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BOOK OF ABSTRACTS

SERI Workshop On The Role of Point Defects/Defect Complexes In Silicon Device Fabrication

August 30-31, 1990

Keystone, Colorado

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SERI Workshop On The Role of Point Defects/Defect Complexes In Silicon Device Fabrication

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Workshop Chairman
Bhushan L. Sopori

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POINT DEFECT CONCERNS FOR HIGH EFFICIENCY SOLAR CELL PROCESS DESIGN/FUTURE MATERIALS RESEARCH

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Point defect processes are becoming increasingly important in microelectronic device fabrication as well for solar cell process design. Current high efficiency solar cell fabrication requires highly controlled processes for junction formation, surface (and bulk defect) passivation, antireflection coatings and contact metallization. A solar cell process designer involved with low-cost substrates is faced with additional problems of predicting complex interactions between extended defects, impurities and non-equilibrium point defect densities, known to be present in the as-grown material. The synergistic effects of interactions among various species of defects and impurities, during device fabrication processes, have been observed by many researchers; such interactions can produce favorable as well as unfavorable results. The objective of this talk is to broadly identify some ares of solar cell processing where general concerns of point defect interactions are perceived. It is expected that such issues will be discussed in detail during the workshop and that the workshop will help define research directions of the future SERI Crystalline Silicon Materials Program.

NOTES

DEFECTS IN SILICON

James W. Corbett
SUNY at Albany

The status of our understanding of defects in silicon will be reviewed with the emphasis on aspects pertinent to photo-voltaic solar cells, i.e., particularly those features related to the minority carrier lifetime. The emphasis will be on single-crystal silicon, but the material is also germane to the defects in the various forms of poly-silicon and amorphous silicon. Defects at surfaces, line defects and point defects will be discussed. Native defects and impurities will be surveyed, including vacancies and vacancy-related aggregates, oxygen and oxygen-related aggregates, transition elements and transition metal aggregates, etc. It will be noted that ionization introduces special problems in defects processes in semiconductors, such as influencing defect reactions and diffusion; these effects and the non-linearity of the diffusion and reaction terms in the equations describing these defects lead to chaos-related phenomena.

NOTES

EQUILIBRIUM AND NON-EQUILIBRIUM POINT DEFECTS IN SILICON

Ulrich Gosele
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Under thermal equilibrium conditions silicon contains intrinsic point defects (vacancies and self-interstitials) the concentrations of which depend on temperature. In spite of large efforts to determine these equilibrium concentrations the available estimates span many orders of magnitude at a given temperature. A similar statement holds for the diffusivities of these intrinsic point defect. The situation for important extrinsic point defects such as oxygen and carbon is much more satisfactory since solubilities and diffusivities are generally known as a function of temperature.

During crystal growth and processing one generally has to deal with non-equilibrium point defect situations and supersaturations and undersaturations of point defects appear to be rather the rule than the exception. Since during precipitation and agglomeration of oxygen and carbon volume changes occur which may be accommodated by the emission or absorption of intrinsic point defects, the poor knowledge of intrinsic point defect properties even impacts on the proper quantitative treatment of precipitation processes.

Possible implications of non-equilibrium point defects on the minority carrier diffusion length in solar grade silicon will be discussed.

NOTES

THE IMPACT OF INTERSTITIAL DEFECTS AND IMPURITIES ON SILICON DEVICE PROCESSING AND PERFORMANCE

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The trends in silicon processing for the next decade feature increasing numbers of more complex processes to produce materials systems with higher levels of heterogeneity and higher tolerances of performance. Defect control based on fundamental understanding, accurate models and precise management of key process variables is required. A five level hierarchy of interstitial defect reactions has been observed in silicon involving oxygen, carbon, Group III and Group V impurities. The deep electronic states of the mobile interstitial defects provide a Fermi level dependent reaction cross section and a pathway for electronically stimulated diffusion. We examine the fundamental limits imposed on perfection and performance by processing and discuss the viability of novel processing schemes. Specific examples of radiation damage, transition metal contamination and reactive ion etching will be given with a discussion of their impact on VLSI and solar cell processing and performance.

