International Journal of ChemTech Research
CODEN(USA): IJCRGG ISSN : 0974-4290
Vol.2, No.2, pp 1267-1270, April-June 2010

The Growth and Properties of the Ultrathin Gate Oxide and Nitride Films on Si(100) Substrate

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Abstract: The continued demand for higher density electronic circuits will meet several barriers with the next few years. One of the more obvious ones is the need for reliable method to grow ultra thin dielectric films, such as Al_2O_3, AlN, TiO_2, Si_3N_4 and Si_xN_y. Here, we dissolve X- ray photoemission spectrum into Si2p, Si2s , O1s and N1s**.** The nitride and oxide film growth procedures are similar and we have thus paid attention to oxide and nitride film growth. We have grown oxide and nitride film on Si (100) substrates. The growth processes of oxide and nitride film on the Si (100) surfaces have been studied by X-ray photoemission spectroscopy. The structural issues were reflected in the deconveluted spectra, as we discussed in our recent works [2-15]. We consider SiO_2/Si (100) and Si_3N_4/Si (100) spectra with referring to our published papers.

Key words: Nanotechnology, Nanostructure, Ultra thin film, silicon oxide and silicon.

Introduction

The development of the microelectronics has entered the nano metric range due to the continuous shrinking of electronics device dimensions [1-5]. The oxide of silicon is a uniquely critical material within silicon semiconductor technology, in that it is a major component for MOS (Metal-Oxide-Semiconductor) and MIS (Metal-Insulator-Semiconductor) devices [6-9]. Therefore, the narrowest feature on present-day integrated circuits is the gate oxide the thin dielectric layer forms the basis of field effect device structures [10-13]. Silicon oxide is the dielectric of choice in where in the current CMOS CPU generation, the silicon gate oxide is 1.2 nm thick and also the silicon structure is Si (100). However, our recent works [5-6] show that silicon nitride as a good candidate of gate dielectrics.

Oxygen and nitrogen can react with Si (100) surfaces. This interaction depends strongly on the purity and chemical structure [14-16] and is determined principally by the number positions of free unstructured dangling bands. We have thus considered the oxidation and nitridation growth on silicon substrate. The obtained results show although both growth are self-limiting, the nitride film is thicker than the oxide film.

Experimental procedures and details

Mirror-polished n-type Si (100) samples were used as substrates. These wafers were cut into $3\times1\times0.2\ cm^3$ and then silicon samples introduced in the UHV (Ultra High Vacuum) chamber after a rinse with ethanol in an ultrasonic bath. The chamber was then baked before the experiments begin. After baking the background pressure was $2\times10^{-10}\ Torr$. Of course, the pressure inside the vacuum chamber increasing during the oxide and nitride growth on silicon substrate. All further cleaning was done inside the UHV chamber by heating with a direct current through the sample, initially up to 1200 ^{0}C and at later at higher temperatures to restore a clean Si surface. Earlier measurements which a residual gas mass spectrometer in the line of the beam has shown a very high proportion (about 50%) of the oxygen and nitrogen which are produced with this setup. Typical total pressures in the chamber during exposure were around 2×10^{-10} $Torr$. The Si structures are kept at room temperature. Referring to our recent works [3,9], the XPS spectra of oxide and nitride are shown in Fig.1. We can also distinguish two different thickness oxide and nitride films on these substrates by looking at Figs.2 and 3.It is clear that the growth of silicon oxide and silicon-nitride on Si (100) have Boltzmann behavior.

Discussion

The Si (l00) 2×1 surface is surely the most amazing reconstruction in surface science. It's complex atomic structure was elucidated by Paul J. E. Reese. et al. in 2001 [17]. Their so-called up and down dimer model is now widely accepted; it involves several special features e.g. up dimmers. When a (100) surface of silicon is heated to medium temperature under the ultra-high vacuum (UHV) conditions, the surface atoms rearrange into a more energetically stable configuration called the 2×1 reconstruction. Instead of a very simple pattern shown above, the new arrangement involves several types of atomic positions in the top three atomic layers to form a much larger unit cell.

