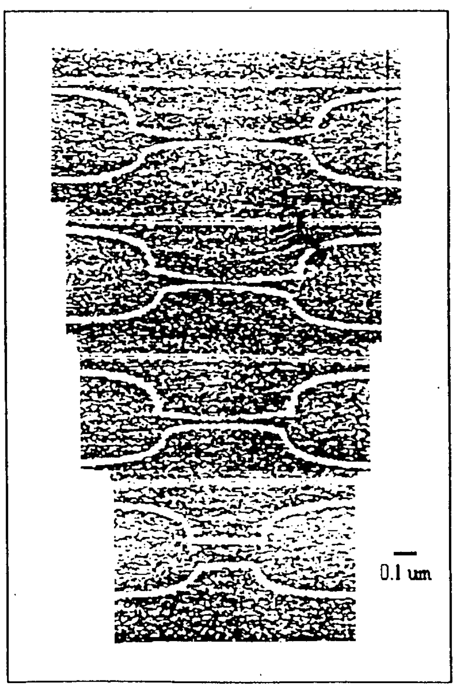

Figure 4. SEM Photography