GSS-TechSim User's Guide

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1 Introduction

1.1 About GSS-TechSim

TechSim is a set of programmes, build on the base of GSS, for the purpose of two-dimensional semiconductor process simulation. It can be used for simulation of thermal diffusion, ion implantation, thermal oxidation, including supports for high-κ materials. By taking the advantages of analytical solution and numerical differential equation solution, TechSim has see the success in simulating bird's beak effect, impurity redistribution effect and some other important phenomenon in semiconductor industry.

1.2 Format and sequence of input card

Since TechSim use a modified command parser as that in GSS, so the format of input card is quite similar to GSS. TechSim can be used to built more accurate and comprehensive device model for the following simulation of GSS command. The doping commands:

```
DIFF    ODE    IONIMP
```

in TechSim can be used together with or instead of PROFILE in GSS, while while commands for the oxidation process:

```
OXIDEBEGIN    MASK    OXIDEEND
```

is strongly recommended not to use with SPREAD in GSS. Moreover, oxidation commands are sequence sensitive and should be used in the right order.

2 Thermal Diffusion

2.1 Introduction

Thermal diffusion is one of the most important impurity doping techniques used in semiconductor fabrication process. TechSim has developed two methods for simulating the diffusion process:

```
DIFF      ODE
```

which supports analytical solution and numerical differential equation solution of Fick's Diffusion Law respectively.

2.2 DIFF

Description

Use analytical solution to simulate the diffusion process in semiconductor.

Syntax

```
DIFF  X.MIN=<n>  X.MAX=<n>  TIME=<n>  DIFF.TEMP=<n>  TECH.ION=<s>
      CONST=<s>  IONDOSE=<n>
```

parameter	type	default	unit	description
X.MIN	number	-	μm	The left edge of the mask window for thermal diffusion.
X.MAX	number	-	μm	The right edge of the mask window for thermal diffusion.
TIME	number	-	hour	The total time for diffusion process.
DIFF.TEMP	number	-	°C	The temperature for diffusion process.
TECH.ION	string	-	-	The impurity atom/ion that is used in thermal diffusion(B,P,As,Sb).
CONST	string	-	-	Mode for diffusion,C for constant surface concentration and Q for predeposition for a given number of atoms per unit area.
IONDOSE	number	-	cm^{-3} / cm^{-2}	The dose of diffused atom. The unit depends on the type of mode for diffusion.cm^{-3} if CONST=C or cm^{-2} if CONST=Q.

Example

```
DIFF  X.MIN=1  X.MAX=3  TIME=0.3  DIFF.TEMP=1200  TECH.ION=As
      CONST=Q  IONDOSE=1e14
```

2.3 ODE

Description

Use numerical solution of diffusion equation to calculate doping profile. This command has included models for influence of previous doping concentration to the diffusion coefficient of the following impurity ions.

Syntax

```
DIFF   X.MIN=<n>   X.MAX=<n>   TIME=<n>   DIFF.TEMP=<n>   TECH.ION=<s>
       CONST=<s>   IONDOSE=<n> Y.EDGE=<n> [STEPS=<n>]     [TS=<s>]
       REGION=<s>
```

parameter	type	default	unit	description
X.MIN	number	-	μm	The left edge of the mask window for thermal diffusion.
X.MAX	number	-	μm	The right edge of the mask window for thermal diffusion.
TIME	number	-	hour(s)	The total time for diffusion process.
DIFF.TEMP	number	-	°C	The temperature for diffusion process.
TECH.ION	string	-	-	The impurity atom/ion that is used in thermal diffusion(B,P,As,Sb).
CONST	string	-	-	Mode for diffusion,C for constant surface concentration and Q for predeposition for a given number of atoms per unit area.
IONDOSE	number	-	cm^{-3} / cm^{-2}	The dose of diffused atom. The unit depends on the type of mode for diffusion.cm^{-3} if CONST=Cn or cm^{-2} if CONST=Q.

Y.EDGE	number	-	μm	The Y coordinate of the mask window.
STEPS	number	-	1000	Total steps for TS solver.
TS	string	-	EULER	The solver for calculating,EULER or CRANK_NICOLSON.
REGION	string	-	-	Specify the region for calculating the diffusion equation.

