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Defects & Disorders in Semiconductors

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Abstract:-

Defects are always undesirable, if only as an indication that the production technology is not fully understood & controlled. Hence it is necessary to have techniques to locate, identify & determine the origin of defects present.

Defects in semiconductor are a problem because of their electronic & optoelectronic effect.Thus it is necessary to be able to determine the electronic properties of defects.A number of techniques are also available for the electronic characterization of defect microstructure such as SEM-EBIC(Scanning electron microscope- electron beam induced current),SEM-CL(Cathodo luminescence)& LBIC Laser or light beam induced current)

Index terms:- Defect Density,Point Defects,Vacancy,Silicon

I.INTRODUCTION:-

The power of semiconductor materials,which have been at the heart of the information technology industry for more than half a century,comes from the ability to modify their electronic properties through the addition of impurity atoms.In the past,these dopants were added to semiconductors in bulk quantities.However,the decades long march of Moore's Law in shrinking the size of semiconductor devices now requires us to focus on the properties of these dopants at the single atom scale.In collaboration with a number of other groups,we are exploring the influence of dopants in conventional semiconductors like silicon[1,2]& GaAS[3] to understand their potential applications for the ultimate limit of electronic devices.Much of this work is through the COMPASS COLLABORATION which focuses on making atomic scale devices in silicon & studying their application for quantum computation.

II.DEFECT TYPES:-

The categories of defective circuits are as follows

(A)Local faults initially in the material
(B)Local faults created during fabrication
(C)Broad faults initially in the material
(D)Broad faults created during fabrication

All defects do not cause operational faults[1].In fact,some defects are intended as expected,during the doping process.For example,carbon had previously been found in many defects observed in silicon semiconductors[2]& a common modern semiconductor is silicon carbide(Sic).Therefore,the chip area is multiplied by a constant,always less than unity,which is defines the active chip area.This area is susceptible to inoperability due to defects[1].However,defects originally created near the surface may be fixed,due to process like polishing,oxidation & chemical etching[3].

The local faults can be categorized into point defects,area defects,lines & clusters.Examples of point defects include pinholes,imbedded grains & dislocations[1].Especially common are vacancies of an atom from a particular lattice position & interstitials,in which an atom is located in between lattice sites.When,dealing with doping or fabrication,one can encounter impurities.These atoms which are different than theoriginal material may be substitutional defects,when they replace an intended atom at a lattice position or interstitial impurities[4].Figure1 provides examples for four of the previously stated defects.

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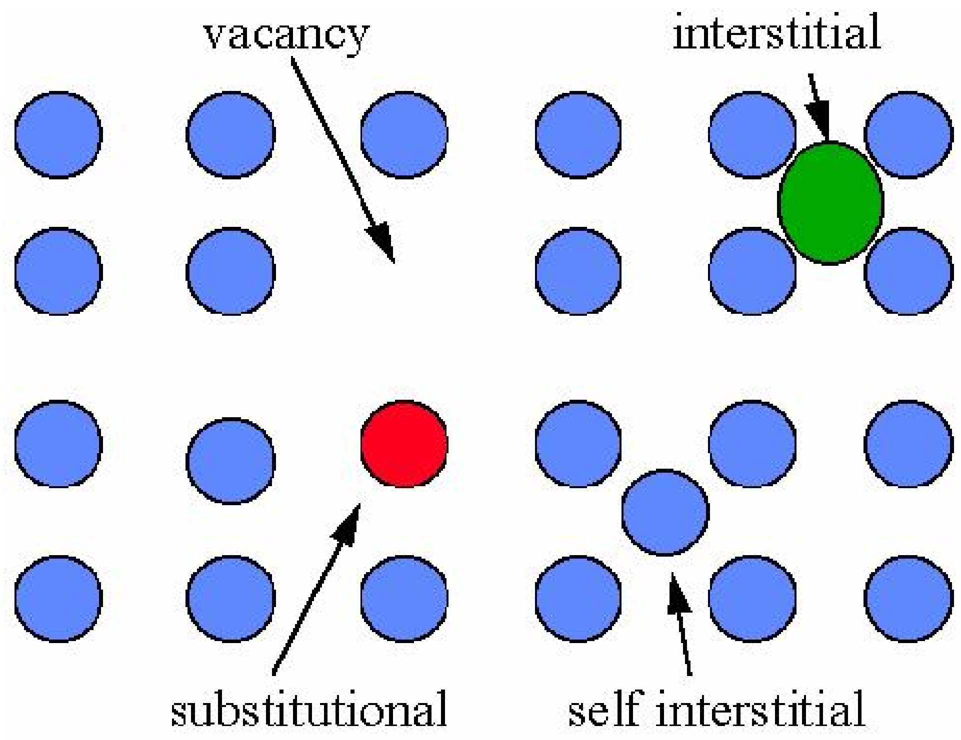

Fig 1. Common point defects in semiconductors. Substitutional and interstitial ion, whereas self interstitials are due to an original atom

Area defects are thought of as extended point defects,particularly epitaxial mounds.They are modeled with both a radial & angular property about the slice.The angular property comes about usually during the high temperature activity phases.This may include gas flow variation,slice insertion as placement techniques[1].

