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Nano Structural properties of Silicon Nitride in CHEM FET

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Abstract: Silicon nitride can be used to construct a chemical field –effect- transistors. (Chem FET).The binding or adsorption of charged species may produce an electric field, which depletes or accumulates carriers within the Si_3N_4 film similar to that by the gate SiO_2 potential.
We have thus demonstrated a series of experiment to grow thin silicon nitride film with using Chemical Vapor Deposition (CVD) technique. The chemical bond between Si and N atoms are studied with FitXPS method.
Keywords: Nano Chem FET, Nano structures, Si_3N_4 and CVD technique.

Introduction:

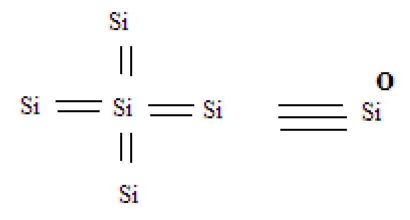
Recently we have studied many dielectric material and carbon nano tubes [1-14] for nano field –effect – transistors elements.
Indeed we have made a break through in the search for a nano scale electronic device. That is needed in the next CMOS (complementary Metal – oxide – semiconductor) generations.
This area of enquiry is attracting a lot of scientific interest [15-20].Although it has only been considered as a good gate dielectric of CMIS; potential future applications include important uses in chem FET and communications technologies.
However, there are some challenges in scaling CMOS technology for ICS due to tunneling, leakage current small atom's penetration through the conventional silicon dioxide film. For this purpose, we have tried to grow thin silicon nitride film with using CVD method and studied its nano structural properties as an alternative material which is still being examined by the Roadmap requirements [21]
As stated above we considered Si_3N_4 as a good candidate for the future of ChemFET devices, because, materials with higher mechanical and chemical structure than Si_3N_4 structure in the immediate vicinity of the chemFET could potentially keep circuits more stable and conductor. The insulator in chem FET was normally a thin layer of thermally grown Si_3N_4 on the silicon substrate, but here Si_3N_4 is a candidate insulator material to improve heat dissipation during transistor operation and to reduce leakage and tunneling current.
The obtained results indicate that the chem FET with Si_3N_4 gate is starting to face less difficult challenges than the conventional SiO_2 insulator material.

Experimental procedure:

The n-type silicon samples with resistivity of 5 Ω-cm and size of 3 cm×1 cm were cut out of the wafer then rinsed with ethanol in an ultrasonic bath and then introduced in the UHV chamber. The chamber was then baked before the measurements. The background pressure was 2×10^{-10} Torr after baking. All further cleaning was done inside the UHV chamber by heating with a direct current through the sample, initially up to 1200 °C and later at higher temperatures to restore a clean Si surface. Earlier measurements with a residual gas mass spectrometer in the line of the beam have shown that a very high proportion (about 50 percent) of oxygen is produced with this setup. Typical total pressure in the chamber during exposure was around 5×10^{-7} Torr.

Discussion:

Silicon nitride films are grown on the Si (100) samples in a NH_3 media at 500^0c and one atmosphere pressure. The deconvoluted of fitted spectra is founed.based on Si component Fig.1 Shows the silicon bulk component in where each Si atom could make bond with 4 nearest neighbor Si atoms, i.e.:



Although there are Si $2p_{3/2}$ and Si $2p_{1/2}$ intensities for each Si component because of $J=L\pm S$ (angular momentum with L=1 and $s=\frac{1}{2}$, we just plot huge peak intensity of each component respect to exposure time of NH_3 molecules. Since there are bonds between N and Si atoms, we expect the silicon nitride bulk is $Si^{(+4)}$, surface is $Si^{(+3)}$. Furthermore, $Si^{(+1)}$ + $Si^{(+2)}$ + $Si^{(+3)}$ components can be attributed to interface of Si_3N_4/Si (100).

