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ELECTRON SYNTHESIS IS A METHOD FOR THE FORMATION OF LAYERS IN MIGRATIONS LEADING TO THE FORMATION OF HETEROSTRUCTURES DURING THE TRANSFER OF A NEW PHASE

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Abstract
Ion-electron synthesis is a method for the formation of implants of a new phase, implants arising during the formation of heterostructures, layers. The formation of a new phase during ion synthesis can occur as a result of the interaction of implanted atoms with target atoms or as a result of their interaction with each other. The use of ion-electron synthesis to create structures based on silicon has undoubted advantages over other methods, since this method is compatible with existing silicon technology.

Keywords: Regularities in the formation of the spatial distribution of nitrogen atoms, defect formation, investigation of silicon under high-temperature conditions, mechanism of nucleation and growth of the silicon nitride phase, thermionic synthesis of silicon, thin silicon upon implantation of large doses of hydrogen ions.

Аннотация
Ионно-электронный синтез — метод формирования имплантов новой фазы, имплантантов, возникающих при формировании гетероструктур, слоев. Образование новой фазы при ионном синтезе может происходить в результате взаимодействия имплантированных атомов с атомами мишени или в результате их взаимодействия друг с другом. Использование ионно-электронного синтеза

для создания структур на основе кремния имеет несомненные преимущества перед другими методами, поскольку этот метод совместим с существующей кремниевой технологией.

Ключевые слова: Закономерности формирования пространственного распределения атомов азота, дефектообразование, исследование кремния в высокотемпературных условиях, механизм зарождения и роста фазы нитрида кремния, термоэмиссионный синтез кремния, тонкий кремний при имплантации больших доз ионы водорода.

Introduction

The formation of a new phase in electron and ion synthesis can occur as a result of the interaction of implanted atoms with target atoms or their interaction with each other. The use of electrons under the influence of temperature to create structures based on silicon has clear advantages over other methods, since this method is compatible with existing silicon technology.[1]

Sample Preparation and Research Methods

The method has ample opportunities for creating various types of systems. In this case, the properties of electronic bond structures are determined by the parameters of ion and electron transfer (type, dose, ion energy, ion flux density, target temperature during migration) and subsequent thermal effects (temperature, duration, pressure) [2].

This method allows a wide range of control of the structural properties of the synthesized objects, their size (from a few nanometers to several micrometers) and their spatial distribution. Until the 1980s, research on the ion synthesis of semiconductor compounds was very sensitive and focused on new possibilities for ion implantation [1-3].

The new growth in interest in ion-electron synthesis was due to the problems of radiation resistance of very large integrated circuits. The solution to this problem was to use silicon layers as a substrate in insulator (SiO_2) rather than cast silicon. The research is mainly aimed at solving practical problems for the formation of dielectric and conductive layers with expanded silicon content. The solution to this problem can be achieved by introducing doses of ions of chemically active elements by ensuring the concentration of implanted atoms in silicon corresponding to the stoichiometric composition of the synthesized compound. Therefore, the researchers were mainly interested in the processes associated with the properties of the introduction of

stoichiometric and super stochiometric doses of oxygen, nitrogen and carbon ions into the silicon matrix. In particular, problems have been solved that allow to determine the spatial distribution of ion energy losses under the changing composition of the object under analysis in terms of layer depth, to take into account the effect of long-term surface scattering of silicon ions.

Results and Discussion

In the matrix of crystalline silicon, in amorphous dielectric matrices based on silicon and near Si/SiO_2, the main physical processes that determine the mechanisms of nucleation and growth of a new phase in ion-electron synthesis have been established. To achieve this goal, the following problems need to be solved. Study of the regularities of the formation of the spatial distribution of nitrogen atoms, the formation of defects, the mechanism of nucleation and growth of the silicon nitride phase in silicon at high temperatures, the thermal effect of silicon on dielectric structures [4-5].

Establish the main patterns of growth of silicon and germanium nanocrystals in the main part of silicon oxide, nitride and oxynitride films. Establishment of the mechanism of nucleation of the crystalline phase of Ge and InSb at the Si/SiO_2 interface. In the process of research, it is necessary to solve a number of technical and technological issues [3].

The main problem of semiconductor physics and technology is the development of the physical foundations for the ion-electronic synthesis of micro- and nanostructures based on silicon, which opens up new prospects for using silicon as a base material. The spatial distribution of nitrogen atoms, the processes of formation of secondary defects, and the initial stage of the nucleation of the silicon nitride phase in single-crystal silicon are studied in detail. The conditions for high-temperature ion implantation were met. The mechanism of nucleation of the Si_3N_4 phase of secondary structural defects in single-crystal silicon has been established. The nature of the difference between the theoretically predicted and experimentally observed spatial distribution of implanted nitrogen atoms and the synthesized phase of silicon nitride under the conditions of ion-electron synthesis is determined [2-7].

