Deposition of a-Si:H using a supersonically expanding argon plasma

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with a particular combination of their characteristic of passivation film.

As a result of experiments, the *a*-Si:H film as a passivation film of the thyristor, not only has a high sodium blocking ability, but also it has a novel ability to draw the impurities from the interface of *c*-Si devices and promote the *c*-Si devices having a high quality. It could set some spoiled products up to grade and some products could be raised to high grade products.

The thermal stability of *a*-Si:H passivated film, e.g. the hydrogen atoms in the random network are not easily evolved and the quality of film does not degrade at the annealing process in the later procedure. It is very important for the use of passivated and protected *c*-Si devices. For this aim we have shown some technological improvement for the deposition of *a*-Si:H films.

High-field electron trapping and detrapping characteristics in thin SiO_xN_y films

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The thin thermally nitrided silicon oxide (SiO_xN_y) films offer many potential advantages over conventional silicon dioxide and have been used as the tunneling insulator of endurance E^2PROM and the insulation gate of MIS transistor of VLSI. The research on the high-field electron trapping and detrapping in the films has an important significance for raising the prediction of the performance of the insulation films and the devices.

In this work, the high-field electron trapping and detrapping behavior in the thin (SiO_xN_y) films (15 nm) have been studied for the first time by the FN technique and *C–V* method. It was observed in the experiment that as the nitridation proceeds the effective electron trap surface concentration (n_t) in the films increases rapidly before the films were nitrided for 30 min, thereafter n_t decreases gradually; at room temperature the detrapping ratio of the trapped charge (electrons) at high-field is the near exponentially dependent on the strength and continuance time of the external applied reverse field, and increases gradually as the nitridation proceeds, but almost independent of the only shortened time for the samples. This fact gives evidence that the depth of the electron trap level in the films is deeper before the films are nitrided for 30 min, thereafter it becomes shallow gradually with the further increasing of the nitridation time under present experiment conditions. These results are an important referable valuable for predicting and controlling the performance of the devices in the design and the preparation.

Silicon nitride film formed by NH_3 plasma enhanced thermal nitridation

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With the rapid development of microelectronics, the device dimension is reduced to micron and submicron. The thickness of the dielectric film will be less than 20 nm. In this work a NH_3 plasma enhanced thermal nitridation (NPTN) technique is investigated to form a high quality thin dielectric film. Besides the thin gate dielectric application it can also be used for a sealed-interface LOCAL oxidation process to obtain a bird's beak free field oxide.

The NPTN reactor consists of a quartz tube, a SiC-coated graphite susceptor and a rf-induction coil. A rf power is applied to the induction coil to heat the susceptor. The NH_3 glow discharge around the susceptor with Si wafer is simultaneously generated by the rf power.

The thermal nitridation was performed in the temperature range of 700–1000°C, and the NH_3 pressure was 1.3E-1 torr. The thicknesses of the grown nitride films were measured using an ellipsometer with a 632.8 nm laser source. From the experimental data the activation energy was found to be 0.38 eV. The nitridation rate is 1.8E-3 $nm^2\ s^{-1}$ for 700°C and 1.6E-2 $nm^2\ s^{-1}$ for 1000°C.

An atomic composition depth profile of 30 nm silicon nitride was obtained by AES. Nearly uniform distributions of N, Si, O were observed along the film. The amount of oxygen was less than 10%. An AES profile of 20 nm silicon nitroxide shows that there are two nitrogen peaks in the film, one at the film surface and another at the SiO_2/Si interface.

The *I–V* and breakdown characteristics of 10 nm SiO_2, silicon nitroxide and silicon nitride show a lower leakage and higher breakdown voltages for the nitrided samples than pure SiO_2. A high-frequency *C–V* curve of a MIS structure with 7 nm silicon nitride shows a comparatively low fixed positive charge density.

The NPTN silicon nitride film demonstrated a strong oxidation-resisting ability at high temperature. The 30 nm NPTN film can be used as a mask to grow a 700 nm field oxide. Its SEM cross-section picture shows that the bird's beak effect is significantly eliminated.

In conclusion,the high-frequency NPTN is a useful technique for Si and SiO_2 nitridation. The grown thin silicon nitride and nitroxide show promising properties and may have application in semiconductor devices fabrication.

Deposition of *a*-Si:H using a supersonically expanding argon plasma

Wilbers

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Amorphous hydrogenated silicon (*a*-Si:H) is a material which is widely used in the field of solar cells and other optoelectronics. The only method available to produce high quality *a*-Si:H is by means of plasma enhanced chemical vapor deposition (PECVD). Radicals responsible for deposition diffuse from a glow discharge towards a substrate which is heated up to 800 K where a layer is grown with a speed of typically 0.3 nm s^{-1}. The deposition rate is limited because the transport is diffusion determined. An increase of this deposition rate and material efficiency can be expected if the radicals are transported towards the substrate using another transport mechanism.