There are also impurities that may be formed from what is known as an octahedral void defect.During oxidation,these impurities may affect the gate -oxide,forming a conducting path within it.As such,a reduction in the gate oxide integrity can occur,including a dielectric breakdown[5].These impurities are called grown in defects.Vacancies are common grown- in defect,usually appearing,when oxidation temperatures reach 1070-1100˚c[6].

Line faults are mainly denoted in the following categories:-

(A)Slip lines due to chipped edges of the slice,in a high temperature phase
(B)Slip lines from thermal gradients at the slice edge via direct contact
(C)Stacking fault defects in the epitaxial layer
(D)Line defects from thermal oxidation
(E)Slip lines from uneven heating & pressure
(F)Scratching

Finally,a defect cluster can be attributed to a dust particle,as a scratch on the mask,perpetuating to multiple slices[1].Above a threshold temperature[8] shows the formation of defect clusters in addition to point defects on silicon.

III.DEFECT DENSITY:-

Defect density play an important role in process control & yield prediction.To improve the accuracy in modeling defect density distributions we present a wafer level methodology to analyze defect data measured on a wafer.

Defect density has been modeled & represented by an empirical equation.The following equation is dependent on the radial variation

$$d(r) = d\{l + 2.5 \exp[0.34X19(1- r/R)]\} \text{ ---------(1)}$$

Here d(r) is the density at point r,d is constant & R is the radius of the slice.The equation infers that the defect density will increase at points near the edge of the wafer.This effect can be seen in figure2.

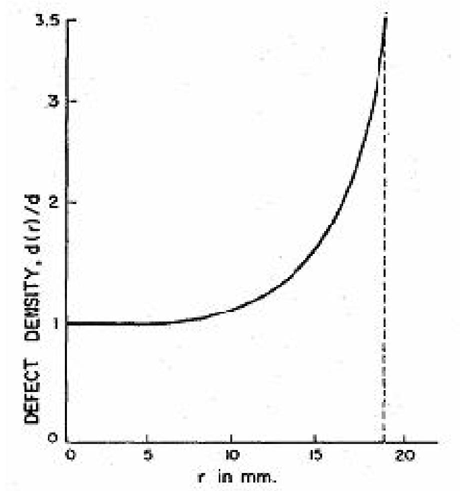

Fig. 2. Radial variation in defect density.

Research in [1] classified defect density analysis into three cases;normal,radial & angular defects;line defects compounded with the basic faults & a cluster of defects at a random point,graphically denoted by a spike.Defects that demonstrate a large electron lattice coupling may affect host's electronic structure,depending on the lattice relaxations near the defect[2].

IV.DIVACANCY:-

We described a basic vacancy defect,where a thermal reaction or ion implanation removed a host atom from its lattice positions.There is another common reaction to irradiation which is known as a divacancy.

There are five general reactions in the event of a divacancy.The first two are consequences of a divacancy & are interstitial.If the interstitial combines with the divacancy,then the semiconductor ultimately has a single vacancy.

V.MATERIAL:-

Silicon is currently the most popular material used in semiconductor devices.The research in [11] shows that the electrical deactivation of arsenic in silicon can create silicon self-interstitials.Other defects arise due to one of the major growth processes,accredited to Jan Czochralski(figure3).

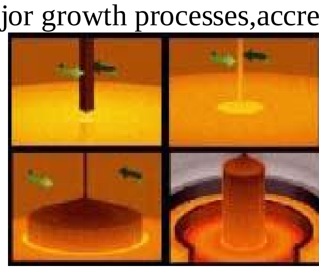

Fig. 3. Czochralski process for silicon wafers. A pure silicon seed is placed into a SiO2 melt, and slowly pulled out while rotated. The result is a pure silicon cylinder, or an ingot

During the formation of Czochralski silicon,it may dissolve the supporting cubicle mode of quartz &the result can lead to trace amounts of oxygen.This oxygen is then dispensed throughout the silicon.

Another popular material used for semiconductors is Gallium Areside(GaAS).A Common defect known as an antisite occurs when an Arsenide atom appears at a Gallium location & vice-versa.Incorrect distribution of chemical compounds can lead to nonstoichiometric defects.However it has been shown that a GaAS melt that favours Arsenic can demonstrate a beneficial affect;a compensation mechanism,attributed to a prevalent semi-insulating property[12].

VI.CONCLUSION:-

Various defects in semiconductor device have been presented,determined & categorized.Equations & graphs are shown that were empirically created by past research to show defect distribution.It has been shown that defects are based on both radial & angular variation.Additionally,carbon may be directly incorporated in most silicon defects,classical & contemporary defect issues have been described,ignoring their current or proposed remedies.

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