SIMULATION OF OXYGEN IMPLANTED DISTRIBUTION FOR SOI STRUCTURE

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SOI structure is thought to be the solution of many submicron *CMOS* problems [1]. However, hitherto, the distribution profile of *oxygen* ions in single crystal silicon has not been simulated in the *VLSI* process simulators. In this paper, we gives out the oxygen implanted distribution model based on the statistical method. Due to its accuracy and simplicity, it is especially available for the process simulators. Also this model can be expanded to the simulation of the distribution of other reactive ions, as well as nonreactive ions such as *B*, *P* and *As*.

First, we discuss the relationship between the threshold dose $Dose_{th}$ and implantation energy E (see Fig.1), where the $Dose_{th}$ is a minimum implantation dose value in a given E for forming buried oxide insulation layer. It can be expressed by *Talor series* to the third order of E, that is :

$$Dose_{th} = \sum_{i=1}^{3} b(i)\cdot E^{i} \qquad (1)$$

Where

$b(1)=4.827\times10^{-3}$, $b(2)=3.345\times10^{-5}$, $b(3)=-1.075\times10^{-7}$

Second, a concentration-position relationship of *oxygen* ions implanted in silicon is presented using *quasi-half-gaussian* frequency function [2] which is written as :

$$f(x) = \frac{1}{\sqrt{\pi}\cdot\sigma_1/2 + (Rm_1 - Rm_2) + \sqrt{\pi}\cdot\sigma_2/2} \cdot \begin{cases} \exp\left(-\dfrac{(x-Rm_1)^2}{2\cdot\sigma_1}\right) & x < Rm_1 \\ 1 & Rm_1 \le x \le Rm_2 \\ \exp\left(-\dfrac{(x-Rm_2)^2}{2\cdot\sigma_2}\right) & x > Rm_2 \end{cases} \qquad (2)$$

The impurity ion concentration $c(x)$ can be determined by :

$$c(x) = Dose\cdot f(x) \qquad (3)$$

Fig.2 shows the results of using *quasi-half-gaussian* function to fit the experiment data from [3]. Table 1 shows the value of Rm_1, Rm_2, σ_1, σ_2 extracted from experiment curves [3].

The general relationship between anyone of Rm_1, Rm_2, σ_1, σ_2 and E, $Dose$ is sought by applying linear regression statistical method. Rm_1, Rm_2 can be expressed as

$$Rm_{1,2} = A(1)\cdot E + A(2)\cdot E^2 + A(3)\cdot E^3 + A(4)\cdot Dose + A(5)\cdot Dose^2 + A(6)\cdot E\cdot Dose \qquad (4)$$

σ_1, σ_2 can be expressed as :

$$\sigma_{1,2} = B(1) + B(2)\cdot E + B(3)\cdot E^2 + B(4)\cdot Dose + B(5)\cdot Dose^2 + B(6)\cdot E\cdot Dose \qquad (5)$$

all coefficients $A(i)$, $B(i)$ and other detail information about statistical analysis are included in Table 2, where $SQRENE = E^2$, $CUBENE = E^3$, $SQRDOS = Dose^2$, $CROSS = E\cdot Dose$. We may note that *R-squared* value is greater than 0.9, which is the general accepted creteria for a statistical model, the modulus of *T-STATs* and *F* values are big, *2-TAIL SIG.* approach zero and *Durbin-waston* statistical value are not far from 2.0, all of the preceding statistical creteria value indicates that our model is acceptable [4]. The comparision between the real distribution of *oxygen* ions [3] and our simulated value is given in Fig.3. Calculations show that the singular comparision accuracy of our model is within 4%

References :

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[2] S.selberherr. Analysis & simulation of semiconductor Devices, spring-verbg vien.New York
[3] K.Das, et al., J.Electro.Mater., vol.13, No.4, 635(1984)
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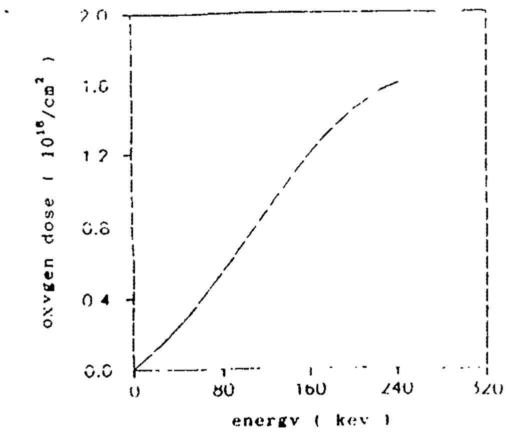

Fig.1 threshold dose versus ion implantation energy for oxygen .

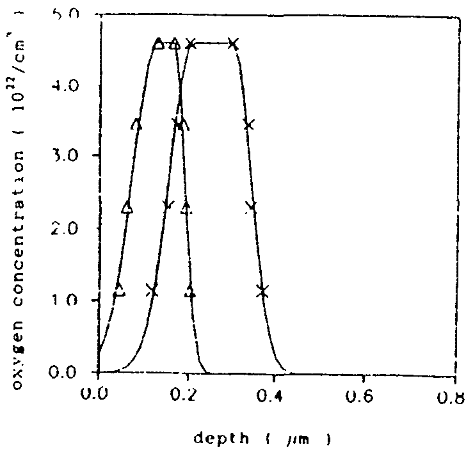

Fig.2 oxygen ion distribution profile
—— theoretically fitted curves ,

ΔΔΔ.experiment (E=50kev,Dose=4.28x10^{17}/cm^2),
xxx.experiment (E=100kev,Dose=5.35x10^{17}/cm^2).

