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The effect of Ar on the growth of Nano silicon oxide

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Abstract: Silicon dioxide ultra thin film has been grown on the Si substrate thermally. Because of native oxide on the substrate and impurities such as, carbon, we could not grow clean oxide film we have thus demonstrated a series of experiments for growing silicon dioxide on Si (111) with and without Ar gas. The clean and amorphous Nano oxide film could be formed in Ar atmosphere. The film structures have been studied by using AES (Auger Electron Spectroscopy) and SEM (Scanning Electron Microscopy) techniques.

Key words: thin film, silicon oxide, AES, SEM Technique, Amorphous material.

Introduction

Silicon have used about forty years, in solar cells, solar automobiles, motor industry, and electronic. One of its more important applications is in monopole and dipole transistors, particularly in Metal-Oxide-Semiconductor-field-Effect-transistors (MOSFET), in which, it has apply as a convenient sub-layer in these electronic devices. This particular role of silicon is due to simple and quick growth of silicon dioxide over silicon sub layer and that, the silicon with four valances is very active. Silicon can quickly form bindings with other reactant atoms, either with oxygen molecule or oxygen atom.

Binding formation of silicon atoms with atoms of other elements has conveniences and inconveniences. The conveniences are lower expensive and simple growth of silicon dioxide and as well forming of oxide film with a pleasant structure[3,4] .

On the other hand, the presence of carbon atoms in the air around silicon substrate causes impurities and dirtiness on it. The presence of impurities and dirtiness put the important problems when the thickness of film is very thin, i.e. the presence of some impurity atoms can prevent its forward use in electronic devices. This impure silicon dioxide ultra thin film could not be use as a suitable

dielectric gate in future nano transistors and must replace by another substance[1-4] .

However, the growing of silicon dioxide ultra thin film, as far as 7Å, is much simple in ultra vacuum condition[3] . But since many studies present important relations and models for the oxides which have grown at high pressure (atmospheric pressure) as Deal – Grove[5] or Massoud[6,7] models, then we try to study the growth of silicon dioxide film on silicon sub layer. Therefore, we put the cleaned Si (111) sub layer in a furnace and we performed the growth of silicon dioxide film in presence and absence of Ar gas. We study then, the structure of silicon dioxide film by Auger method (AES).

By comparing the films (in presence and absence of Ar gas) deduce that, Ar gas has an important role in growth of very clean silicon dioxide film, i.e. without using inert gases as Ar (or N_2) it is not possible to obtain a clean structure of oxide.

Experiments

1. Instruments

a) Digital ultrasonic bath room EURONDA 4D model.

b) Auger electron spectroscope Perkine Elemer Model.

2. Procedure technique and data analyze

In fact, we need very clean silicon for growth silicon dioxide over silicon substrate**.** We have cut two 10 ×10 mm sheets of Si (111) of n-silicon type which its thickness are 2 mm and its specific resistance are 5 Ω cm. We had put these sheets of Si for 2 hours in a becker with ethanol for cleaning the dirt from surface of sheets and then wash them with acetone.

After this elementary cleaning, we have put these two samples in a becker which have ethanol inside and put it in the digital ultrasonic bath room with variable frequency at 60 ^{o}C for one hour.

The digital ultrasonic bath room eliminates impurity from silicon surface by vibration and thus a clean surface will obtain.
Auger electronic spectrum (AES) shows that the sample has not any impurity (Fig.1).
As we observe, there is only the peak of silicon on this spectrum and the peaks of other elements, particularly carbon, are not present.
The presence of carbon in these types of works always, is due to solvent evaporation or existent atmosphere,is observed by a peak at 280 eV. Thus, we have obtained a clean layer, without any impurity, and pleasant for growing nano silicon dioxide. Therefore, we start with two samples of silicon with clean surfaces.

