

“GROWTH AND CHARACTERIZATIONS OF SiO₂ THIN FILM ON SILICON SUBSTRATES”

*A Dissertation submitted in partial fulfillment of
the requirements for the degree of*



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By

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CERTIFICATE

This to certify that the work in the report entitled “*Growth and Characterizations of SiO₂ thin films on Silicon substrates*” by *Miss Maheswari Majhi*, in partial fulfilment of Master of Science degree in PHYSICS at the National Institute of Technology, Rourkela, is an authentic work carried out by her under my supervision and guidance. The work is satisfactory to the best of my knowledge.

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Date:

Maheswari Majhi

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Abstract

SiO₂ thin films were prepared on Silicon n-type substrates using thermal oxidation method in a horizontal oxide furnace at 1000 °C. Three SiO₂ samples were taken. One was not annealed while the rest two were annealed at different temperatures. The films are of 300 nm. Two SiO₂ samples were annealed at 800 °C and 1000 °C in a furnace in the presence of N₂. The samples morphological characterizations are done using XRD and SEM. And electrical characterizations are done using C-V and I-V. XRD and SEM confirmed its amorphous nature. Electrical properties were found out by C-V and I-V.

Keywords: Thin film, Silicon dioxide, Thermal oxidation

INTRODUCTION

Chapter-1

1.1. Motivation and Background

It dates back to millions of years when Silicon dioxide was formed, nearly back to the times after earth was formed. At that time the earliest forms of life made their skeletons from silicon dioxide, plants were using silicon dioxide for support structures. Berzelius (1779-1848) "discovered" SiO_2 in 1824. Later on, on the timeline of earth when existence of human being starts the mighty Romans used silicon dioxide in the form of sand to strengthen the invention of concrete. The upper class Romans utilized quartz which is another form silicon dioxide for gemstones in jewellery. During the same period in Asia, Hindu monks used to spent large portions of their life using silicon dioxide in the form of sand to make designs and destroy them and then make another design which still continued till date. Glass which is another form of silica was first invented by the Venetians of Italy. Glass is mainly made of silicon dioxide with other compounds such as Na_2O , CaO , and Al_2O_3 . Silicon dioxide has played a significant role in the world's history and will continue to throughout the ages. It is believed by many people that in the future the majority of life forms will no longer be based on carbon but on silicon. Silicon Dioxide, whose common name is silica, is a white or transparent, crystalline and odourless solid. It belongs to group IV of the chemical family called metal oxides. It is a very stable compound, and only reacts with hydrofluoric acid. Silicon dioxide is an acidic oxide and acidic nature is due to the production of hydrogen ions when it is in water. Silicon dioxide transmits visible and ultraviolet light. Silicon Dioxide comes in many different geometrical patterns. Till date near about 35 crystalline shapes have been observed which results in different density of each group of atoms. Another crystalline form of silicon dioxide known as kettite was produced during the first atomic bomb test run that was dropped in New Mexico. Quartz one of the most common shapes can transform when silicon dioxide is heated over 867°C . Silicon dioxide is held together by double, covalent bonds. Silicon Dioxide is one of the most abundant compounds on the planet earth and has many different uses. Thus world without glasses will be unimaginable.

Silicon can be easily found in the earth's crust in crystalline form or in amorphous powder form. 75% of the earth's crust is made up of Silicon and oxygen together. Sand is Silicon Dioxide only and that makes sandy areas such as the beach and deserts which make a good resource for silicon dioxide. Silicon dioxide can be found in the earth crust in quartz form also. Silicon dioxide is a compound of many uses and has been for many years. Due to its abundance it is used commercially as a resource for pure silicon. Large furnaces are used to heat silicon dioxide, they remove oxygen and leave pure silicon behind. The modern electronics world greatly depends on silicon dioxide for the manufacture of semiconductors, wire insulation, and fibre optic cables. Since quartz (SiO_2) has piezoelectric properties this makes silicon an ever more-valuable compound to modern electronics. This property of quartz allows for radio and TV stations to transmit, stabilize, and receive signals. Sonar also uses piezoelectric property to detect vibrations. Wrist watches also use quartz to help keep accurate time. The oil industry today uses silicon dioxide gel to help refine crude oil into usable fuel such as gasoline. Silicon dioxide also finds usage in field of engineering. It is also used in glasses for windows, metal alloys, pipe flux, metal alloys, concrete, sand for foundations, sealants, sandblasting, and many more applications. Silicon dioxide (silica) is one of the most commonly encountered substances in both daily life and in electronics manufacturing. Crystalline silicon dioxide has several forms such as quartz, cristobalite and tridymite. Today, the modern electronics world greatly depends on silicon dioxide for the manufacture of semiconductors, wire insulation, and fibre optic cables. Its high melting temperature and chemical stability make it perfect for use in insulating wires.

SiO_2 is a three dimensional structure and comes from the tetrahedral structure, SiO_4 . Each of the Silicon atoms is connected to each other with an oxygen atom, which creates a "diamond type network". The bond angle of Si-O-Si is around 145 degrees.