NOTES

FORMATION OF MICRODEFECTS AND THEIR ELECTRICAL PROPERTIES IN FLOAT-ZONED SILICON CRYSTAL GROWTH

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At dopant concentrations lower than 10^{17} cm^{-3}, the bulk minority charge carrier lifetime τ in silicon is mainly determined by Shockley-Read-Hall (SRH) recombination. Grain boundaries, dislocations, and deep level impurities are known to lower lifetime substantially. But even high-purity, dislocation-free float-zoning usually results in lifetimes in the vicinity of 10^3 µsec which is far shorter than those expected from SRH recombination based merely on residual impurity centers. When silicon crystals are dislocation-free, microdefects such as swirls (A, B-type) and D-type defects may exist. In addition, fast cooling of grown crystals can produce frozen-in defects. We have found swirl defects and frozen-in defects to be carrier recombination centers in dislocation-free, as-grown, float-zoned Si crystals. The A-type defect has an effective carrier capture range of ~40µm, as determined by EBIC analysis. The activation energy for forming the fast cooling frozen-in defects was estimated to be about 0.31 eV. Hydrogen doping can suppress swirl defect formation but causes other recombination centers. Defect formation can be changed by growth conditions, and long minority charge-carrier lifetimes are achieved through moderately high growth speeds and low thermal gradients during crystal growth, by which both swirl-defects and frozen-in defects are avoided.

NOTES

INTRINSIC GETTERING IN CZ SILICON
-FUTURE DIRECTIONS-

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Since its introduction into the semiconductor community by Tan and Tice in 1976, intrinsic gettering has been one of the most extensively discussed topics. Thanks to advancement of various chemical, electrical and structural characterization tools, impressive progress in understanding this method has been made, and numerous successful implementation of intrinsic gettering method into actual device lines has also been reported in open literature. However, there still remains several unanswered questions in this field. In this presentation, I will discuss some of these unanswered and unexplored areas and suggest some future recommended research topics.

NOTES

TRANSITION METALS IN SILICON

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Transition metals are ubiquitous impurities in silicon used for photovoltaic (PV) applications. They are present in low-cost starting material and can additionally be introduced during device processing. They form deep energy levels and thus result in drastic lifetime shortening of PV-Si. Although this is known since several decades, a thorough understanding of the behavior of transition metals in silicon and of methods to remove them by gettering treatments is just now emerging.

In the first part of this contribution, an overview of the diffusion, solubility, lattice site, complexing and precipitation behavior, and of the electronic properties of transition metals in silicon will be given. Recent research in this area yields a good understanding of the apparent chemical trends in this field.

In the second part, strategies to reduce the concentration of transition metals by gettering treatments will be discussed, making use of the experience gained from the study of internal and external gettering mechanisms in Si IC technology.

NOTES

NONCONTACT ELECTRICAL CHARACTERIZATION FOR VLSI/ULSI-GRADE SILICON CRYSTALS

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Minority-carrier recombination lifetimes have been extensively measured with a noncontact laser/microwave method for *p-type* CZ, MCZ, and FZ silicon crystals in the temperature range from room temperature to 250°C. The effect of metallic impurities (Fe, Cr, Ni, W, Au, etc.) and oxygen related defects on the lifetime is investigated. The effect of iron as low as $1\times10^{11}\text{cm}^{-3}$ on the lifetime can be detected with the technique. It is further shown that the lifetime measurement is very sensitive to grown-in defects, most likely oxygen-related defects, which cannot be perceived with conventional techniques such as IR absorption spectroscopy or TEM. Finally, noncontact laser/microwave deep level transition spectroscopy (LM-DLTS) has been developed and applied to *p-type* CZ silicon crystals deliberately doped with metallic impurities. With the technique, the energy levels related to metallic impurities have been obtained for the first time without any electrode contact or special sample preparation.

NOTES

POINT DEFECTS IN POLYCRYSTALLINE SILICON

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There have been persistent beliefs that point defects, both native and impurity related, play a significant role in determining the lifetime properties even in heavily polycrystalline and rather defective silicon.

Such evidence is however mostly indirect and rests in the fact that minority carrier lifetime changes can be observed, while it can be simultaneously shown, on various levels of resolution, that the line and volume defect picture of the material under investigation in not changing.