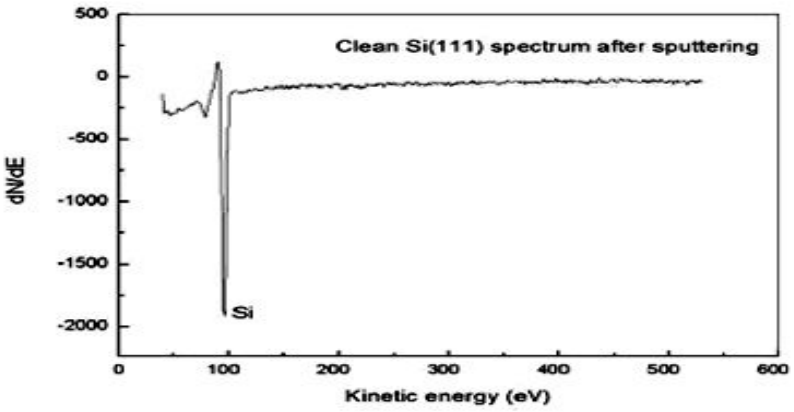

Figure 1 . AES spectrum of a sample of pure silicon with cleaned surface

a) Sample No. 1

Firstly, we have clean the sample into an ultrasonic bath room for half an hour, and straight away, we put it into a furnace. We allow the temperature increase to about 1000 ^{o}C, for removing again the remaining dirtiness. Then we allow temperature decrease to 500 ^{o}C. In this stage we inject determined and controlled volume of very pure oxygen gas into the furnace for about 20 second. Later we turn off the furnace and allow cooling the sample *in situ* to ambient temperature.
Then we study the auger electronic spectrum (AES) of this sample. AES shows the peaks due to presence of Si, O and C (figure 2). The height of each peak shows its intensity. On this AES spectrum we can distinguish very simply the main and side peaks. The higher peaks depend to K_{α} transition (transition from L=1 and S=0 levels) and secondary peaks next to the main peaks depend to K_{β}, K_{γ} and other transitions according to quantum selection rule[3,4] . There are 3 peaks at 97, 280, and 510 eV due to presence of Si, C and O respectively. The height of each peak shows its intensity. On this AES spectrum we can distinguish very simply the main and side peaks. The higher peaks depend to K_{α} transition (transition from L=1 and S=0 levels) and secondary peaks next to the main peaks depend to K_{β}, K_{γ} and other transitions according to quantum selection rule[3,4] . There are 3 peaks at 97, 280, and 510 eV due to presence of Si, C and O respectively.

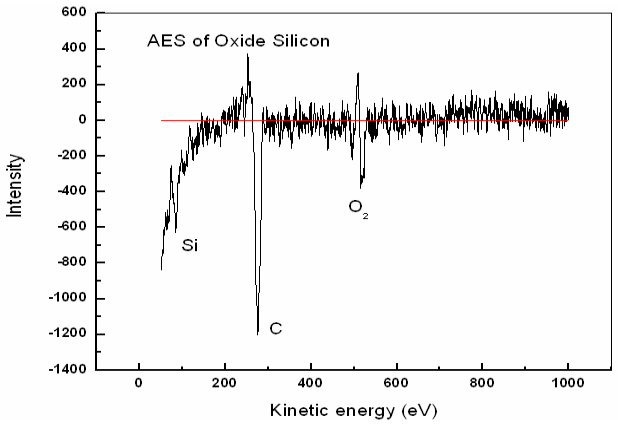

Figure 2 . AES of growing film of SiO_2 over Si sub layer in Ar absence

b) Sample No. 2:

We put this sample into an ultrasonic bath room and then we treat it, before injecting oxygen gas, as well sample No. 1. Before treating O_2, we have injected calmly the determined and controlled volume of very pure Ar gas for about 2 minutes. In this case Ar atoms can eliminate impurities and dirtiness on the sample surface. Then we have injected determined and controlled volume of very pure O_2 for about 20 second. Then we turn off the furnace and allow

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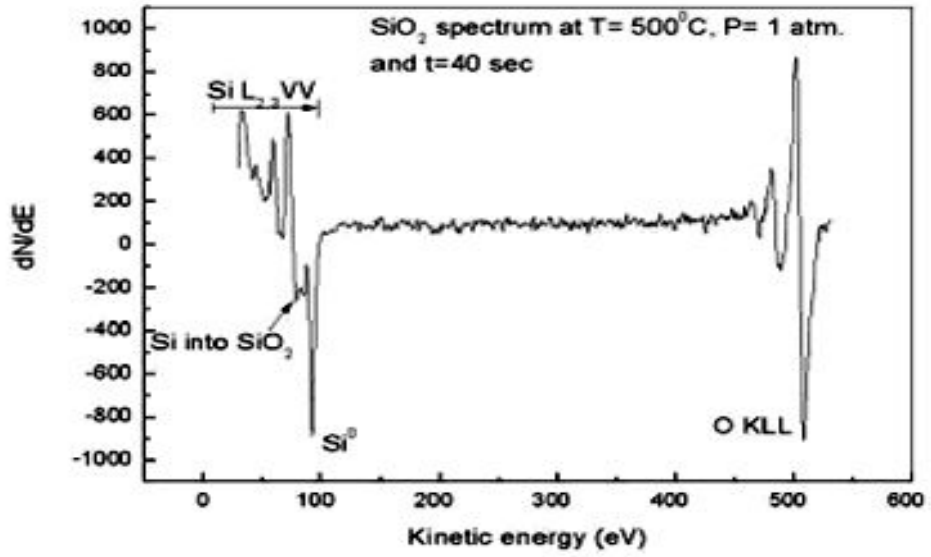