1.2. Literature Survey

Basically, thermal oxidation is a way to produce a thin layer of oxide (usually silicon dioxide) on the surface of a wafer. According to this technique an oxidizing agent is forced to diffuse into the wafer at high temperature and react with it. The rate of oxide growth is predicted by the Deal-Grove model. Thermal oxidation can be applied to different materials. Growth of thin silicon oxide is the basis for modern IC technologies. The Deal-Grove model is applicable

only for the growth of oxide for thick films not to thin films. Other models based on the Deal-Grove mechanisms cannot be extended out of their fitting ranges to thinner films either. Recently, advanced experimentation such as isotopic labelling and medium-energy ion-scattering spectroscopy has found a hybrid or transitional layer between pure silicon dioxide and pure silicon during silicon oxidation. SiO_2 is one of the "building block" films for fabrication of semiconductor devices. Generally when silicon dioxide is grown with a high purity low defect silicon substrate, it can be an excellent dielectric (Insulating) thin film. It is normally found on a device such as "field oxide" electrically isolating Polysilicon, metal or other conductive thin film(s) from the Silicon substrate or "bulk" of the device. It is also found on the device as a "gate oxide," this is a very thin thermal oxide located over the gate or active region of the individual transistors. Thermal oxidation and chemical vapour deposition (CVD) are two major methods to form silicon oxide films. Low-temperature deposition of SiO_2 ($<500\text{ }^\circ\text{C}$) is possible with CVD, which has been used for intermetal dielectric (IMD) and interlayer dielectric (ILD). In order to enable utilization of low-cost glass substrates low-temperature deposition is necessary for application of thin-film-transistor liquid crystal display (TFT-LCD). Till date hydrogenated amorphous silicon (a-Si:H) TFTs with silicon nitride as a gate insulator have been used for LCDs, because a-Si for active layers can be easily deposited on large-area and is inexpensive too. On the other hand, the electron mobility in polysilicon is higher than in a-Si, and one of the advantages of poly-Si TFTs is their potential for integrated-array driver circuits [11, 12]. The development of a low-temperature process for the deposition of poly-Si and gate insulator is required. In this case, silicon oxide is preferred as a gate insulator, since poly-Si has been known to have good interface properties with silicon oxide.

Silicon exhibits a different kind of face-centered cubic structure known as the diamond lattice which is a combination of two face centered cubic unit cells in which one cell has been slide along the main diagonal of the cube one-fourth of the distance along the diagonal shown in Fig. 1.1.

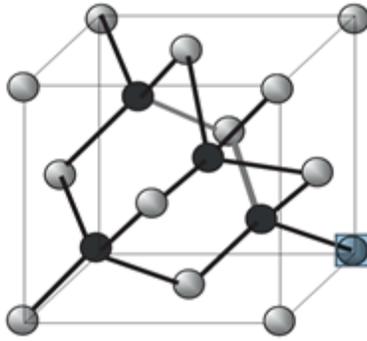


Fig.1.1 The diamond lattice structure

There are eight atoms in this structure, four from each cell. Each Si atom is surrounded by four nearest neighbours in a tetrahedral configuration with the original Si atom located at the centre of the tetrahedron. Since Si has four valence electrons, it shares these electrons with its four nearest neighbours in covalent bonds. Modelling Si atoms as hard spheres, the Si radius is 1.18\AA with a lattice constant of 5.43\AA . The distance between nearest neighbours is $d = \frac{\sqrt{3}}{4}a = 2.35\text{\AA}$. Silicon wafers are classified in part by the orientation of their various crystal planes with relation to the surface plane of the wafer itself. Termed as (100) wafer corresponds to a {100} crystal plane. Likewise, the plane of a (111) wafer coincides with the {111} plane [7-11]. The addition of straight edges, or flats to the otherwise circular wafers reflects the identity of the crystalline orientation of the wafers as well their type i.e. P type or N-type. P-type and n-type refer to wafer's doping, a process affecting the wafer's semiconductor properties. Fig.1.2 & Fig.1.3 shows the relative orientations of the three important cubic directions for a {100} wafer.

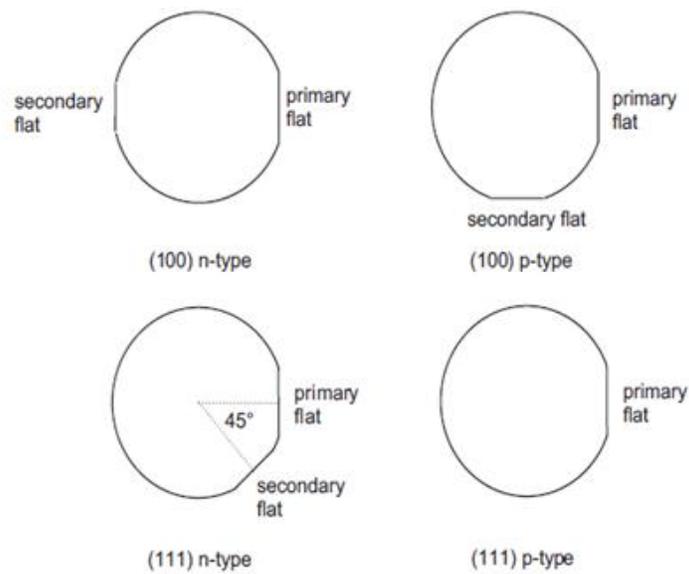


Fig.1.2 Wafer flats are used to identify wafer crystalline orientation and doping