The kinds of phenomena seen range from the effects of hydrogen passivation to such observations as the improvement of lifetime properties with oxygen addition in some materials, or deterioration in others. Also, changes in phosphorus diffusion properties are generally observed, as is a deterioration of lifetime with doping level, beyond that expected from Auger recombination calculations. Finally, many of the polycrystalline silicon types are surprisingly insensitive to impurity introduction in regard to their lifetime properties, while yet not showing widespread microprecipitation.

All these phenomena have frequently given rise to the speculation that mobile point defects and their association - disassociation reactions into small clusters, perhaps at nucleation sites presented by larger defects, are at the heart of all these observations.

However, at this time, any direct evidence for either mobile defects or their clustering is lacking entirely, both crystallographically and electronically. It is hoped that the panel, along with the audience, can address the validity of the proposition made here and evolve some better approaches to proving or disproving both the effects and their purported explanations.

NOTES

ANALYSIS OF OXYGEN GETTERING AND DISLOCATION LOCKING IN SILICON

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Interstitial oxygen is the main impurity in silicon grown by the Czochralski method. In an originally dislocation free silicon wafer, dislocations are generated either from microscopic surface irregularities or from microdefects that exist in the bulk under the action of thermal stresses developed during processing. Oxygen atoms are gettered by dislocations because of the interaction between the interstitial atom and the stress field of the dislocation in the crystalline lattice. The gettering of oxygen results in dislocation locking when dislocations are either immobile or move at velocities which are low compared to the rate of oxygen migration to the dislocation. Dislocation immobilization stops dislocation multiplication and leads to significant lattice hardening. Although experimental results for oxygen gettering in silicon are available, systematic modelling and theoretical prediction of the strength of silicon wafers during thermal processing have not been attempted.

We have developed a systematic method for the study of oxygen gettering by dislocations in silicon. Both the atomic structure and the macroscopic configuration of glide dislocations are taken into account. The dislocation field is modelled as a regular array of parallel 60° dislocations. Quantitative modelling of oxygen gettering is based on the solution of the macroscopic transport equation

$$\frac{\partial n}{\partial t} = -\nabla \cdot (\mathrm{u}_d - \mathrm{v})n + \nabla \cdot (\mathrm{D} \cdot \nabla n),$$

where n is the number density of oxygen. U_d is the inhomogeneous oxygen drift velocity, v is the velocity of the gliding dislocation and D is the anisotropic and inhomogeneous diffusivity tensor in the stress field created by the dislocation in the silicon lattice. A constitutive model for the dependence of U_d and D on the interaction force between the oxygen atoms and the dislocation and on temperature has been developed [1] based on atomistic simulations and moment analysis of the macroscopic transport equation. The diffusivity tensor is predicted to be anisotropic and to depend on the applied force and temperature.

The macroscopic transport equation is solved numerically. Experimental data for oxygen solubility in silicon are used to determine the boundary condition at the dislocation core. The solution of the transport equation and dislocation field theory are used to calculate the drag force on the gliding dislocation by the gettered oxygen. The phenomenological model of Haasen for the dynamics of plastic deformation in diamond structure crystals is used to incorporate other mechanisms of dislocation drag. The predicted dependence of the dislocation velocity on the applied stress at specific conditions of temperature and oxygen concentration is shown in Fig. 1 and is in good agreement with the experimental data of Sumino [2].

REFERENCES

[1] D. Maroudas, and R. A. Brown, in preparation (1990).
[2] M. Imai, and K. Sumino, *Phil. Mag*, A47, 599 (1983).