We have built an apparatus which uses a supersonically expanding cascaded arc argon plasma in which silane (SiH_4) is injected to direct the radicals towards the substrate. It is expected that the deposition rate will be up to 100 times as high as in normal PECVD. A further advantage is that the larger spatial separation of the processes dissociation, transport and ionization allows more independent optimization of these three processes.

First experiments show that the deposition rate is 7 nm s^{-1} yielding a material with a refractive index of 3.7. Absorption spectroscopy shows only absorption by SiH stretching and bending modes. Further optimization and research is needed to explore the possibilities of this method.

Charge characteristics of thin rapid thermal nitrided SiO_xN_y film in MIS structure

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This paper has studied the charge characteristics of thin rapid thermal nitrided (RTN) SiO_xN_y film and thin reoxidized nitrided SiO_xN_y film by the new photo *I-V* method and the avalanche hot-electron injection technique.

The samples were fabricated on *p*-type (100) silicon polishing wafers of 0.10–0.31 ohm-cm. The wafers were oxidized in standard dry O_2 at 970°C for 55 min (d_{ox} = 35–40 nm). The thin RTN SiO_xN_y film was performed in ultrapure ammonia at 1150°C for 30–180 s. And rapid reoxidation (RO) was performed at 1150°C for 60 s. The MIS capacitors fabricated finally received a post-metallization annealing in pure N_2 at 400°C for 30 min.

In order to investigate the charge characteristics of thin RTN SiO_xN_y film, the new photo *I–V* experiment and the avalanche hot-electron injection technique were used. The test of high frequency *C–V* and quasistatic *C–V* characteristics was also performed. The thin SiO_xN_y film thicknesses were measured by an ellipsometer. The data handling and drawing were performed with microcomputer.

Experimental results gave the bulk charge density and its distribution centroid position of thin RTN SiO_xN_y film and thin conventional SiO_2 film. Results also indicated that reoxidation processing after RTN would reduce effectively the densities of bulk electron trapping and interface state in thin RTN SiO_xN_y films. In addition, a physical model explanation of weakly-present 'N' form change for flatband voltage shift with avalanche injection dose was presented. The change relationship of energy distribution for interface state density with injection dose was obtained. In this paper theoretical analyses and discussions of these research results are made.

Invited paper

Optical thin film devices

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Thin film devices are applied to almost all modern science instruments for obtaining optimal performance, and play an important role in the quality of instruments, especially optical instruments. Now there are many kinds of thin film devices with different applications, and more and more scientists and engineers are devoted to this area. Publications on thin film devices have increased steadily in recent years, and the book *Thin Film Devices Applications* by K L Chopra presents basic knowledge and a general review.

The optical thin film devices have developed quickly in recent decades. Though Prof L Holland contributed a good book *Vacuum Deposition of Thin Films* at an early time, coating equipments, especially automatic techniques, were not good enough to meet many practical requirements. Later, Prof A Thelen has given a number of papers on the theory and techniques of optical thin film devices, Prof H A Macleod's *Thin Film Optical Filter* has concisely concluded the important concepts of optical thin film devices, and Dr J A Dobrowoski has proposed very successful designing methods and results.

At the present time, different monitors or analyzers in automatic coating plants for controlling the parameters of the systems, especially film thickness controlled by optical or oscillating crystal methods, are manufactured by Balzers, Leybold, Satis, etc. which results in good agreement between the designs and the practical performances of optical thin film devices. However, the automatic coating equipments are not commonly used due to their high cost. In order to improve the lifetime and to lower the cost of optical thin film devices, such as for high damage threshold laser coatings and uv to X-ray coatings, much research work has been carried out searching for new materials with low absorption, low scattering, high hardness and environmental stability.

The following is a description of laboratory work on the research and development of optical thin film devices. This gives the reflectance curves of antireflection coatings, which are used for wide-band or wide-angle lens and optical communication. A transmittance curve of dichroic beamsplitter, which can be used in color-printing, is also shown together with the transmittance curves of sharp edged interference filters, the parts for fluoroscopes.

The structures of all the designs mentioned above are integral stacks, which can be conveniently fabricated.

Optical and structural properties of superfine stratified periodic and aperiodic structures

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The successful solution of many problems of fundamental and applied optics is closely connected with the use of various stratified optical structures.

At the same time using stratified media with quarter-wave or half-wave thicknesses of layers (which is traditional for the visible range) turns out to be impossible in the ir-range due to relatively large geometric thicknesses of both the individual layers and the structure as a whole.

However, recent theoretical and experimental investigations have shown that it is possible to analytically synthesize multilayer periodic and aperiodic structures with layer thicknesses being much less than quarter-wave; this fact provides an opportunity to solve many problems of rf-optics.

Simple analytical relations permit not only synthesis of structures of this type, but also performance of generalized analysis of their fundamental optical and structural properties.