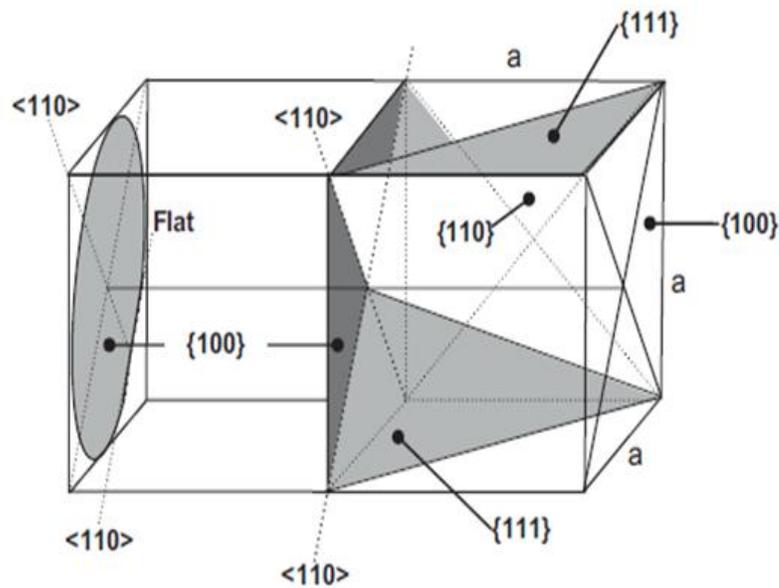


Fig.1.3 Orientations of various crystal directions and planes in a (100) wafer

(Adapted from Peeters, 1994)

1.3. Properties

The melting point of silicon dioxide is very high due to its tetrahedral structure. The strong silicon-oxygen covalent bonds get broken at very high temperatures, close to 1700 °C. Also, silicon dioxide is very hard and rigid, and this is due to the strong covalent bond that exists between silicon and oxygen. Due to the absence of free electrons, silicon dioxide acts as an

insulator. It is insoluble in water and in all organic solvents. But it is soluble in alkalis and hydrofluoric acid. It reacts with very few substances. Reliability of highly integrated Si devices is critically dependent on the characteristics of the vitreous oxide film like thickness uniformity, defect density, dielectric strength, and others, as well as on those of the oxide/Si interface like roughness, electronic states density and others [1, 2].

Some of the properties are listed in the table below [3]:

Properties	SiO ₂
Structure	Amorphous
Melting Point (°C)	Approximately 1600
Density (gm/cm ³)	2.2
Refractive index	1.46
Dielectric constant	3.9
Dielectric strength (V/cm)	10 ⁷
Infrared absorption band (μm)	9.3
Energy gap at 300 K(eV)	9
Linear coefficient of thermal expansion ΔL/L/ΔT (1/ °C)	5×10 ⁻⁷
Thermal Conductivity at 300 K(W/cm-degree K)	0.014
DC resistivity at 25 °C (ohm-cm)	10 ¹⁴ -10 ¹⁶

Table.1 Properties of SiO₂

1.4. Application

Following are some important applications of silicon dioxide:

1. Quartz is used in the glass industry as a raw material for manufacturing glass.
2. Silica is used as a raw material for manufacturing concrete.
3. Silica is added to varnishes because of its hardness and resistance to scratch.

4. Amorphous silica is added as fillers to the rubber during the manufacturing of tires. This helps reduce the fuel consumption of the vehicle.
5. Silica is used in the production of silicon.
6. As silica is a good insulator, it is used as a filler material in electronic circuits.
7. Quartz has piezoelectric properties so it is also used in transducers.
8. Its ability to absorb moisture is utilised by using as a desiccant.

Silicon Dioxide is used in semiconductor fabrication especially for MOS technology. In comparison to other materials which suffer from one or more problem, SiO_2 offers a lot of desired characteristics and advantages. Some of the important roles of SiO_2 are:

1. Mask against implantation or diffusion of dopant into Silicon
2. Surface passivation
3. Device isolation
4. Component in MOS structures (gate oxides)
5. Electrical isolation of multi-level metallization systems
6. High thermal conductivity
7. No diffusion of Cu or other ions into dielectric
8. No leakage between conductors

1.5. The MOS Structure

The metal-oxide-semiconductor diode or MOS capacitor is an important structure of most semiconductor devices. It is the heart of a MOSFET which in turn is an important device used in large-scale integration [4]. The MOS capacitor consists of a thin film SiO_2 layer sandwiched between a Silicon substrates and a metallic field plate. The most common field plate materials are Aluminium and heavily doped polycrystalline Silicon. A second metallic layer present along the back or bottom side of the semiconductor provides an electrical contact to the Silicon substrate.

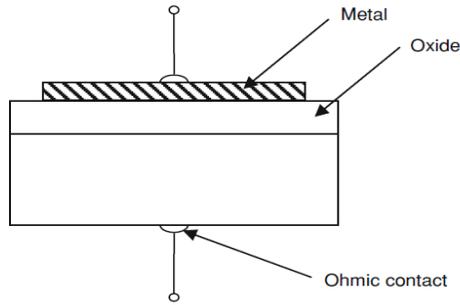


Fig.1.4 Cross-sectional view of a MOS structure

1.5.1. Ideal MOS Structure

For an ideal MOS structure the following conditions should be met:

1. The work function of metal W_m and work function of silicon W_s are equal, $W_m = W_s$, which implies that in the three materials, all energy levels are flat, when no voltage applied to the structure.
2. There exists no charge in the oxide and at the Si-SiO₂ interface, which implies that the electric field is zero everywhere in the absence of any applied voltage.