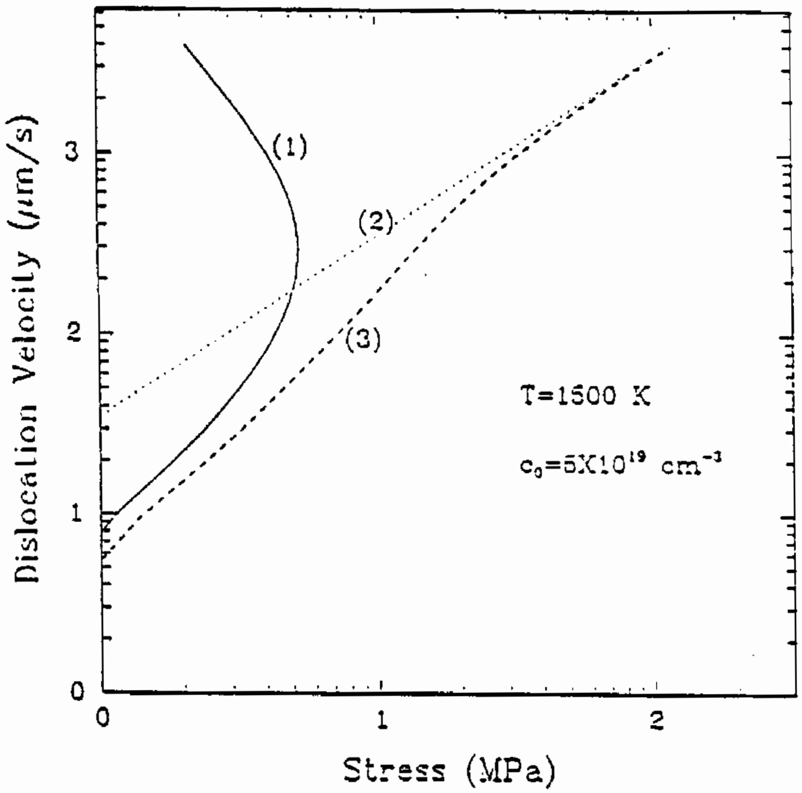

Fig. 1. Dislocation velocity as a function of applied stress for 60° dislocations in silicon doped with oxygen. Line (2) is the result for undoped silicon according to the Haasen model. Curve (3) is the result for doped silicon according to our model (1) and line (2).

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INFLUENCE OF ION-IMPLANTED TITANIUM ON THE PERFORMANCE OF EFG SOLAR CELLS

Jeff Borenstein, Jack Hanoka, B.R. Bathey and Juris Kalejs
Mobil Solar Energy Corporation, Billerica, MA 01821
Sam Mil'shtein
University of Lowell, Lowell, MA 01854

The electrical effects of ion-implanted titanium of Edge-Defined, Film-Fed Grown (EFG) silicon solar cells have been investigated using a combination of solar cell measurements and Deep Level Transient Spectroscopy. The implanted titanium indiffuses during cell fabrication, and generates a layer of low minority carrier lifetime extending beneath the space-charge region. Comparisons with earlier studies of Ti-doped crystals and with DLTS spectra of Ti-implanted single-crystal Si demonstrate that 1) Implanted titanium generates the same trap level as does grown-in Ti, and 2) The titanium trap level is the same in both single-crystal and polycrystalline silicon.

NOTES

ATOM PROBE STUDY OF DEFECT-ASSISTED SiO_x PRECIPITATION AND CORRELATION WITH MINORITY CARRIER LIFETIME IN DENDRITIC WEB SILICON SOLAR CELLS

John Spitznagel and Dan Meier
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&
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Atom Probe Field Ion Microscopy has been used to study the microchemistry of the twinned region of high and low efficiency solar cells fabricated from web silicon. The results have been combined with those of cross section TEM, LBIC and DLTS measurements to arrive at the conclusion that small minority carrier lifetimes in low efficiency cells are not due to bulk impurity effects but are linked to impurity decorated dislocations near internal twin boundaries. The impurities have been identified as oxygen precipitates of composition SiO_x. The precipitates must have a critical size before they can act as recombination sites. APFIM and lifetime measurements suggest that the critical precipitate radius is approximately 5 nm.

NOTES

REVIEW OF POINT-DEFECT AND DIFFUSION PHENOMENA IN SILICON

Paul Fahey

IBM Watson Research Center, Yorktown Heights, NY 10598

This talk reviews the present understanding of point defects and diffusion in silicon. It has been known for many years that oxidation of the silicon surface injects self-interstitials into the bulk, causing the growth of extrinsic stacking faults and enhanced diffusion of some dopants. Many experiments have been performed in efforts to understand and model this phenomenon. In spite of all this work, only recently have researchers gained a clear picture of what knowledge must be obtained in order to gain a full understanding of point-defect behavior in silicon. For example, it has become apparent that surface processes other than oxidation -nitridation and silicidation are two recent examples- also inject point defects into the silicon substrate. At present no model exists that can predict whether a particular surface process will affect point-defect concentrations in the bulk. In addition, attempts at modeling diffusion phenomena in two and three dimensions have brought to the fore many new phenomena and questions that never arose in the previous one-dimensional view of silicon substrates. Among the topics covered are: how fast point defects diffuse, what interactions point defects have with native and non-native point defects, and the importance of surface as sources and sinks of point defects.