As discussed above, the growth of the oxygen and nitrogen film on the silicon substrate is self-limiting growth and adsorbed oxygen which atomically inserted on Si (100) surfaces, but in relatively different co-ordinations on the Si (100) surface, nitrogen atoms sit in the back bonds, whilst oxygen atoms enter the bridging dimer bond on the Si (100) surface. Therefore, the largest fraction of oxidized silicon atoms is in the interface region of Si (100), whereas the Si (100) structures contain more bulk in oxide, for equivalent processing steps. Limiting thickness obtained is almost independent of the temperature the regime covered here. We can extract more information about the chemical bonding of Si in the sampled volume from with looking at the core level Si2p spectra. It includes the effects of band bending which is a function of charges in the oxygen and nitrogen layers and can serve as a monitor of these effects. this reconstruction is often referred to as the 4×2 reconstruction. These reconstructions are lost when the oxidation or nitridation starts. Furthermore, the growth of both oxide and nitride are thus reflected in (Fig.1). Growth of silicon oxide and silicon nitride during isothermal plasma oxidation and nitridation are shown in Figs.2,3.

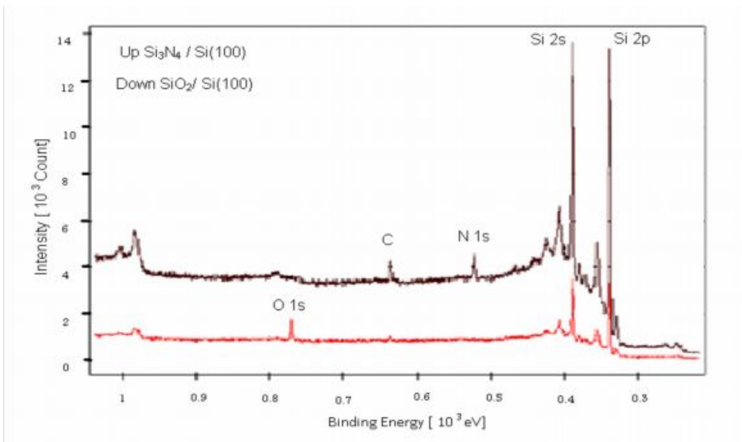

Fig.1. XPS spectra of silicon oxide (down) and silicon nitride (up) on SiO_2 at 500 ^{0}C, (gas exposing time: 20 min and pressure $P=5\times10^{-8}Torr$.(for details ref [1,3].

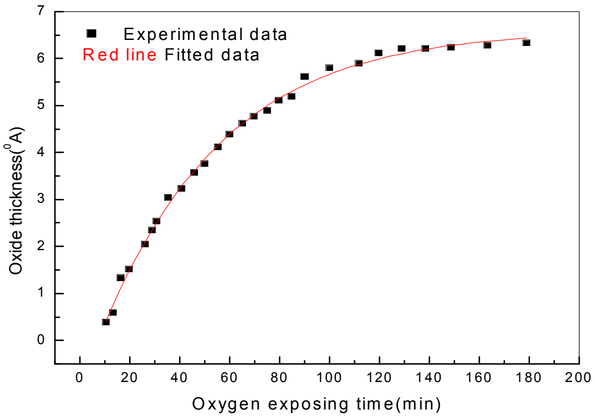

Fig.2. Isothermal plasma nitridation and saturation growth of a uniform oxide on Si (100) 2×1 at 500 ^{0}C and $5\times10^{-9}Torr$.

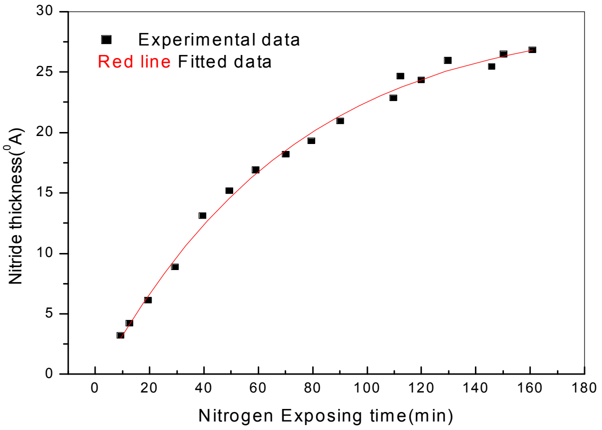

Fig.3. Isothermal plasma nitridation and saturation growth of a uniform nitride on Si (100) 2×1 at 500 ^{0}C and $5\times10^{-9}Torr$.

Conclusion

Various thermal oxidation and nitridation methods have proven to be accurate, reliable and to produce an extremely high film quality. Nonetheless there do remain other purposes for our work.
Therefore, the largest fraction of nitrided silicon atoms is in the interface region, whereas the Sio_2/Si (100) structures contain more bulk oxide, for equivalent processing steps. To our knowledge, pure and amorphous nitride film can be grown on Si (100) substrate and be used for the future of CMIS devices.

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