Masking Oxide Effects on Boron Diffusion in Silicon

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ABSTRACT

It has been reported earlier that in the case of diffusion of boron into silicon, the sheet resistance values observed in narrow diffusion windows differ significantly from the values obtained on plain un-marked check slices with the former always being greater than the latter. The actual value of this discrepancy depends upon several factors such as the size of the window, the surrounding masking oxide geometry and the process parameters. These observations add another important factor in 2-D simulation for diffusion processes. An attempt has been made to present a theoretical model to explain the experimental observations. The results of a careful series of experiments using multilayered mask structures have been presented. On the basis of these experiments it is suggested that most of the experimental observations may be explained with the help of a theoretical model based on surface diffusion of boron over silicon and silicon dioxide. The model is based upon the phenomenon of surface diffusion over silicon and silicon dioxide with a high solubility of boron in oxide. Numerical calculations demonstrate the capability of the model to explain most of the experimental observations. Further details of the modeling and calculations will be presented.

Keywords: Boron, Diffusion, Silicon, Oxide, Masking

1. INTRODUCTION

It has been reported earlier (1) that in the case of diffusion of boron, the sheet resistance obtained on diffused resistors depends upon the surrounding masking oxide frame width. The results of a more careful investigation have been reported (2,3). It has been observed that the sheet resistance on boron diffused resistors is always greater than the sheet resistance measured on a large area check slice, using the four point probe method (3). These values are referred as ρ_s (res) and ρ_s (4 pt) respectively, and the normalized value of ρ_s (res) expressed as a percentage of ρ_s (4 pt) is denoted by ρ_{sn}. It has been concluded on the basis of a thorough study that the discrepancy between the values of the sheet resistance is observed only with boron and is due to the presence of masking oxide surrounding the window, which is absent in the case of a plain check slice. The experimental results (3) that the effect occurs at the predeposition stage and is independent of background concentration in silicon, oxide thickness, oxide growth condition and decreases in the total amount of doping per unit surface area. The discrepancy disappears if boron is ion-implanted. A significant reduction in free carrier concentration (increase in sheet resistance) has been observed even at distances of several hundred microns from an oxide edge on an open slice. This indicates that the effect of masking oxide on boron diffusion is of long-range nature.

Further investigations have therefore been made in order to find a satisfactory explanation of the observed results. An attempt to present a theoretical model has been made.

2. QUALITATIVE MODEL:

The predisposition system of boron through patterned silicon is shown in Fig. 1. The following simplifying assumptions are made:

(i) The flux of boron going in to the silicon bulk at any point of the surface is negligible compared to the lateral flux due to the surface diffusion.

(ii) In the absence of complete understanding of boron deposition kinetics, the flux F_n of boron atoms arriving at the surface of the water, from the source per unit area per unit time is considered to be constant.

(iii) The surface diffusion is considered to take place both over the silicon window as well as the surrounding oxide, with the same surface diffusion coefficient.

(iv) The boron is dissolved uniformly all over the oxide width up to a maximum concentration of C_L atoms/sq.cms.

(v) The rate at which the boron may be dissolved in oxide is proportional to the difference between C_L and actual concentration of boron in the oxide. Thus, if the concentration of boron in the oxide at any instant of time 't' is Cox(t), the rate at which boron may be dissolved in the oxide is equal to $G(C_L\text{-Cox})$; where G is the constant of proportionality. In the beginning of diffusion, however, the boron surface concentration at the oxide will be zero until the above value becomes less than the total rate of arrival of boron atoms at the oxide.

(vi) Because of much greater solubility of boron in oxide the rate of boron reflected back from the oxide surface may be much smaller compare to that over silicon.

(vii) The ideal one-dimensional diffusion corresponding to a single diffusion coefficient in the silicon bulk is assumed (8).