NOTES

EFFECT OF IMPLANTATION DAMAGE DEPTH ON POINT-DEFECT GENERATION AND DAMAGE PRODUCTION

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&
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Tradeoffs between implant damage annealing and shallow junction formation have been studied using TEM, dopant profile measurements, computer modeling and diode fabrication. We have found that ultra-low energy implantation produces defect-free junctions with little excess point-defect generation. The mechanism is related to the fact that implant damage, which is responsible for point-defect production, anneals rapidly as the implant depth decreases. We have found a fourth power dependence for annealing time on damage depth. The depth effect depends on the type of amorphizing ion. It is shown that as a result, implanted B in Ge-preamorphized Si diffuses with no detectable self-interstitial supersaturation if the damage is < 600Å deep. Conditions for forming defect-free, shallow $p^{+}n$ junctions are described in design curves and comparisons are made between several junction-formation approaches. Implantation of B at energies below 2 keV offers an attractive way of achieving 500Å junctions.

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THE OPTIMIZATION OF DEVICE DESIGN AND FABRICATION PROCESSES FOR HIGH-EFFICIENCY SILICON SOLAR CELLS

Ronald Sinton and Richard Swanson
Stanford University

The high-efficiency silicon solar cell designs pursued at Stanford University all required exceptionally long bulk lifetimes in finished devices. This talk will present some of our experiences in developing fabrication techniques that maintain the lifetime in float-zone and magnetic-Czochralski material despite repeated high-temperature process steps. Some devices made with these techniques were used in studies of the fundamental Auger lifetime for Si. These studies lead us to believe that the bulk lifetime in our solar cells under operating conditions is determined by this fundamental Auger lifetime.

Some modeling results will be presented for the sensitivity of the efficiencies of our cell designs to the bulk lifetime parameters. When we use FZ or MCZ material, our solar cell efficiencies are not determined by any bulk material property so much as they are by the front-surface passivation. This surface passivation is a complex function of surface-doping type and level, processing history, surface topography, and exposure to UV light.

NOTES

IMPACT OF DEFECTS ON THE PERFORMANCE OF SILICON SOLAR CELLS MADE ON CAST POLYCRYSTALLINE SILICON

John H. Wohlgemuth and Srinivasamohan Narayanan
Solarex Corporation, Frederick, MD 21701

This presentation will review the status of cast polycrystalline silicon as a substrate for fabrication of solar cells, with emphasis on the relationships between the presence of specific defects and cell efficiency. Cell processing experiments at Solarex and at the University of New South Wales on gettering and/or passivating of defects to increase cell efficiency will be discussed. The differences between cast polycrystalline silicon and single crystal silicon (CZ and FZ) will be discussed. The conclusion of the talk will be designed to pose questions for discussion at the workshop including:

1) What are the limitations on defect densities in cast material?
2) Can subsequent cell processing passivate (or neutralize) the effects of these defects on solar cell performance?

NOTES

HYDROGEN IN SILICON: A VIEW OF THE TIP OF THE ICEBERG

Carl Seager

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The use of H in-diffusion to passivate defects in silicon provides a practical way to improve minority carrier lifetimes and junction properties in solar cells made with ribbon silicon, cast polysilicon, and thin film deposited silicon. Yet, despite almost a decade of using this technology to improve research and commercial cells, little is understood about the detailed nature of the in-diffusion process. The reason for this lies partly in past unwillingness to attack the research aspects of this problem properly, and even more crucially on the complex nature of the charge states, diffusion, and trapping effects that determine how H moves in silicon. This problem has been further compounded by the fact that the plasma techniques most widely used for research hydrogenation experiments create subsurface H densities that are influenced by plasma glow, E fields, and particle fluxes and energies in a way that is singularly difficult to unravel. Even so, the past five years has brought some progress in both theoretical calculations of H configurations and motion and experimental observations of diffusivities, charge states, and trapping phenomena. In this talk I shall summarize recent progress in this area including, not surprisingly, some of the work done at Sandia Laboratories. I will become clear that recent research, while painting a discouragingly complex picture, has at least phenomenologically identified the major impediments which slow diffusive H motion. The challenge now is to better understand these phenomena so that we may pursue the most efficient techniques to get H into silicon solar cells.