When an ideal MOS diode is biased with positive or negative voltages, three cases may exist at the semiconductor surface:

- a) Accumulation
- b) Depletion
- c) Inversion

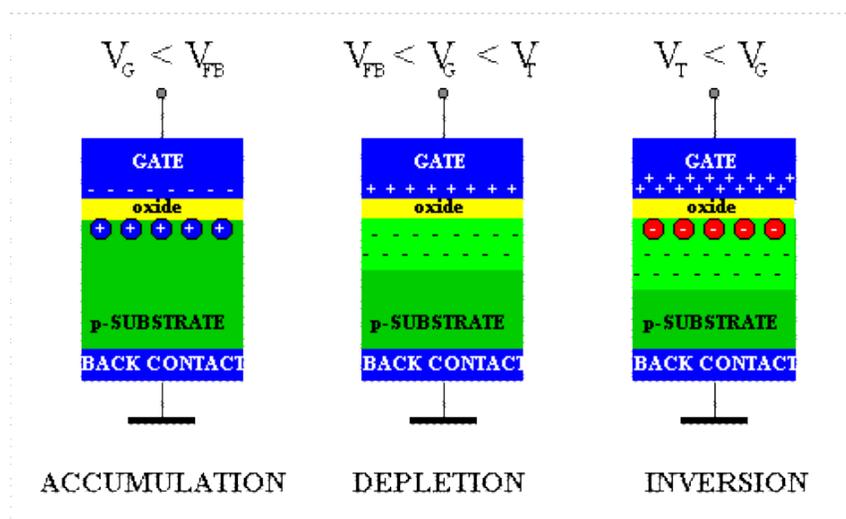


Fig. 1.5 The three regions accumulation, depletion and inversion

1.5.2. Accumulation

When an external voltage V_G is applied to the silicon surface in MOS capacitor, the carrier densities change accordingly in its surface region. When large negative bias is applied to the gate, holes are attracted by the negative charges to form an accumulation layer.

1.5.3. Depletion

When negative charges are removed from the gate, holes leave the accumulation layer until the silicon will be neutral everywhere. This applied gate bias is called the flat band voltage. As the bias on the gate is made more positive with respect to flat band, holes are repelled and a region is formed at the surface which is depleted of carriers called the depletion layer.

1.5.4. Inversion

When the positive voltage is kept on increased, the surface depletion region will then continue to widen until the onset of surface inversion is observed, an inversion layer is formed. The two voltages that separate the three regimes are:

- a) Flat band voltage (V_G) which separates the accumulation regime from the depletion regime.
- b) Threshold (V_T) which demarcates the depletion regime from the inversion regime.

Chapter-2

2.1. Fabrication Technology of Silicon Dioxide Thin Film

Silicon dioxide (SiO_2) layers are grown over Si surfaces in order to form electrically insulating regions during integrated circuit manufacturing. There are several techniques to form oxide layers such as:

1. Thermal oxidation
2. Chemical Vapour Deposition (CVD)
3. Pulsed Laser Deposition (PLD)
4. Atomic Layer Deposition (ALD)
5. Physical Vapour Deposition (PVD)
6. Plasma oxidation
7. Plasma Enhanced Chemical Vapour Deposition (PECVD)
8. Wet anodization

Thermal oxidation tends to yield the cleanest oxide layer with the least amount of interfacial defects. Thermal oxidation by far is the most important method for growing a SiO_2 thin film in contrast to several other methods like PECVD and electrochemical process. Thermal SiO_2 films has been most widely used in integrated circuits due to superior insulating of SiO_2 films, thermal stability, a stable SiO_2 and Si interface and simple processing requirements.

2.2. Thermal Oxidation

Thermal SiO_2 films has been most widely used in integrated circuits due to superior insulating of SiO_2 films, thermal stability, a stable SiO_2 and Si interface and simple processing requirements [5]. The oxide of silicon is one of the most important ingredients in semiconductor manufacturing. It has played a crucial role in the development of semiconductor planar processing. The formation of SiO_2 on a silicon surface is most often accomplished through a process called thermal oxidation. Thermal oxidation is a technique that uses extremely high temperatures (usually between 700-1300 °C) to promote the growth rate of oxide layers. If grown correctly using a high purity low defect Silicon substrate it can be an excellent dielectric thin film. The thermal oxidation of SiO_2 consists of exposing the silicon substrate to an oxidizing environment of O_2 or H_2O at elevated temperature and producing oxide films whose thicknesses

range from 60 to 10000 Å. Oxidation of silicon is easily possible, since silicon can form a stable oxide even at room temperature, as long as an oxidizing environment is present. The elevated temperature serves primarily as an accelerator of the oxidation process, resulting in thicker oxide layers.

Depending on which oxidant species is used (O_2 or H_2O), the thermal oxidation of SiO_2 may either be in the form of dry oxidation (wherein the oxidant is O_2) or wet oxidation (wherein the oxidant is H_2O).

2.2.1. Dry oxidation method

In this oxidation the oxidant used is oxygen. A dry oxidation produces a more uniform and denser thermal oxide with even higher dielectric strength than compared to wet oxide. The major difference in the growth of wet and dry oxide is the growth rate. Dry oxide grows at a much slower rate than wet oxide. For this reason dry oxides do not exceed 1000 Å in thickness and are primarily used for thin gate and capacitor oxides where high uniformity and high dielectric strength are needed.