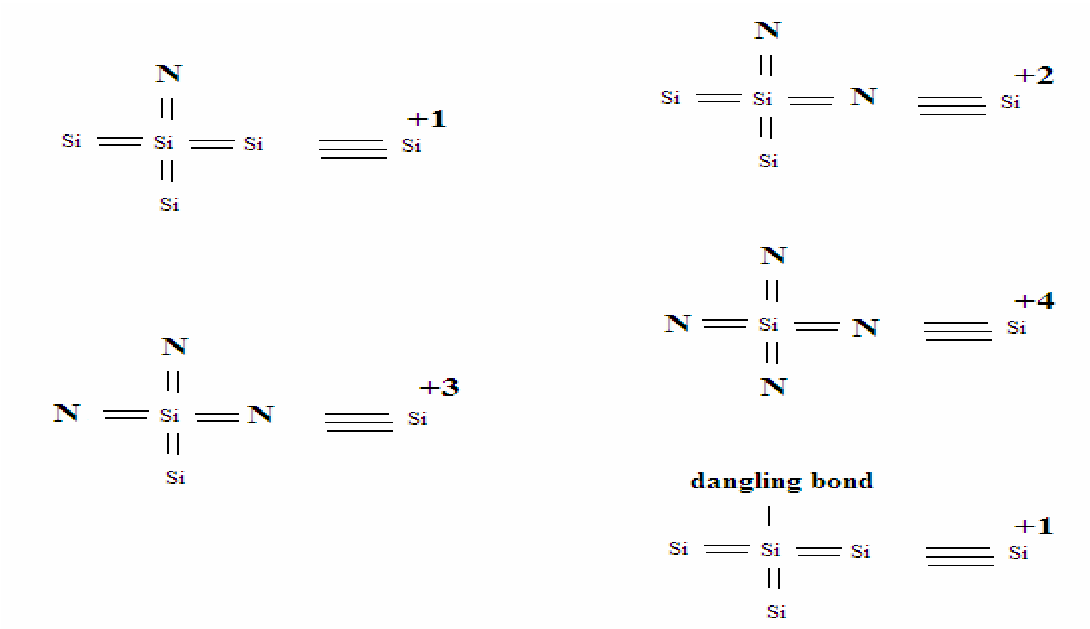


Fig.1 $Si^{(+1)}$, $Si^{(+2)}$, $Si^{(+3)}$ and $Si^{(+4)}$ bonds in Si_3N_4/Si (100)

We plot $Si^{(0)}$, $Si^{(+4)}$ and interface components ($Si^{(+1)}$ + $Si^{(+2)}$ + $Si^{(+3)}$) .
As shown in Figs. (2), (3) and (4), when $Si^{(0)}$ component is decaying linearly, both silicon nitride bulk and Si_3N_4 /Si (100) interface components have Boltzmann behavior. It means that the thick silicon nitride film (>15 nm) on the silicon substrate cannot be formed with the present growth procedure. Moreover, silicon atoms can make bond with incoming nitrogen atoms (and/or molecules) whenever they meet each other, but the growth rate will be faster if there are so dangling on the silicon surface.

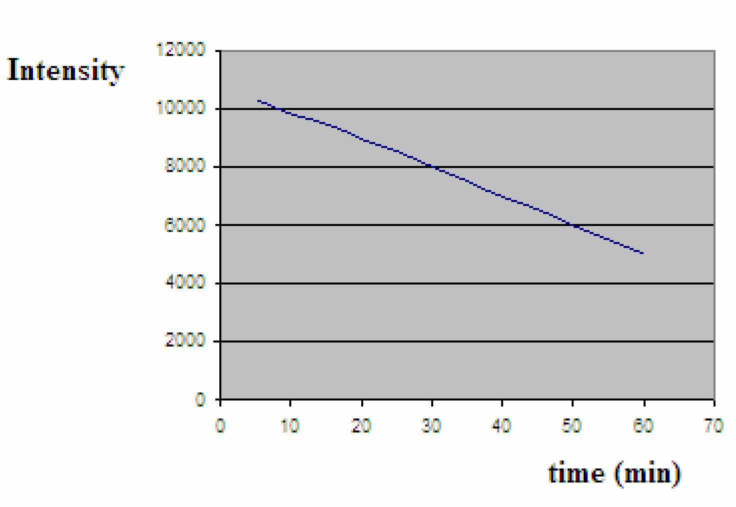


Fig.2. The intensity of Si° versus nitrogen atom exposing time.

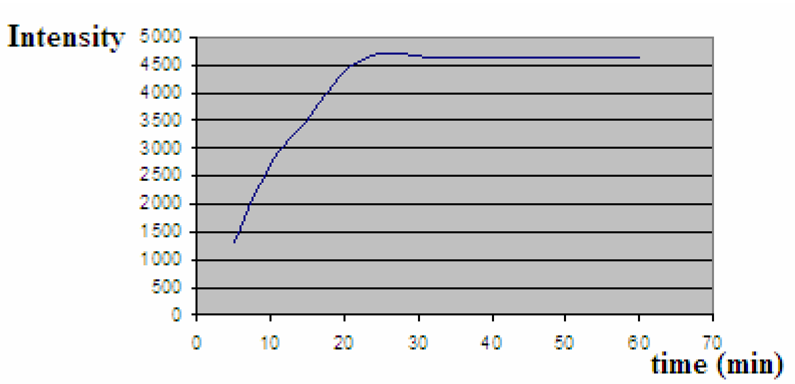


Fig.3. The intensity of Si^{+4} versus nitrogen atom exposing time.

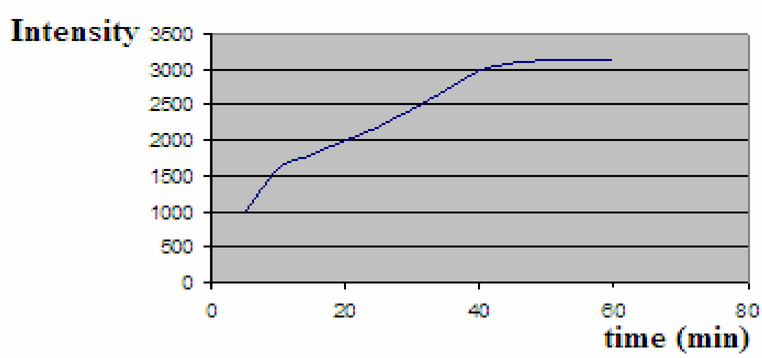


Fig.4. The intensity of $Si^{+1} + Si^{+2} + Si^{+3}$ versus nitrogen atom exposing time.

Conclusions:

The present work include Si_3N_4 film as the other potential dielectric material for chem FET as diffusion limiting layers between the bulk silicon and other high – k dielectric materials currently examined for use in future chem FET components.

Knowledge about the electronic and chemical structures and bandings in this material is also the key to understanding all its other important material properties. We suggest the Si_3N_4 will be tested in the future of chem FET and MISFET devices.

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