Referring to Fig. 2 the equations to be solved are as follows using the well established concepts (8) : On Silicon Surface:

$$\frac{\partial C(x,t)}{\partial t} = D_s \frac{\partial^2 C(x,t)}{\partial x^2} + Fn \;; \qquad -L < x < L$$

On oxide surface

$$\frac{\partial C(x,t)}{\partial t} = D_s \frac{\partial^2 C(x,t)}{\partial x^2} + Fn \text{ - } G[CL - Cox(x,t)] \;; -L < x < L+a$$

3. RESULTS OF CALCULATIONS

To study window frame width effect, calculations are done with a window width of 40 μm and the frame width of 4, 8, 24, 60 and 100 μm. For window width effect, the resistor width have been taken to be 12, 20, 40 and 80 μm with a 100 μm wide window frame. The value of ρ_s (res) have been normalized and expressed as a percentage of ρ_s (plane) and are denoted by ρ_{sn}.

The results of numerical calculations are presented in Table 1 .

4. CONCLUSIONS

A careful and accurate investigation of the effects of masking oxide on the diffusion of boron into silicon has been made. A quantitative difference in the results compared to the previously published ones has been observed. An attempt to explain the observed effects has been made and a theoretical model has been developed. The capability of the theoretical model proposed to explain experimental observations quantitatively. Further work is being done to improve the model by developing efficient algorithms. An attempt is also being made to perform experiments to extract the values of the parameters used in the model, once this is done, the model may be incorporated in a 2-D process simulator.

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Table 1: Comparison of Calculated and Experimental Results

Oxide Frame Width Effect Window Width = 40 µm			Window Width Effect Oxide Width = 100 µm		
Oxide Width	ρ_{sn} (%)		Window Width	ρ_{sn} (%)	
	Experimental	Calculated		Experimental	Calculated
4 µm	119.8±2.2	102.6	12 µm	136.0±2.3	137.5
8 µm	121.6±2.6	104.8	20 µm	131.5±3.5	133.5
28 µm	122.7±2.8	111.7	40 µm	126.2±2.1	126.5
60 µm	124.5±2.5	120.9	80 µm	126.8±2.9	118.3
100 µm	126.2±2.1	126.5			

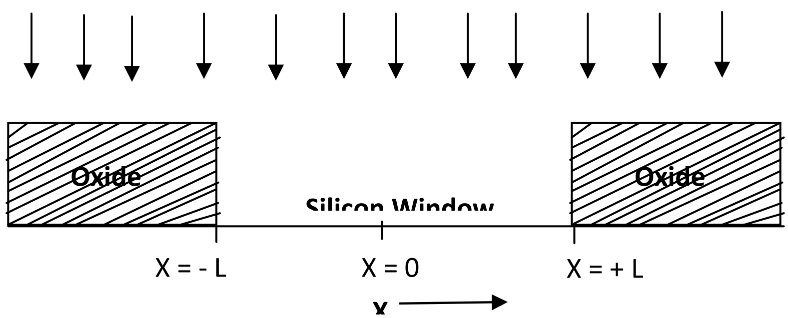

Fig.1 Pre-deposition System of Boron

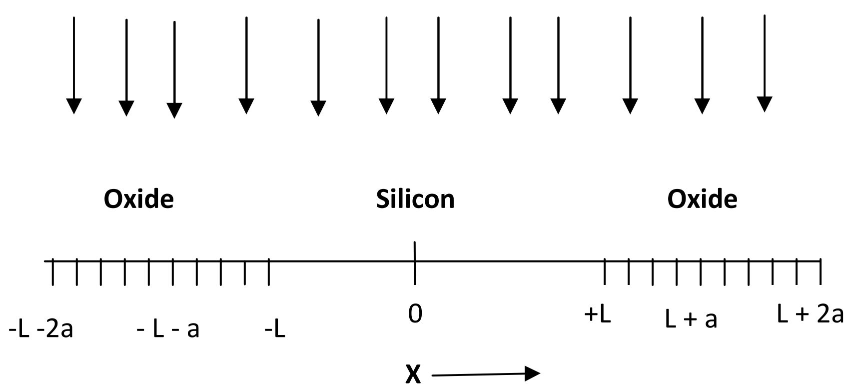

Fig.2 Pre-deposition System of Boron