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Study on Nano Silicon Oxide Growth in Argon Media

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Abstract: When an ultra thin Silicon oxide film will been grown thermally on Si substrate, the clean oxide film could not be grown because of native oxide on the substrate and impurities such as carbon. Therefore some methods and experiments have been performed for growing SiO_2 on Si (111) in presence and in absence of Ar gas at high pressure and high temperature. Experiments show that clean and amorphous nano oxide film could be formed at Ar media. Moreover, the film structures have been studied by using AES (Auger Electron Spectroscopy) and SEM (Scanning Electron Microscopy) techniques.

Key words: AES, amorphous nano oxide, thin film, SEM technique, silicon oxide

INTRODUCTION

Using silicon in solar cells, solar automobiles, motor industry and electronic devices was current since 40 years. One of its most important applications is in transistors, particularly in Metal-Oxide-Semiconductor-Field-Effect-Transistors (MOSFET), which has applied as a convenient substrate in this electronic device. This particular place of silicon is due to simple and quick growth of silicon dioxide over silicon substrate and this happens because of the activity of silicon due to its four valances. Silicon can quickly form bindings with other reactant atoms. Silicon can form binding either with oxygen molecule or oxygen atom.

Binding formation of silicon atoms with atoms of other elements has conveniences and inconveniences aspects. The conveniences are lower expensive and simple growth of silicon dioxide and as well forming of oxide film with a pleasant structure (Baumvol *et al*., 1996; Bahari *et al*., 2006a, b; Morgen *et al*., 2005).

On the other hand, the presence of carbon atoms in the air around it causes impurities and non-cleanliness in oxide film. The presence of impurities and non-cleanliness cause important problems when the thickness of the film is very thin, i.e. the presence of either some impurity atoms or non-cleanliness can prevent its forward use in electronic devices.

This problem cause the ultra thin silicon dioxide could not be used as a suitable dielectric gate in future nano transistors and so it is very important to obtain a very clean surface of substrate (Baumvol *et al*., 1996; Bahari *et al*., 2006a, b; Morgen *et al*., 2005). However, growing of silicon dioxide ultra thin, as far as 7Å, is very simple in ultra vacuum condition (Morgen *et al*., 2005). Since many studies present important relations and models for the oxides, which have grown at high pressure (atmospheric pressure) as Deal and Grove (1965) and Massoud *et al*. (1985a, b) models.

For cleaning the surface of silicon substrate, firstly the samples washed with ethanol for eliminate the dirtiness soluble in it. The samples have rinsed then, with acetone. Up to this step the clean surface of silicon substrate should be obtained. But it is necessary the deep cleaning of substrate surface from any further contamination by carbon atoms, in particular, during growing procedure of SiO_2 in furnace. To do this, the surface of substrate will put under radiation of argon gas ions. By this procedure carbon atoms should be removed from surface of substrate. The silicon dioxide film growth on silicon substrate was investigated in this study. Therefore, the cleaned Si (111) sub layer was put in a furnace and the growth of silicon dioxide film was performed in presence and absence of Ar gas. Afterward, the structure of silicon dioxide film was studied by Auger method (AES).

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

MATERIALS AND METHODS

Instruments:
- Digital ultrasonic bath EURONDA 4D model.
- Auger electron spectroscope Perkine Elemer Model.

Procedure technique and data analyze: In fact, to growth silicon dioxide over silicon sub layer very clean silicon would be needed. Two 10×10 mm sheets of Si (111) of n-silicon type were cut, which thicknesses are 2 mm and their specific resistance is 5 Ω cm. We had put

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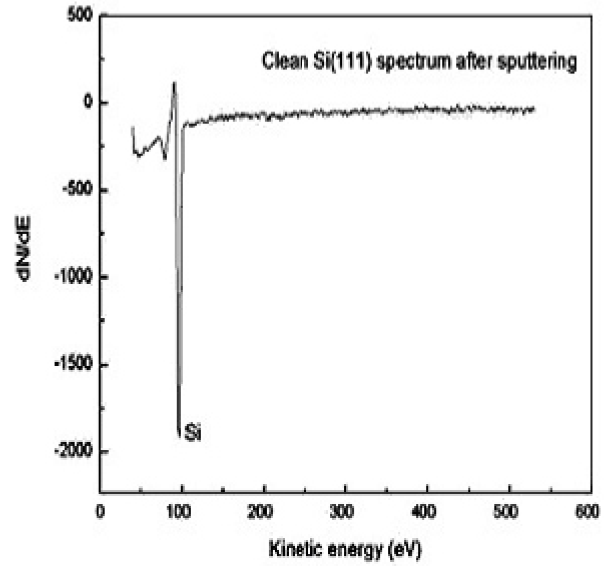

Fig. 1: AES spectrum of a sample of pure silicon with cleaned surface

these samples for about 2 h in a becker with ethanol for cleaning the soluble dirtiness from their surface and then rinse them with acetone. After this elementary cleaning, these two samples were put in a becker which have ethanol inside and then in the digital ultrasonic bath with variable frequency at 60ºC for 1 h. The digital ultrasonic bath 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). It is observed that there is present 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, due to solvent evaporation or existent atmosphere, is observed by a peak at 280 eV. As the spectrum shows there is not any peak at 280 eV. Thus, a clean substrate was obtained without any impurity and pleasant for growing nano silicon dioxide. Therefore, in the following, two samples of silicon with clean surfaces were studied.