Example

```
DIFF  X.MIN=1  X.MAX=3  TIME=0.3  DIFF.TEMP=1200  TECH.ION=As
      CONST=Q  IONDOSE=1e14 STEPS=5000 TS=BEULER  REGION=Si
```

2.4 Examples

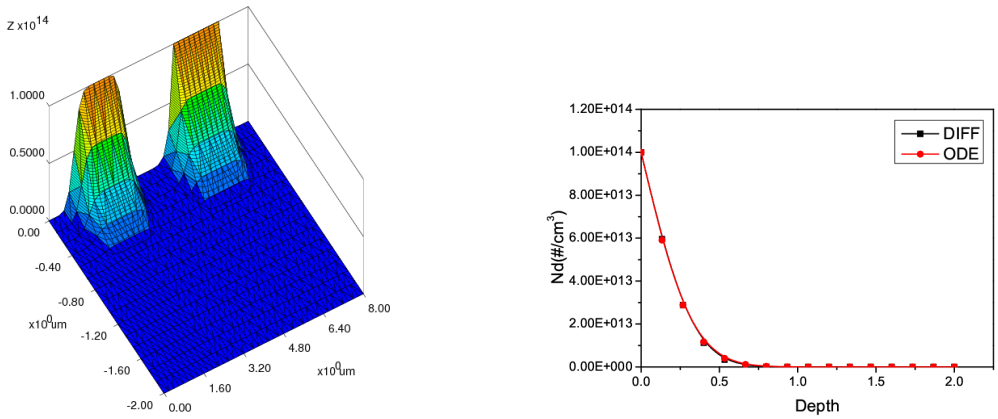

Figure 1: Compare of the result calculated by ODE and DIFF

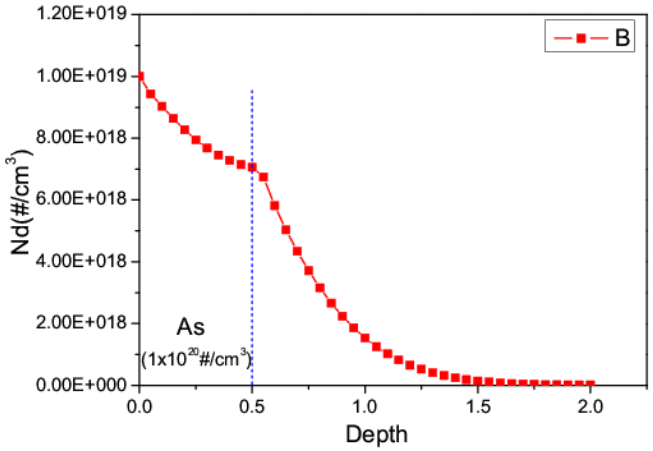

Figure 2: Redistribution of B due to previous exist As doping

3 Ion Implantation

Theory has predicted Gauss like distribution of ions implanted into polysilicon semiconductors. While various techniques has been develop to avoid channel effect, the distribution in single silicon semiconductor can be described by the Gauss function. Since more accurate Monte-Carlo simulation is too time consuming, Gauss distribution provides a balance in the tradeoff between accuracy and complexity.

3.1 IONIMP

Description

Use Gauss Distribution to simulate the ion implantation process.

Syntax

```
IONIMP   X.MIN=<n>   X.MAX=<n>   TIME=<n>   IMPENG=<n>   TECH.ION=<s>
         IONDOSE=<n>
```

parameter	type	default	unit	description
X.MIN	number	-	μm	The left edge of the mask window for ion implantation.
X.MAX	number	-	μm	The right edge of the mask window for ion implantation.
TECH.ION	string	-	-	The impurity atom/ion that is used in ion implantation(Al,As,B,Ga,In,N,P,Sb).
IONDOSE	number	-	cm^{-2}	The dose of implanted ions(0-200keV).
IMPENG	number	-	keV	Implantation Engery for ions

Example

```
IONIMP  X.MIN=1.5  X.MAX=2.5  TECH.ION=B  IMPENG=800  IONDOSE=1e15
```

3.2 Examples

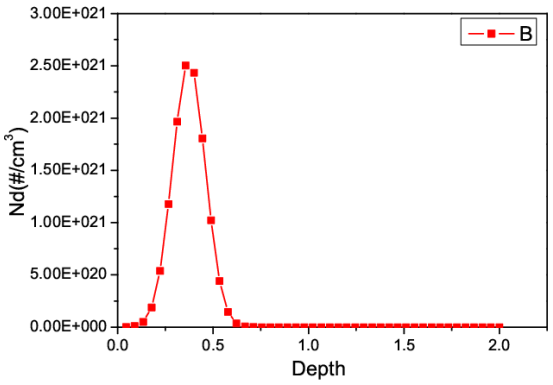

Figure 3: Ion implantation simulation result for B ion

4 Oxidation

Famous Deal-Grove Model is used for predicting the thickness of oxidation layer in given reaction conditions, and analytical solution is applied to calculate the shape of bird's beak according the stress exert by the nitride layer to the oxidation layer.