Figure 3 . AES spectrum of SiO_2 growing above Si layer in Ar presence

cooling the sample *in situ* to room temperature. Finally, we inject Ar gas for 3 minutes. Electronic spectrum (AES) of this sample shows only two peaks due to presence of Si and O (figure 3).This spectrum shows clearly, the absence of a peak at 280 eV due to presence of C. By comparison figures 2 and 3, we observe that the impurity of C has eliminated by using argon gas and pure SiO_2 without any dirtiness has grown on silicon sub-layer.

3. Results and discussion

This work has been done at high pressure and high temperature compared with frequent techniques for preparation the nano scale materials. In fact, figure 4 shows two domains for growing of silicon dioxide film. We can consider two passive and active zones for this growing (figure 4). P_c shows the boundary between oxide phases and its surface and P_{tr} shows also the boundary between oxide and Si (111) 7×7 sub-layer. In fact, 7×7 is the arrangement structure of atoms on silicon sub-layer cooling from high temperature.

Following reactions occur in active and passive zones.

$$Si + O_2 \rightarrow SiO_2$$

$$Si + \frac{1}{2}O_2 \rightarrow SiO$$

$$SiO + \frac{1}{2}O_2 \rightarrow SiO_2$$

Firstly, in passive zone SiO forms on sub-layer, then by excessive oxygen forms SiO_2. But in passive zone we can observe forming of SiO_2 film because oxygen doesn't escape from surface. For studying nano structure of silicon dioxide, we use sputtering method with Ar^+ ion. By this method we can remove external dioxide film, layer by layer and thus the thickness of settled SiO_2 film on silicon surface is measurable. In our study sputtering has done by bombarding SiO_2 by Ar^+ ions and these ions

remove dioxide layer in molecular scale. Continuing the work, we will sputter silicon dioxide film, layer by layer until receiving the pure silicon sub-layer (figure 5).

Because of low diffusion of Ar^+ ions, we have the possibility of measuring the thickness of silicon dioxide layer. We can consider uniform the rate of sputtering and by ellipsometery technique we can obtain this rate equal to 17Å per minute. Therefore, sputtering will do slowly and moderately and thus the structure of film will have not any problem[2,8-12] .

4 – Calculation of film layer thickness

The thickness of layer will calculate by following formula:

$$x = n \cdot v \cdot t$$

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$$x = n \cdot v \cdot t$$

Where *x* is the thickness of film layer, *n* is the number of layers, *v* is the rate of sputtering and will calculate by ellipsometery technique which depends to the type of sputtering instrument and t is sputtering time. In this work *n* is 10 layer, *v* is 17 Å min^{-1} and *t* is 10 seconds and therefore the thickness of silicon dioxide layer will be:

$$x = 10 \times 17 \frac{Å}{min} \times \frac{0.1nm}{1Å} \times \frac{1min}{60s} \times 10s = 2.8nm$$

Conclusion

Growing of nano silicon dioxide, on the surface of cleaned silicon substrate has been performed in presence of argon in furnace at atmospheric pressure. AES spectrum of samples confirms forming of ultra thick silicon dioxide layer. By sputtering method we calculate the thickness of this film equal to 2.8 nm. This performance offers the possibility of using silicon dioxide as a dielectric gate. Whereas, there may be the effects as tunneling, Born diffusion, current effusion by using ultra thick silicon dioxide (< 1nm).