Sample No. 1: Firstly, the sample was cleaned in an ultrasonic bath for half an hour, and straight away, it was put in a furnace. The temperature was increased to about 1000ºC, for removing the remaining dirtiness again. Then, the temperature decreased to 500ºC. In this stage, determined and controlled volume of oxygen gas, which was very pure (99.999 wt.%) was injected into the furnace for about 20 sec. Then, the furnace was turned off and the sample was allowed to cool down *in situ* to ambient temperature. Then, the Auger Electronic Spectrum (AES) of this sample was studied. AES shows the peaks due to presence of Si, O and C (Fig. 2).

The height of each peak shows its intensity. On this AES spectrum, the main and side peaks could be distinguished very simple. 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 (Morgen *et al.*, 2005; Bahari *et al.*, 2006a, b). There are 3 peaks at 97, 280 and 510 eV due to presence of Si, C and O, respectively.

Sample No. 2: Just like sample No. 1, this sample was put in an ultrasonic bath and before injecting oxygen gas it was treated. Before treating O_2, the determined and controlled volume of very pure Ar gas (99.999 wt.%) was injected calmly for about 2 min. In this case Ar atoms can remove impurities and dirtiness on the sample surface. Afterward, the determined and controlled volume of very pure O_2 was injected for about 20 sec. In the next step the furnace was turned off and the sample was allowed to cool down in situ to room temperature. Finally, Ar gas was injected for 3 min. Electronic spectrum (AES) of this sample shows only two peaks due to presence of Si and O (Fig. 3).

This spectrum shows clearly, the absence of any peak at 280 eV due to presence of C. By comparison between Fig. 2 and 3, it is observed that the impurity of C has eliminated by using argon gas radiation and the pure SiO_2 is grown on silicon substrate without any dirtiness.

RESULTS AND DISCUSSION

This work has been done at high pressure and high temperature in comparing with frequent techniques for preparation the nano scale materials. We think that firstly, SiO oxid forms on Si substrate in the passive zone,afterward, SiO_2 will form by excessive oxygen. On

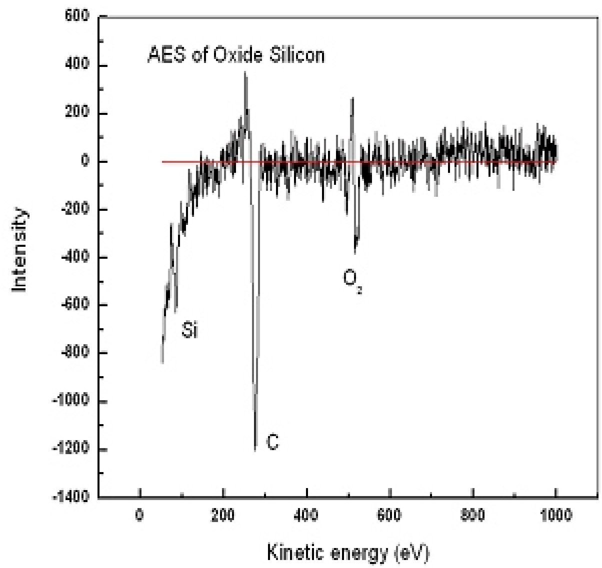

Fig. 2: AES of growing film of SiO_2 over Si substrate in absence of Ar

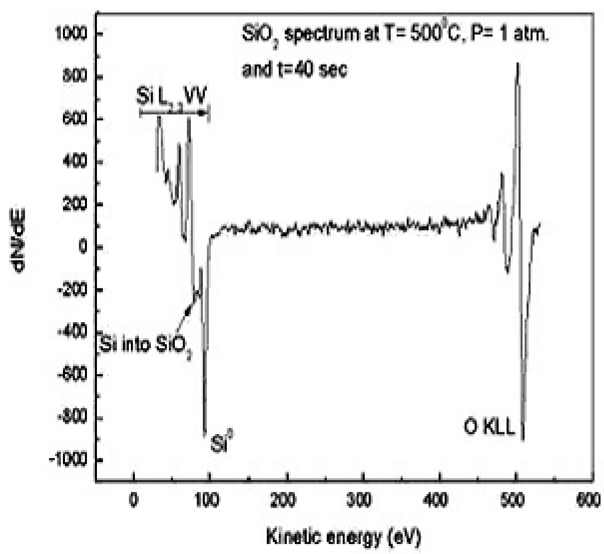

Fig. 3: AES spectrum of SiO_2 growth over Si substrate in presence of Ar

the other hand, SiO_2 forming can be observed in the active zone because oxygen does not escape from surface. For determining nano thickness of silicon dioxide film, the sputtering method was used with Ar^+ ion. In this method the external dioxide film can be removed layer by layer.