NOTES

HYDROGEN TRANSPORT PROCESSES IN CRYSTALLINE SILICON

Juris Kalejs and S. Rajendran
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A model for atomic hydrogen diffusion in crystalline silicon is presented that allows prediction of the advancement of the front of trapped hydrogen that is formed during deactivation of dopants or passivation of electrically active structural defects responsible for limiting lifetime. Model calculations and experimental data are used to derive information on trapping, deactivation rate and hydrogen molecule formation parameters during boron deactivation at 150 C. Bulk hydrogen diffusion during boron deactivation is shown to take place under diffusion limited conditions where the trap density is much greater than the diffusing hydrogen concentration. The results demonstrate the need to use a diffusivity for atomic hydrogen in the absence of traps that is obtained from extrapolation of the high temperature data of Van Wieringen and Warmoltz (Physica 22,849(1956)). Analysis of the passivation of dislocations at 400 C leads to identification of other regimes for bulk hydrogen transport. The model illustrates limits of available experimental data in providing information on the temperature dependence of hydrogen transport phenomena. The analysis establishes a common framework with which to treat boron deactivation and passivation of dislocations in crystalline silicon used in solar cell applications on an equal footing and provides a consistent approach from which to evaluate a large body of hydrogen transport data.

NOTES

POINT DEFECT INJECTION AND ENHANCED Sb DIFFUSION IN Si DURING Co AND Ti SILICIDATION REACTIONS

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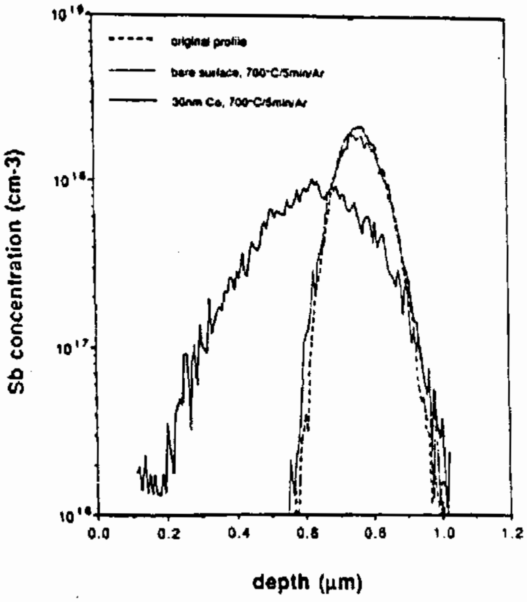
Injection of point defects into silicon during thermal silicidation reactions of deposited metals on silicon has been shown in several reports to enhance the removal of ion implantation induced interstitial defects and perturb dopant diffusion. To study the effects of silicidation-induced point defects on diffusion in silicon, buried Sb and P doped layers in (100) silicon have been formed by ion implantation followed by silicon epitaxy. After thermal evaporation of patterned Co and Ti, followed by rapid thermal annealing, the bevel and stain technique and secondary ion mass spectrometry were used to measure buried layer diffusion profiles under silicided and non-silicided regions of the Si wafer. Greatly enhanced and asymmetric Sb diffusion is observed after reaction of 30nm of Co at 700°C for 5 min, with a time-averaged Sb diffusion coefficient of 3×10^{-13} cm^2/sec. Reaction of 200nm of Ti at 800°C for 5 min resulted in asymmetric diffusion of Sb at a rate of 5×10^{-14} cm^2/sec. The calculated diffusion coefficients suggest excess vacancy concentrations of several orders of magnitude over equilibrium values. These and other results are presented and discussed in terms of point defect injection mechanisms and calculated point defect supersaturations. Implications for shallow junction processing and process modelling are discussed.