Based on their research, they are developed at the level of inventions and tested under the conditions of production of an ion-modified embedded dielectric silicon insulator structure. A method has been proposed and implemented for creating intermediate germanium Si/SiO_2 epitaxial layers, which makes it possible to create silicon-germanium dielectric structures[3-9].

The liquid-phase solubility of N in Si has a higher binding energy than the formation energy of this $Si-SiO_2$ bond. Oxygen atoms also have a much higher solubility in silicon.

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This means that under conditions of electron irradiation, when the low temperature reaches 500–700 °C and higher, the formation of Si/SiO_2 bonds can occur as the dose increases [2-3].

When the observed glass concentration is reached, the subsequent formation of Si/SiO_2 bonds in the mobile region stops, and dispersion of excess oxygen atoms with a high diffusion coefficient in SiO_2 from the diffusion zone also occurs in the glass. It is in the region of the edges of the maximum distribution of ions that new Si-SiO_2 bonds are formed. Unlike oxygen atoms, nitrogen atoms are slightly soluble in silicon (their equilibrium solubility is 3 times less than that of oxygen) and have a very low diffusion coefficient. The spatial distribution of nitrogen atoms in silicon during the deposition of high-temperature ions and the kinetics of nitrogen accumulation in silicon are studied from the point of view of its interaction with competing deposits in the crystalline matrix [5-6].

Nitrogen ions with an energy of 130-140 keV in doses of $5x10^{16}$ -$5x10^{17}$ sm^{-2}, introduced directly during bombardment with nitrogen (N) atoms, were introduced into a target made of single-crystal silicon KEF*-4.5 in the direction <100> Implantation samples Ti = 700-1100°C (Ti - implantation temperature) was heated by direct current to a temperature [7-9].

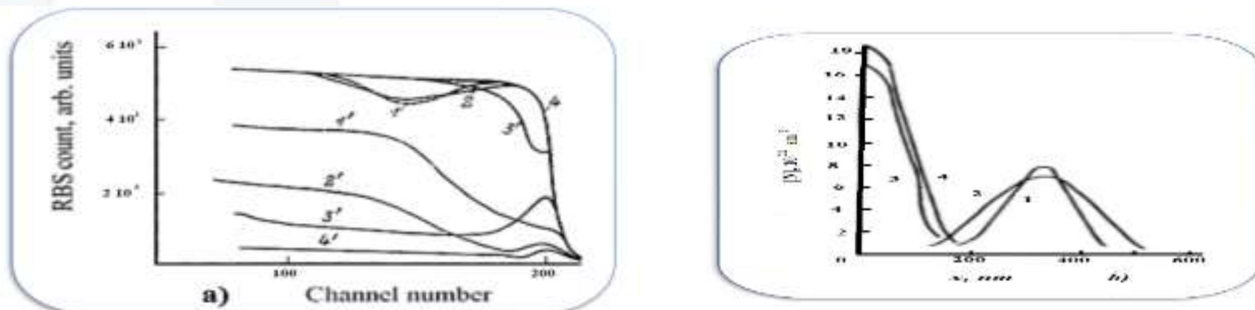

Figure 1.1 a) spectra of directional (1'-4') and non-directional (1-4') regression scattering. samples; T_i-°C during implantation with N+ ions at a dose of 1.5 10^{17} sm^{-2}: 1, 1' - 700; 2, 2' - 900; 3, 3' - 1000; 4, 4' - not implanted. b) distribution of nitrogen atoms Silicon implanted with N + ions at a dose of 1.5 10^{17} sm^{-2} at Ti-°C (according to the spectra of the redistribution pattern): 1 - 700; 2 - 900; 3 - 1000; 4 - 1100.

At Ti = 900 °C, a slight diffusion expansion of the distribution is observed. The spectra obtained under conditions of the most precise directivity of the probing light along the <100> channels show that after Ti = 700–900 °C the upper silicon layer retains its crystallinity [3-6].

In this case, an increase in the implantation temperature in the specified Ti range is accompanied by a decrease in the exit velocity from the channel, which indicates an improvement in the crystal structure as a result of defective light. An increase in Ti to 1000°C stops the accumulation of nitrogen in the buried layer and causes it to flow out to the sample surface, where it accumulates in a layer about 200 nm thick. Calculations show that the integral concentration of nitrogen in the layer corresponds to the dose of introduced N+ ions. An increase in Ti about 1100 near C does not lead to a change in the nitrogen distribution. This means that nitrogen does not leave the sample and remains concentrated in the silicon layer near the thin surface. The nitrogen does not leave the sample and remains concentrated in the silicon layer near the thin surface. Interestingly, in the middle ionic range, the wastewater level continues to decrease and approaches its value in unimplanted silicon [3-4].