The chemical reaction involved is:

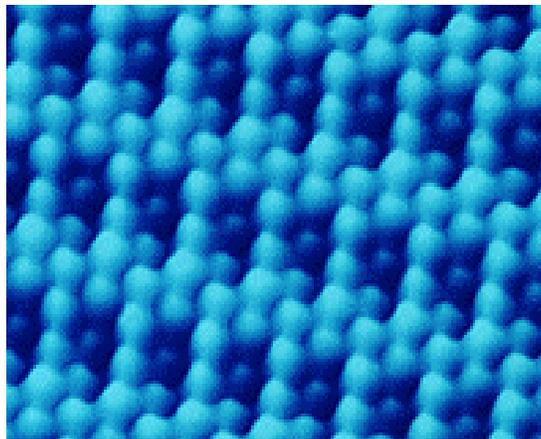


Fig.2.1 Oxygen atoms combined with Silicon atoms to form SiO_2 at the Silicon interface (picture taken with an atomic force microscope)

2.2.2. Wet Oxide method

In this process steam is used as an oxidant. This method is used to produce a thicker oxide 2,000-24,000Å, this thick oxide is usually called "field oxide" and it is found in areas on the device where high dielectric strength is needed.

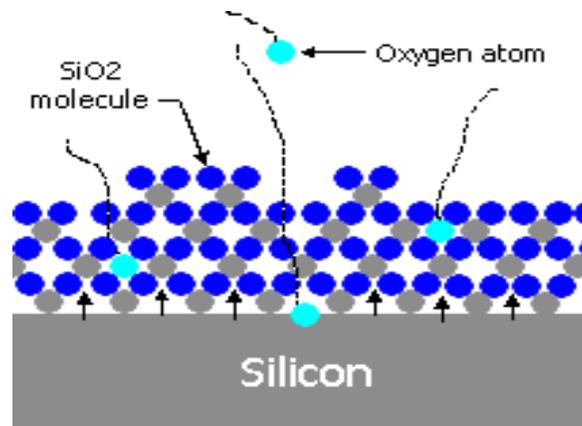
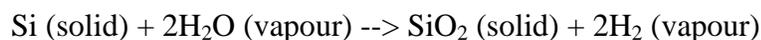


Fig. 2.2 Silicon Dioxide thin film growth process

Thermal oxide growth occurs at the Silicon/Oxide interface where it actually grows from the bottom-up and each new layer is in essence is being "pushed-up" instead being deposited or "piled on". Thus thermal oxide growth is not linear, as the oxide grows the rate of growth slows down, because as more oxide is present on the surface of the Silicon it takes longer time for the Oxygen atoms to penetrate and reach the Silicon interface and then combine with Silicon atoms to form more SiO₂. When this oxide reaches about 19Å it stops growing. Additional oxide must be grown at high temperature.

The chemical reaction involved is:



Chapter-3

3.1. Sample preparation

Dry oxidation of silicon is typically used to grow a thin, high quality oxide for use in transistor gates and capacitors. The SiO_2 thin films were grown on Silicon n-type substrate using Thermal oxidation by the dry oxide method.

3.2. Procedure

A horizontal oxide furnace was used for the growth process. The inner side of the horizontal oxide furnace was made of Quartz. It has three temperature zones to maintain temperature stability. At first, the pre-cleaned Si substrate was kept in middle temperature zone by a quartz push rod at room temperature. The Si substrates were placed vertically on the quartz boat. Thereafter, dry nitrogen was allowed to pass through the furnace till the temperature reached 1000°C . After the temperature becomes constant, the nitrogen flow was stopped & dry oxygen gas was introduced through the furnace. After the oxidation of 1 hour the flow of oxygen is stopped. Again, dry nitrogen gas was allowed to flow to cool down. After proper cooling of the furnace the sample was taken away using push rod. SiO_2 thin films of 300 nm were grown by this procedure which was found using Ellipsometry.

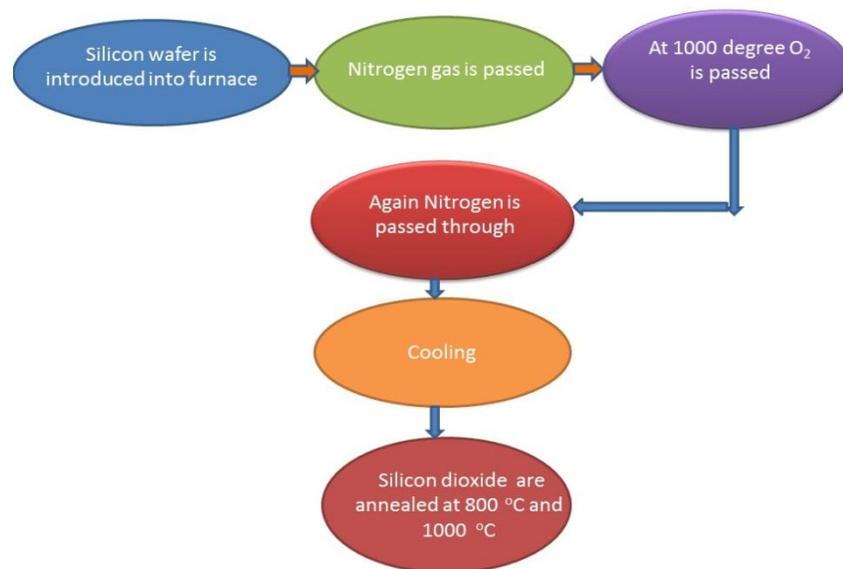


Fig. 3.1 Synthesis process flowchart

3.3. Annealing

Three samples of grown SiO_2 were taken and two samples were annealed at $800\text{ }^\circ\text{C}$ and $1000\text{ }^\circ\text{C}$ in a furnace for 1 hour in presence of N_2 . Annealing is basically done to affect their electrical properties. They are heated in order to activate dopants, densify deposited films, change states of grown films, repair damage from implants, move dopants or drive dopants from film into the wafer substrate.