SIMS - Sb Buried Layer Depth Profile

- 30 nm Co evaporation
- 700°C / 5min / Ar anneal
- $CoSi_2$ etched



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ROLE OF REDUCED THERMAL BUDGET IN SITU PROCESSING OF SILICON SOLAR CELLS

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Defects may be present in the as-grown material or unintentionally introduced during high-temperature processing steps of silicon solar cells. Reduced thermal budget processing (integral of processing time and temperature) is one possible way of avoiding high temperature steps. In the conventional furnace processing, radiations in the infrared region (wavelength greater than about 0.8 micron) result into thermal reactions where the ground state molecules are raised to higher vibrational levels of the electronic ground state and dissociation occurs when sufficient energies are concentrated in the bond to be broken. On the other hand, photo-assisted process are initiated by the absorption of a light quantum (wavelength from vacuum ultra violet to visible region) by atoms and molecules. From a practical point of view, photo-assisted processes can be used to reduce the thermal budget for virtually every processing step used in any device in general and solar cells in particular. By incorporating a vacuum ultra violet (VUV) in the rapid isothermal processing (RIP) assisted chemical vapor deposition (CVD) system, we have oxidized silicon at temperatures as low as 300°C. The use of complete radiation spectrum (from VUV to IR) suggests that defects can be controlled during the processing of silicon solar cells. In this paper, we will present the role of in-situ photo-assisted deposition and annealing processes and present several examples that are relevant to solar cells.

NOTES

ANNEALING, GETTERING, AND PASSIVATION OF DEFECTS IN SOLAR CELL SI: AN OUTSIDER'S VIEW

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In solar cell Si one is mainly concerned with minority carrier recombination life times (τ) or diffusion lengths (L). As limited by band-band recombination mechanisms, in perfect and pure intrinsic Si τ reaches 10^4 sec and L reaches meters at room temperature. The value of τ drops to ~0.1 sec as doping level increases to $\sim 10^{16}$ cm^{-3}, with L still reaching the order of 1 cm. Owing to the existence of recombination centers which are consisting of electrically active impurities and (presumably) point defects, τ typically reaches $\sim 10^{-3}$ sec in commercially available CZ Si used for IC fabrications. The existence of the recombination centers has the beneficial effect of helping to make fast switching devices. Too much impurities and defects, however, lead to large leakage current and device failures. For fabricating ICs, which are consisting of monolithic devices, *GETTERING* is used as a continuous in process *cleaning* method to remove processing introduced metallic impurities from the device active regions, which are the wafer front surface regions. Thus, wafer interior and back surfaces are available as gettering sites for *intrinsic* and *extrinsic* gettering schemes respectively. Solar cells are bulk devices which lack convenient gettering site locations. Thus, for high efficiency solar cell fabrication using FZ Si, it is probably best *not* to attempt gettering. Introduction of metallic impurities should be avoided and a post fabrication passivation process may be helpful. CZ Si should be avoided. For low cost solar cells, the material, e.g., EFG Si, contains grain boundaries, dislocations, inert impurities C and O, metallic impurities Ni, Fe, Cu, etc., and precipitates of the impurities. This seems to be a *self-gettered* ensemble in the sense that most of the impurities are in precipitates which leaves the Si crystal region free from precipitates not to be burdened with an excess of metallic impurity atoms, while in the mean time the precipitate-Si interface introduced a continuous distribution of band gap states, probably both donor and acceptor types. The result is a fairly low but still respectable τ value ($\sim 10^{-6}$ sec). Within the *low cost* constraint, questions to be addressed will thus include: (i) Will additional gettering be helpful (modifying self-gettering in the ensemble)? How to do it? Where to put the gettering centers? (ii) Will post processing high temperature short time annealing be helpful? such an annealing will dissolve small SiO_2 precipitates and thus eliminating some interface states, but it will be at the cost of releasing precipitated metals into atomic form and thus increasing their gap state density. What should be the results of such compensating factors? and (iii) What are the effects of passivation? Are there ways to simultaneously passivate donor as well as acceptor states?

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GETTERING, ANNEALING, AND PASSIVATION...

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The passivation by hydrogen of electrically active impurities (or other defects) in semiconductors has been observed for many deep and shallow centers. Hydrogen is attracted to and reacts with vacancies, transition metal impurities, shallow acceptors and donors, including things like oxygen-related thermal donors. Hydrogen can also activate normally inactive impurities. In a few cases, the passivated structure of the complex is known. It often involves a strong *Si-H* bond. This brief presentation will focus on some of the less well understood problems: re-activation mechanisms, trapping of multiple *H* atoms at a given site, passivation of transition metal impurities, passivation by elements other than hydrogen, meta- or bi-stability, etc.

NOTES

WORKSHOP ON THE ROLE OF POINT DEFECTS/DEFECT COMPLEXES IN SILICON DEVICE FABRICATION

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