This indicates the recombination of defects resulting from the implantation of nitrogen ions and the structural perfection of the layer. The higher the efficiency of applying nitrogen to a thin layer, the lower the dissipation temperature. The second part of the implanted nitrogen diffuses to the crystal surface, where it accumulates in a narrow layer about 50 nm thick. With an increase in the holding temperature to 900 °C, the nitrogen flow dominates over the sample surface during subsequent high-temperature melting, and it ceases to accumulate in the region of the average projection range of N+ ions .

It is known that nitrogen in silicon in a highly saturated state (above 10^{15}–10^{16} sm^{-3}) is present mainly in the form of pairs of nitrogen atoms, which weakly interact with the silicon lattice. However, the appearance of radiation defects in the Si matrix leads to an increase in the concentration of suspended silicon bonds.

This allows the formation of additional Si-N bonds in the silicon matrix of an increasing electron.

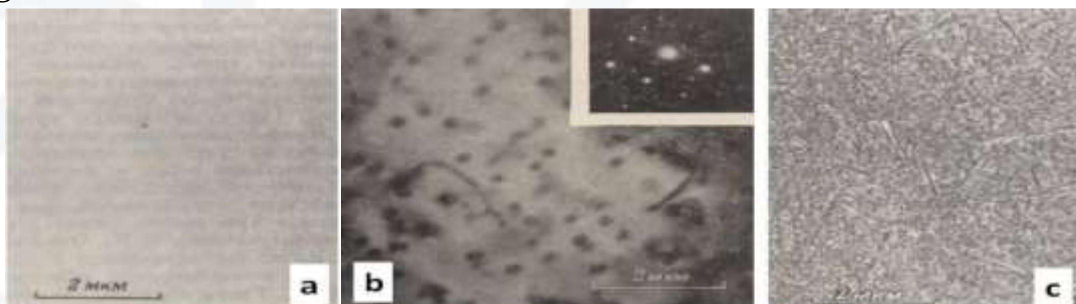

Figure 1.2 The electron has a microscopic image and the electron has an energy of 135 keV. Silicon samples implanted with N+ ions microdiffraction; Doses 5×10^{16} sm^{-2} (a, b) and 8×10^{17} sm^{-2} (c) at a current density of 3-5 μA/sm^2. The temperature at the time of implantation was 600°C (a) and 900°C (b, c).

Excess concentrations of unsaturated Si bonds are present near dislocation rings, at interphase boundaries, and on the silicon surface. Post-implantation of silicon layers at high temperatures with high doses of N+ ions (higher than the silicon amorphization dose) can lead to nitrogen accumulation at the interface between the crystalline and amorphous regions. Under these conditions, the formation of expanded structural defects is suppressed, which ensures the formation of Si-N bonds in the region of maximum ionic elastic losses. The absence of precipitation in the main part of the crystal increases the role of sedimentation of nitrogen atoms on the actual surface of the crystal.

Indeed, the diffusion length of nitrogen atoms at the used flash point is comparable to the distance from P_p N to the real surface of the crystal. Due to the diffusion coefficient of nitrogen in silicon:

$$D = 0.87\exp(-3.29/kT), \quad (1)$$

Here k = 8.62·10-5 eV/K, Boltzmann's constant, temperature T, then the diffusion length of the nitrogen atoms to use is such that flash times at 1150°C (3 hours) are about 530 nm. This value is almost twice the maximum distance. (PpN - nitrogen distribution on the silicon surface)

$$[ND] = (1 / L_D)^3, \quad (2)$$

where ND is the concentration of defects (deposit for nitrogen atoms), L_D is the distance between defects, and their maximum value corresponds to the diffusion length of atoms. Nitrogen (in this case - at a temperature of 900 ° C). Calculations show that the N_D value can be at least ~10^{16} sm^{-3}.

Conclusion

At all implantation and flash temperatures, nitrogen is not redistributed to a depth exceeding the average range of ions and does not evaporate in a vacuum. The critical temperature is enough to stop accumulation in the nitrogen-saturated layer. The sample is poured onto the surface at a temperature of 900 °C and above the critical temperature for the formation of secondary defects (for example, dislocation rings and dipoles) by nitrogen ions during the movement of an ion electron. The observed effects show that the appearance of secondary radiation defects in silicon creates conditions for the accumulation of nitrogen atoms in the layer [7].

*__Note:__ K- is the material it is made from, in this case silicon.
E - is the type of conductivity, which means the type of electron.
F - refers to the material from which the alloy is made, in this case with phosphorus Alloy.

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