4.1 OXIDEBEGION

Description

Set up the initial condition for the following oxidation process and calculate the final thickness of oxidation layer by Deal-Grove model.

Syntax

```
OXIDEBEGIN    Upper=<i>    Lower=<i>    THICK.N=<n>    THICK.OX=<n>
              TIME=<n>     OX.TEMP=<n>  CONDITION=<s>  [ORIEN=<s>]
```

parameter	type	default	unit	description
Upper	integer	-	-	The index of the upper y-grid line of the oxidation region.
Lower	integer	-	-	The index of the lower y-grid line of the oxidation region.
THICK.N	number	-	-	Original thickness of masking nitride layer.
THICK.OX	number	-	μm	Original thickness of oxidation layer.
TIME	number	-	hour	Oxidation duration.
OX.TEMP	number	-	°C	Temperature for oxidation process.
CONDITION	string	-	-	Oxidation condition (dry,wet).
ORIEN	string		-	The orientation of the silicon substrate(Si_111,Si_100).

Example

```
OXIDEBEGIN    Upper=0    Lower=2    THICK.N=0.1    THICK.OX=0.05    TIME=2
              OX.TEMP=1200  CONDITION=dry ORIEN=Si_111
```

4.2 MASK

Description

Specify the boundary of the nitride masking layer. This command MASK can be used repeatedly between OXIDEBEGION and OXIDEEND to create multiple windows.

Syntax

```
MASK    [X.MIN=<n>]   [X.MAX=<n>]
```

parameter	type	default	unit	description
X.MIN	number	-	-	The left edge of the masking nitride layer.
X.MAX	number	-	-	The right edge of the masking nitride layer.

4.3 OXIDEEND

Description

This command comes without any parameters, it is just for indicating the completing of masking process and move the points in the mesh grid to form the proper shape.

4.4 Examples

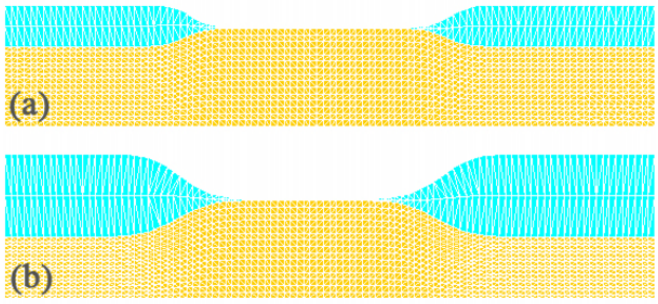

Figure 4: Bird's Beak with small stress

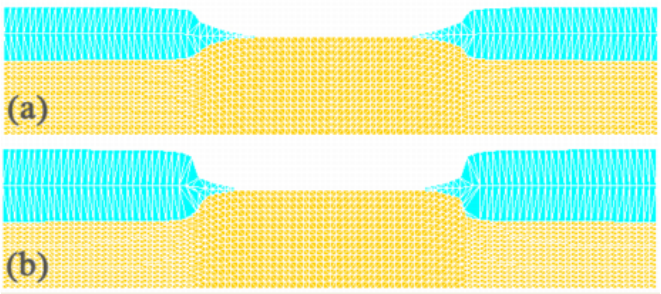

Figure 5: Bird's Beak with strong stress

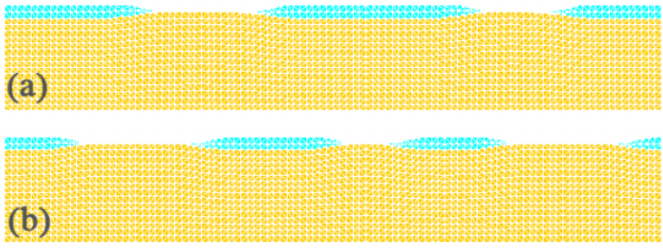

Figure 6: Multi-mask generated oxidation layer

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