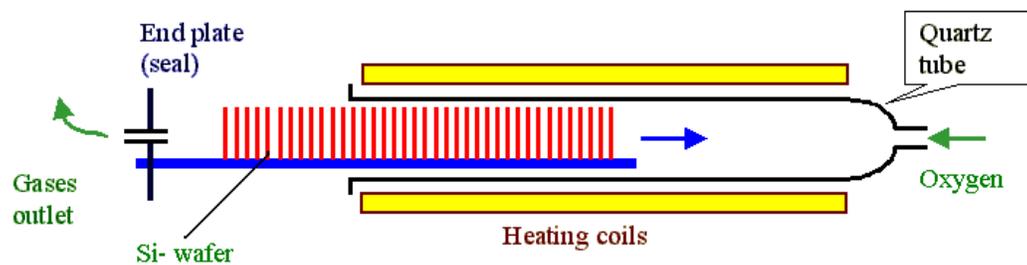


Fig. 3.2 Horizontal oxidation furnace

Chapter-4

4. Characterization Techniques

4.1. X-ray Diffraction (XRD)

X-ray diffraction (XRD) represents the classical method to determine the crystalline structure of solid materials. For the X-rays to yield useful information about the structure, the wavelength of the incident X-rays should be of the same order of magnitude as the interatomic spacing in the crystal structure. The dominant effect that occurs when an incident beam of monochromatic X-rays interacts with a target material is scattering of those X-rays from atoms within the target material.

In materials with regular structure (i.e. crystalline), the scattered X-rays undergo constructive and destructive interference. This is the process of diffraction. The diffraction of X-rays by crystals is described by Bragg's Law, $n\lambda=2d\sin\theta$. Interference occurs among the waves scattered by the atoms when crystalline solids are exposed to X-rays. Constructive interference occurs when the waves are moving in phase with each other. Destructive interference occurs when the waves are out of phase. The diffracted intensity is shown as a function of the scattering angle 2θ . The diffraction pattern obtained acts like a unique "fingerprint" of materials. Identification is done by comparing it to the known standards.

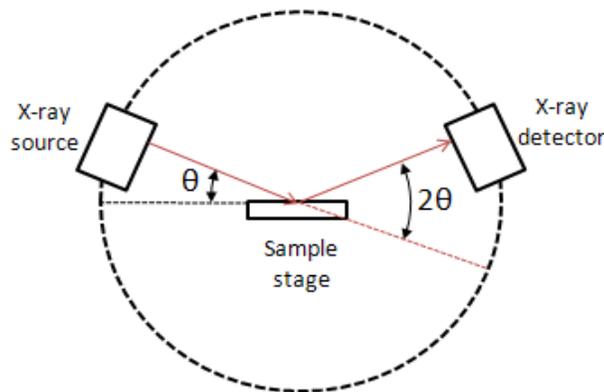


Fig. 4.1 Schematic diagram of X-ray Diffraction

Some applications are:

- (1) To differentiate between crystalline and amorphous materials
- (2) To determine the structure of crystalline material
- (3) Identification of crystalline phases and measurement of the relative proportions
- (4) To measure various kinds of randomness, disorder and imperfections in crystals

4.2. Scanning Electron Microscopy (SEM)

The SEM is a microscope that uses electrons instead of light to form an image. Its key components consist of an electron gun, a lens system, sample chamber, scanning coils, detector and a cathode ray display tube (CRT). The electron energy is typically 10–30 keV for most samples, but for insulating samples the energy has to be as low as several hundred eV. SEM gives the information regarding the topography, morphology, composition and crystallographic orientation of the sample. The scanning electron microscope has got many advantages over traditional microscopes. Its large depth of field allows more of a specimen to be in focus at one time. Its higher resolution enables closely spaced specimens to be magnified at much higher levels. Because electromagnets are used rather than lenses, one can have much more control in the degree of magnification [6].

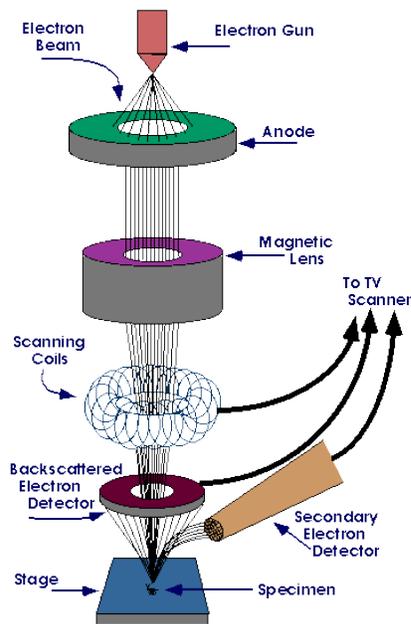


Fig. 4.2 Schematic diagram of Scanning Electron Microscope

Accelerated electrons in an SEM carry significant amounts of kinetic energy. And those electrons go and interact with the sample. There are four possibilities of emission of x rays, backscattered electrons, secondary electrons and auger electrons when the electron hit the sample. Detectors are used to collect them and convert into signal. The most common imaging mode collects low-energy (<50 eV) secondary electrons that are ejected from the k-orbitals of the specimen atoms by inelastic scattering interactions with beam electrons. [7] We can know the grain size of the sample and get a three dimensional image of the sample.

