Numerical Modeling of Glass Flow and Spin-On Planarization

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ABSTRACT

A model for PSG and BPSG glass flow has been developed and integrated into the SAMPLE process simulation program. The physical basis of the model is the deformation of the glass in such a way as to decrease the surface free energy; the kinetics of the deformation are assumed to be controlled by a surface diffusion process. The model is applicable to 2-D and quasi-3-D (cylindrically symmetric) structures.

The boundary conditions of the model can be adjusted for different situations. For example, the flowing glass can be allowed to "wet" the silicon surface by requiring that the glass meet the substrate at a certain angle; on the other hand, the glass can be prevented from flowing onto the substrate by requiring that that the glass meets the substrate at a certain fixed point. A third type of boundary condition allows the simulation of densification or reflow over a step. An example of a BPSG contact reflow is shown in Fig. 1.

The flow of the glass in this model is determined only by surface energy; for this reason, many parameters of the processing conditions (temperature, composition of the ambient, and the concentration of boron and phosphorus) are included in the model only indirectly through the free energy parameter. The surface free energy is the only adjustable parameter. Therefore, this model is primarily useful for studying the geometrical properties of reflow. A series of simulations are presented showing the effect of poly step height and poly to contact spacing on the reflow profile.

A model of the planarizing effect of spin-on-glass, polyimide, or photoresist has also been developed. This model combines a volumetric shrink of the planarizing layer with a simultaneous flow of the surface to reduce surface energy. The shrink, which is assumed to be caused by evaporation of the solvent during the spinning process, adds an additional adjustable parameter to the model. An example of a spin-on-glass simulation is shown in Fig. 2, where the spin-on-glass is used to planarize the space between two metal lines.

Because the flow model is fully incorporated into the SAMPLE simulation program, initial profiles can be obtained as the result of previous SAMPLE simulations, while the resultant profiles can be used as the basis for subsequent SAMPLE simulations. These models allow SAMPLE to perform more complete simulations of realistic semiconductor IC processes.

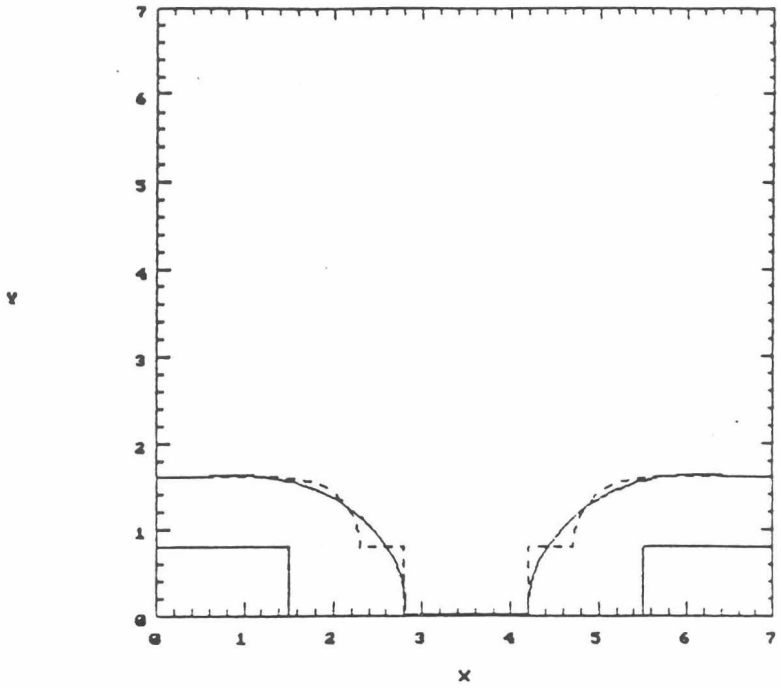

FIG. 1 This simulation consisted of conformal deposition of BPSG over polysilicon gates, followed by etching of the contact opening and reflow of the BPSG. The BPSG profile is shown both before (dashed line) and after (solid line) reflow.

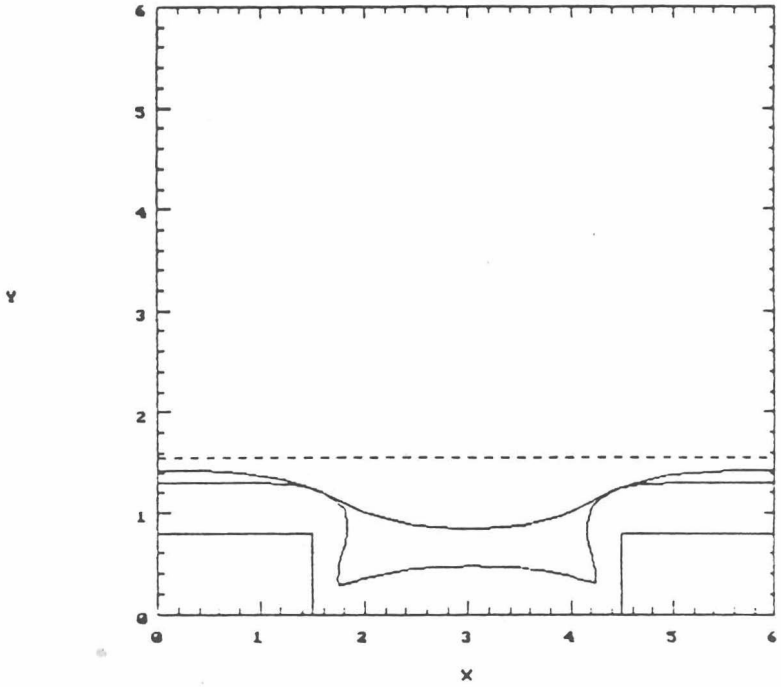

Fig. 2 This simulation consisted of plasma oxide deposition over two metal lines, followed by spin-on-glass planarization. The glass profile is shown both before (dashed line) and after (solid line) solvent evaporation.