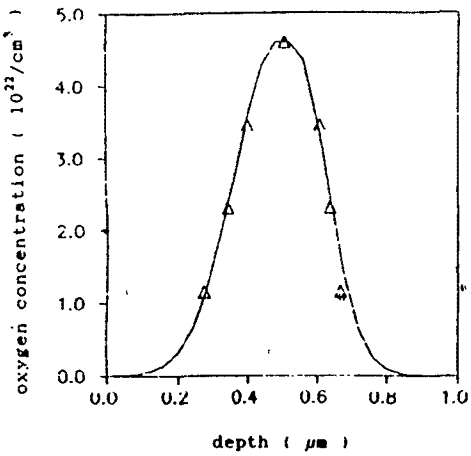

Fig.3 oxygen ion distribution profile
—— simulated ,ΔΔΔ experiment

(E = 200 kev , Dose = 1.41x10^{18}/cm^2).

Table 1 Rm_1(μm),Rm_2(μm),σ_1(μm),σ_2(μm) extracted from experiment data .(unit for Energy : kev , for Dose : x $10^{18}/cm^2$).

obs	RM1	RM2	SIGMA1	SIGMA2	ENERGY	DOSE
1	0.373984	0.582446	0.082372	0.070559	200.0000	1.840610
2	0.442552	0.564393	0.100950	0.077559	200.0000	1.589610
3	0.500536	0.508342	0.134265	0.108058	200.0000	1.366170
4	0.500791	0.500845	0.120756	0.096964	200.0000	0.991209
5	0.124160	0.164955	0.051359	0.023705	50.00000	0.615791
6	0.205036	0.299569	0.050050	0.042706	100.0000	0.969681
7	0.407903	0.417489	0.138774	0.067449	150.0000	1.230390

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
ENERGY	-0.0315020	0.0081522	-3.8642217	0.161
SQRENE	0.0002698	6.545D-05	4.1221238	0.152
CUBENE	-5.421D-07	1.216D-07	-4.4568498	0.141
DOSE	2.3831465	0.5751319	4.1439999	0.151
SQRDOS	-0.2747252	0.0710753	-3.8652715	0.161
CROSS	-0.0087990	0.0031285	2.8125675	0.217

R-squared	0.998931	Mean of dependent var	0.364995
Adjusted R squared	0.993584	S.D. of dependent var	0.146252
S.E. of regression	0.011715	Sum of squared resid	0.000137
Durbin Watson stat	3.369757	F-statistic	186.8297
Log likelihood	28.00641		

(a)

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
ENERGY	0.0025837	0.0154061	0.1677062	0.894
SQRENE	-5.895D-07	0.0001237	-0.0047658	0.997
CUBENE	7.467D-09	2.299D-07	0.0324812	0.979
DOSE	0.0541178	1.0864918	0.0497914	0.968
SQRDOS	0.0875753	0.1343189	0.6519956	0.632
CROSS	-0.0009816	0.0059122	-0.1660326	0.895

R-squared	0.996493	Mean of dependent var	0.434006
Adjusted R-squared	0.978959	S.D. of dependent var	0.152623
S.E. of regression	0.022139	Sum of squared resid	0.000490
Durbin-Watson stat	3.369757	F-statistic	56.83125
Log likelihood	23.55107		

(b)

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	0.7929971	0.2559245	3.0985590	0.199
ENERGY	0.0152850	0.0045120	3.3699267	0.184
DOSE	-2.7237912	0.8714982	-3.1254411	0.197
SQRENE	-9.729D-05	2.818D-05	-3.4526894	0.179
SQRDOS	-0.1265824	0.0823290	-1.5375181	0.367
CROSS	0.0151555	0.0042764	3.5419472	0.175

R-squared	0.977585	Mean of dependent var	0.096912
Adjusted R-squared	0.865512	S.D. of dependent var	0.037842
S.E. of regression	0.011570	Sum of squared resid	0.000184
Durbin Watson stat	3.369757	F statistic	8.722740
Log likelihood	26.97752		

(c)

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	0.0049672	0.2771785	0.0179206	0.989
ENERGY	0.0002917	0.0048867	0.0596930	0.962
DOSE	0.0215261	0.9438656	0.0228063	0.985
SQRENE	-1.410D-06	3.052D-05	-0.0593104	0.962
SQRDOS	-0.0795765	0.0891663	-0.8924510	0.536
CROSS	0.0008314	0.0046316	0.1795059	0.887

R-squared	0.957866	Mean of dependent var	0.069571
Adjusted R squared	0.747197	S.D. of dependent var	0.029230
S.E. of regression	0.014697	Sum of squared resid	0.000216
Durbin-Watson stat	3.369757	F-statistic	4.546784
Log likelihood	26.41906		

(d)

Table 2 statistical analysis results of (a)Rm_1, (b)Rm_2 , (c)σ_1, (d)σ_2 .