4.3. Capacitance- Voltage Measurement (C-V)

Capacitance-voltage (C-V) testing is widely used to determine semiconductor parameters in MOSFET structures. It is an electric, non-destructive measurement of the barrier capacitance of semiconductor junctions, like p-n junctions, metal- semiconductor junctions and even metal-oxide-semiconductor (MOS) structures. It can help to understand the properties of the SiO₂ and Si interface. They can reveal oxide thickness, oxide charges, contamination from mobile ions, and interface trap density. The basic structure used to make C-V measurements is the MOS capacitor, consisting of a semiconductor, a dielectric layer and a metal conducting electrode. The capacitance-voltage technique relies on the fact that the width of a reverse-biased space-charge region (scr) of a semiconductor junction device depends on the applied voltage. The scr width dependence on voltage lies at the heart of the C-V technique [8].

The procedure for taking C-V measurements involves the application of DC bias voltages across the capacitor while making the measurements with an AC signal. A DC bias voltage is

applied that drives the MOSFET structure from its accumulation region into the depletion region and then into inversion. A strong DC bias causes majority carriers from the substrate to accumulate near the insulator interface. As they can't get through the insulating layer, capacitance is at a maximum in the accumulation region as the charges stack up near that interface because d is minimum. Fundamental parameters that can be derived from C-V accumulation measurements is the silicon dioxide thickness. As the bias voltage decreases, majority carriers get pushed away from the oxide interface, and the depletion region gets formed. When the bias voltage is reversed, charge carriers move away from the oxide layer, and capacitance is at a minimum because d is at a maximum. From this inversion region capacitance, the number of majority carriers can be found out [9].

For the study of the samples, electrical contacts were made using silver paste on the two faces of each sample. The structure is made similar to a MOS capacitor [10]. The area of the silver paste electrode is approximately circular and its diameter is about 2 mm. C-V measurement was performed using Agilent LCR meter by applying a DC bias.

4.4. Current-Voltage Measurement (I-V)

A current–voltage characteristic or I–V curve is a relationship, typically represented as graph, between the electric current through a material, and the corresponding voltage, or potential difference across it. A general form of current–voltage characteristic describes the dependence of a terminal current on more than one terminal voltage difference [11]. Current-voltage (I-V) measurements can indicate the conduction mechanism in sample. Current-Voltage measurements were taken using a Pico-ammeter.



Fig 4.3 Pico-ammeter

Chapter-5

5.Results and Discussions

5.1. X-ray diffraction (XRD)

Fig. 5.1 shows the X-ray diffraction pattern of grown as well as annealed sample. The sharp prominent peak corresponds to the crystalline silicon substrates. The absence any other peak confirms the amorphous nature of SiO_2 film. The amorphous phase of SiO_2 depicts the absence of grain in the grown film. The presence of grain boundaries usually provides a path for the transport of charge carriers which is not seen here.

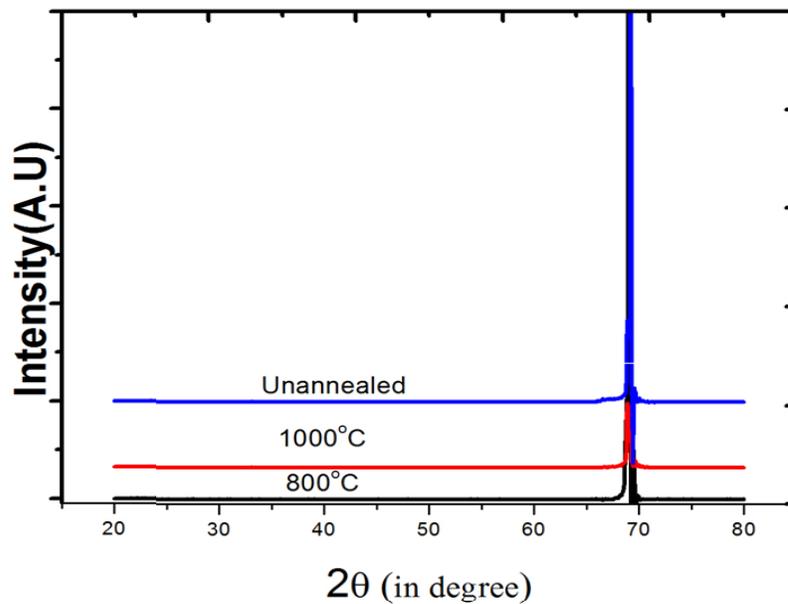


Fig. 5.1 Shows the XRD peaks of sample annealed in 800 °C, 1000 °C and unannealed

5.2. Scanning Electron Microscope (SEM)

Fig. 5.2 shows the SEM images of SiO₂ films (100-200 nm). The morphology is uniform and homogeneous without any surface modulation. There is no formation of particulates and grains during thermal oxidation, which gives rise to an amorphous phase with smoother surface.