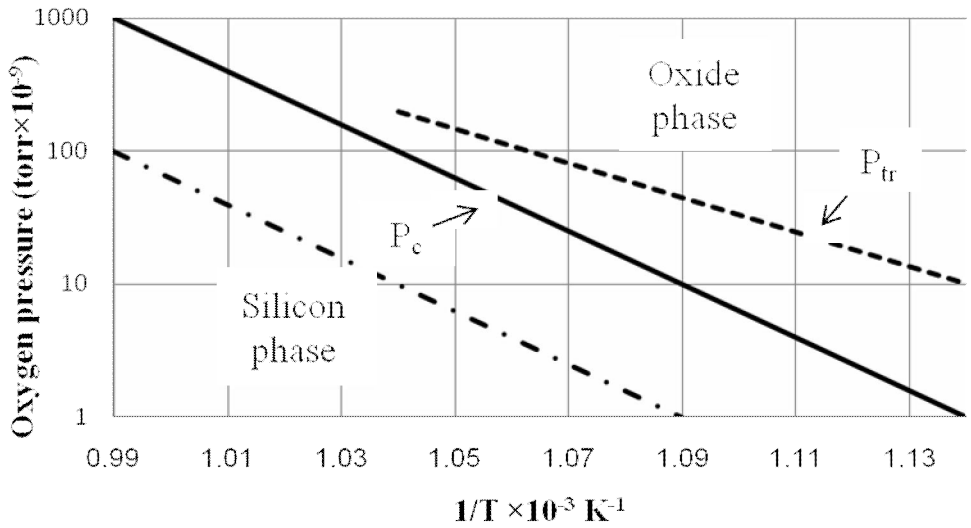

Figure 4 . Plot of oxygen pressure versus inverse of temperature

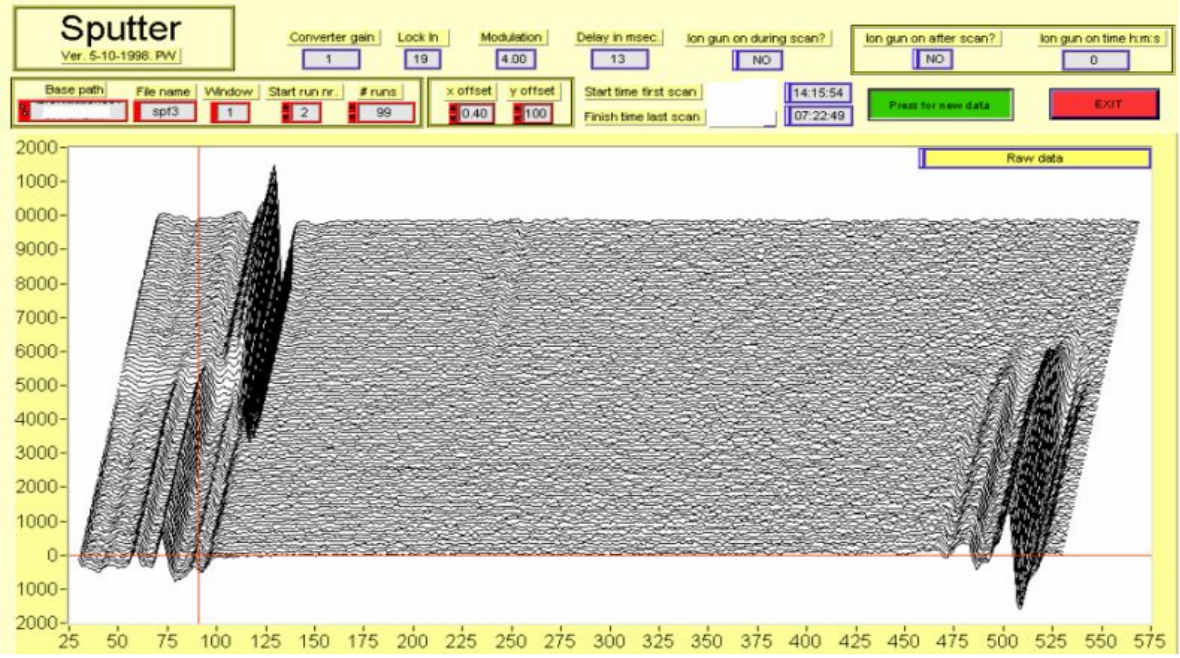

Figure 5. Sputtering spectrum of SiO_2 film

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