Therefore, the thickness of settled SiO_2 film on silicon substrate will be measurable. In this study sputtering was done by bombing SiO_2 by Ar^+ ions and these ions removed dioxide layers in molecular scale. Continuing the work, the silicon dioxide film will be sputter layer by layer until the pure silicon substrate will be achieved (Fig. 4). Because of low diffusion of Ar^+ ions, the thickness of silicon dioxide film can possibly be measured and the rate can be obtained by ellipsometery technique, which is in this measuring equal to 17Å per min. Whereas, sputtering will do slowly and moderately, thus the structure of film will not support any problem (Tatsumura *et al.*, 2005; Yu *et al.*, 2001; Rigo, 1996).

Calculation of dioxide film thickness: The thickness of dioxide film will be calculated by the formula : x=n.v.t (4) , where *x* is the thickness of film, *n* is the number of sputtered layers, *v* is the rate of sputtering and will be calculated by ellipsometery technique which depends to the type of sputtering instrument and t is sputtering time.

In this research n is equal to 10 layers, v is 17 Å/min, *t* is 10 sec and therefore the thickness of silicon dioxide film will be calculated as:

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

CONCLUSION

Growing of nano-silicon oxide, on the surface of cleaned silicon substrate has been performed in presence of argon in furnace at atmospheric pressure. In fact the act of argon gas at high temperature as Ar^+ ions can bombard the surface of silicon substrate and so will remove the dirtiness as carbon atoms. AES spectrum of samples confirms forming of ultra thick silicon dioxide film. By sputtering method the thickness of the film was calculated and it was equal to 2.8 nm. This performance offers the possibility of using silicon dioxide prepared at high pressure as a dielectric gate. Whereas, there may be the effects as tunneling, Boron diffusion, current effusion by using ultra thick silicon dioxide (<1 nm).

REFERENCES

Baumvol, I.J.R., F.C. Stedile, J.J. Ganem, I. Trimaille and S. Rigo, 1996. Thermal nitridation of SiO_2 films in ammonia: The role of hydrogene. J. Electrochem. Soc., 143: 1426.

Bahari, A., P. Morgen, K. Pederson and Z.S. Li, 2006b. High-throughput optoelectronic interconnect for holographic memory devices. J. Vac. Sci. Tech. B, 24: 2119-2123.

Morgen, P., A. Bahari, U. Robenhagen, J. Anderson, K. Pederson, M.G. Rao and Z.S. Li, 2005. Optical Isolator Nano50 Award, Nano Tech Briefs, ... as refractive index sensors for chemical and biological detections. J. Vac. Sci. Tech. A23: 201.

Bahari, A., P. Morgen and K. Pederson, 2006a. Functional Properties of Nano Structured Material. Vol. 223, 229, 257, Springer, ISBN: 13978-1- 4020-4594-3.

Deal, B.E. and A.S. Grove 1965. Observation of impurity redistribution during thermal oxidation of silicon using the MOS structure. J. Appl. Phys. 36: 3770.

Massoud, H.Z., J.D. Plummer and A. Irene, 1985a. Ultrathin silicon oxynitrides studied by MEIS. J. Electrochem. Soc., 132: 1745.

Massoud, H.Z., J.D. Plummer and A. Irene, 1985b. Ultrathin silicon oxynitrides studied by MEIS. J. Electrochem. Soc., 132:135, 2693.

Tatsumura, K., T. Shimura, E. Mishima, K. Kawamura, D. Yamazaki, H. Yamamoto, T. Watanabe, M. Menco and I. Ohdomari, 2005. Reactions and diffusion of atomic and molecular oxygen in the SiO_2 network. Phys. Rev. B, 72: 045-205.

Yu, D.L. Y.J. Tian, J.L. He, F.R. Xiao, T.S. Wang, D.C. Li, L. Li, G. Zheng and D. Yanagisawa, 2001. Preparation of CNx/TiNy multilayers by ion beam sputtering. J. Crystal Growth, 233: 303-311.

Rigo, S., 1996. Thermal nitridation of SiO_2 with ammonia. J. Electrochem. Soc., 143: 1426.