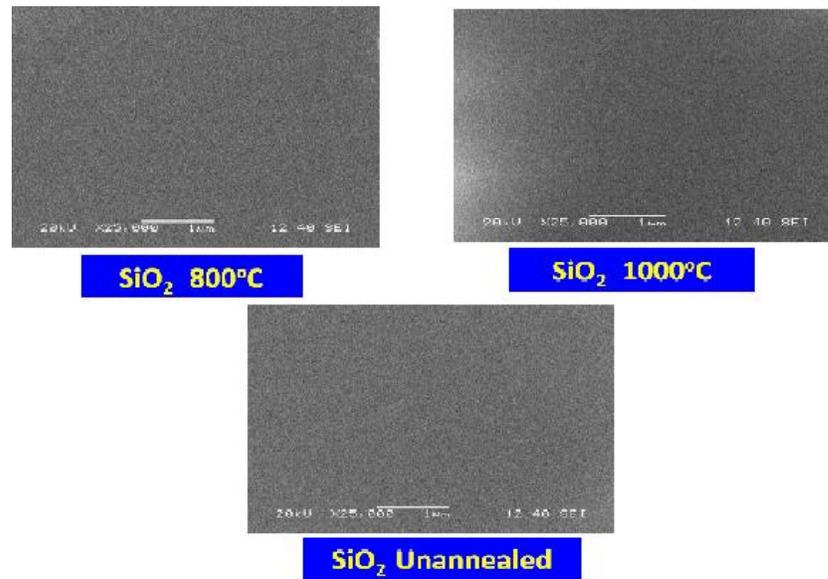


Fig. 5.2 SEM images of SiO₂ samples annealed in 800 °C, 1000 °C and unannealed

5.3. Capacitance-Voltage Measurement (C-V)

Capacitance is at a maximum during the positive voltage sweep, which depicts the substrate is n type. Three regions namely accumulation, depletion and inversion are clearly observed from C-V plot (Fig. 5.3) The C-V curves shifted towards zero voltage with increase in annealing temperature, which shows the reduction in bulk charge densities. This may be due to the annihilation of defects, during annealing. Furthermore the stretch out of the C-V curve is more for unannealed sample. The stretch out of the curve decreases with annealing, which depicts the decrease in interface trapped density. The interface trapped density decreases due to the reduction of dangling bonds or unsaturated bonds at the interface.

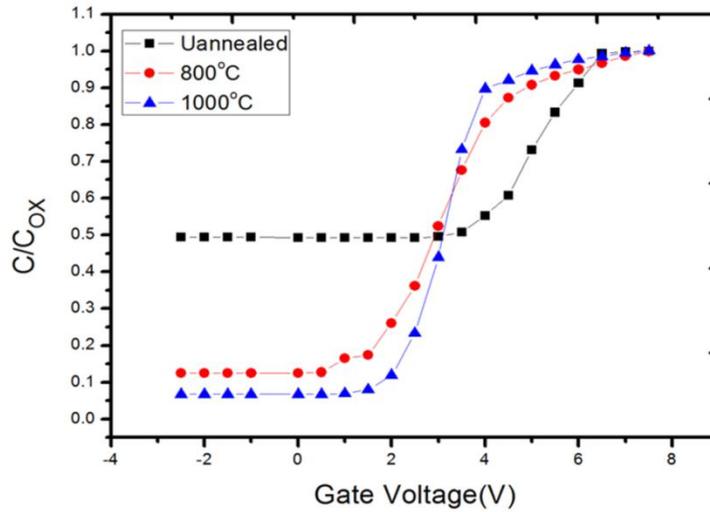


Fig. 5.3 Capacitance-Voltage graph of SiO₂ samples annealed in 800 °C, 1000 °C and unannealed

5.4. Current-Voltage Measurement (I-V)

The figure shows the non-linear current-voltage characteristics of silicon dioxide based MOS structure. The leakage current at a gate potential of 1V is found to be around 7pA.

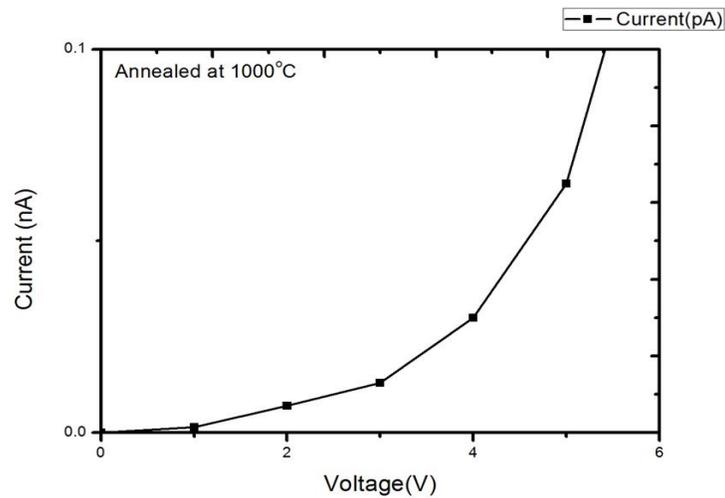


Fig. 5.4 I-V characteristic of SiO₂ annealed in 1000 °C

Chapter-6

Conclusion

SiO₂ thin films were prepared on Silicon n-type substrates using thermal oxidation method in a horizontal oxide furnace at 1000 °C. Three SiO₂ samples were taken. One was not annealed while the rest two were annealed at different temperatures. The films are of 300 nm. Two SiO₂ samples were annealed at 800 °C and 1000 °C in a furnace in the presence of N₂. The samples morphological characterizations are done using XRD and SEM. And electrical characterizations are done using C-V and I-V. XRD and SEM confirmed its amorphous nature. Current-voltage characteristics of silicon dioxide based MOS structure. The leakage current at a gate potential of 1V is found to be around 7pA. The stretch out of the C-V curve is more for unannealed sample. The stretch out of the curve decreases with annealing, which depicts the decrease in interface trapped density.

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