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FORMATION OF LAYERS IN THE MIGRATION OF ELECTRONS WHEN HETEROSTRUCTURES OCCUR IN MDYA STRUCTURES

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Abstract

This is due to the interaction of silicon bonding at a temperature of 3500 C where hydrogen atoms can form stable Si-H. Passivation of defects in thin films, ie to protect the metal surface from defects corrosion. Their formation is energetically favorable because the total energy of the complex is 1.2 eV less than the total energy of H2, and neutral hydrogen atoms are observed to diffuse and behave. The mitigation of the simplest defects is accompanied by the restoration of the suspended bonds, and the release of hydrogen from the bonded state is indicated. The breaking energy of the Si-H bond is about 1.8 eV and the diffusion energy of atomic hydrogen is about 0.48 eV.

Keywords: Passivation-corrosion protection, antibody, cluster, complexes, thermodynamics, immobilization, monoatomic, radical, configuration, lamellae, wafers, anisotropic, micro cavitation, exfoliation, energy, hydrogenation, substrate, evaporation.

Introduction

Physical properties of hydrogen in silicon.

The properties of the hydrogen atoms in the Si lattice depend on their chemical nature and the concentration of the implanted hydrogen. Implantation Small doses of silicon hydrogen atoms stimulate the glare of radiation defects due to the passivation of suspended bonds.

This is due to the interaction of silicon bonding at a temperature of 3500 C where hydrogen atoms can form stable *Si-H*. Crystallization of the excitatory amorphous silicon is also formed by adding to the voltage Si-Si bond. Passivation of defects in thin films, ie to protect the metal surface from corrosion of defects, at different temperatures, the proportion of hydrogen required for passivation significantly exceeds the possible defect density. This is because passivation occurs in the formation of suspended and weakened *Si-Si* bonds H_2 or H_n complexes. (Figure 1). Their formation is energetically favorable because the total energy of the complex is 1.2 eV less than the total energy of H_2, and neutral hydrogen atoms are observed to diffuse and behave.

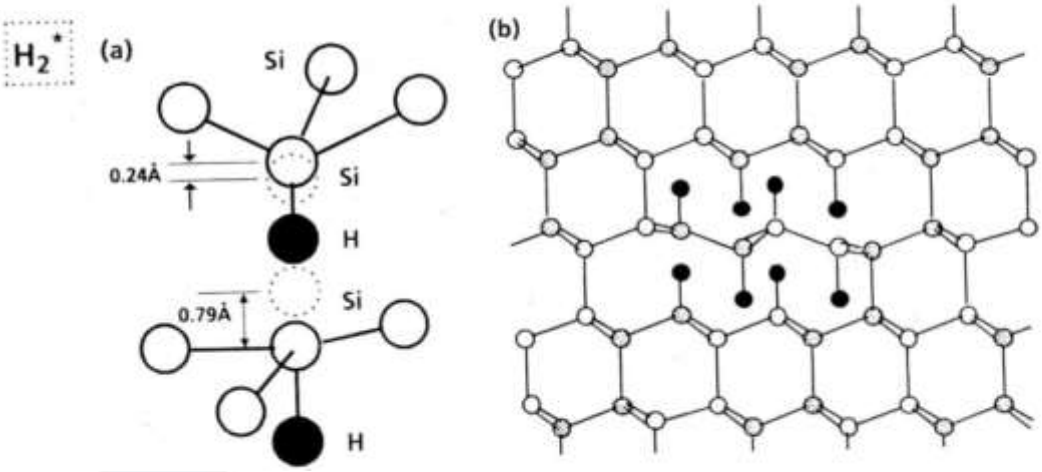

Figure 1. H structure2 * (a) and H_n * (b) hydrogen complexes.

In the case of the H2 complex, one atom of hydrogen occupies a central position in the Si-Si bond to form the Si-H bond, while the other H atom is in the antibacterial intermediate state, forming the Si-H bond. The crystallization of amorphous Si thin films under the influence of suspended bond hydrogen is broken down into mechanisms and energy of hydrogen introduction into Si-Si bonds. Complex Hn is considered to be enlarged, which may result. Planar defects in silicon Defects in single-crystal silicon are formed as a result of hydrogenation. Clusters H_2 complexes are hydrogen complexes in hydrogenated silicon.

The mitigation of the simplest defects is accompanied by the restoration of the suspended bonds, and the release of hydrogen from the bonded state is indicated. The breaking energy of a *Si-H* bond is about 1.8 eV, and the diffusion energy of atomic hydrogen is about 0.48 eV, i.e., a thermodynamic model of the decomposition of a silicon surface layer under the influence of hydrogen.

According to the literature, the immobilization of hydrogen atoms in the silicon p-n junction is observed. In a perfect silicon lattice, the state of the tetrahedral spaces within the configuration H2 contains more stable hydrogen radicals than individual monoatomics (as a single atom). Therefore, H2 molecules are formed in silicon after polishing at a temperature of 2000C. in p-type silicon, this process occurs mainly as a result of relaxation. $H + + H_0 \rightarrow H_2 + h +$. The chemical interaction between the H_2 molecules then results in the formation of hydrogen bubbles.

The mechanism of hydrogen bubble formation has been studied experimentally by many authors. The formation of interface bubbles in silicon wafers is explained by the thermodynamic model of decomposition of the silicon surface layer under the influence of hydrogen, substrate structures corresponding to the lower limit of implant density leading to wafer splitting during formation, and the use of hydrogen ion beams in silicon insulating materials. Hydrogen implantation primarily results in the formation of layered defects (Fig. 2). Hydrogen atoms are in planes parallel to the <100> or <111> planes. In the process, the presence of pressurized hydrogen gas inside the ideal atoms leads to an increase in their volume, as diffuse hydrogen enters idyllic defects and forms H2 molecules. However, growth in the early stages occurs mainly in the direction of the levels.

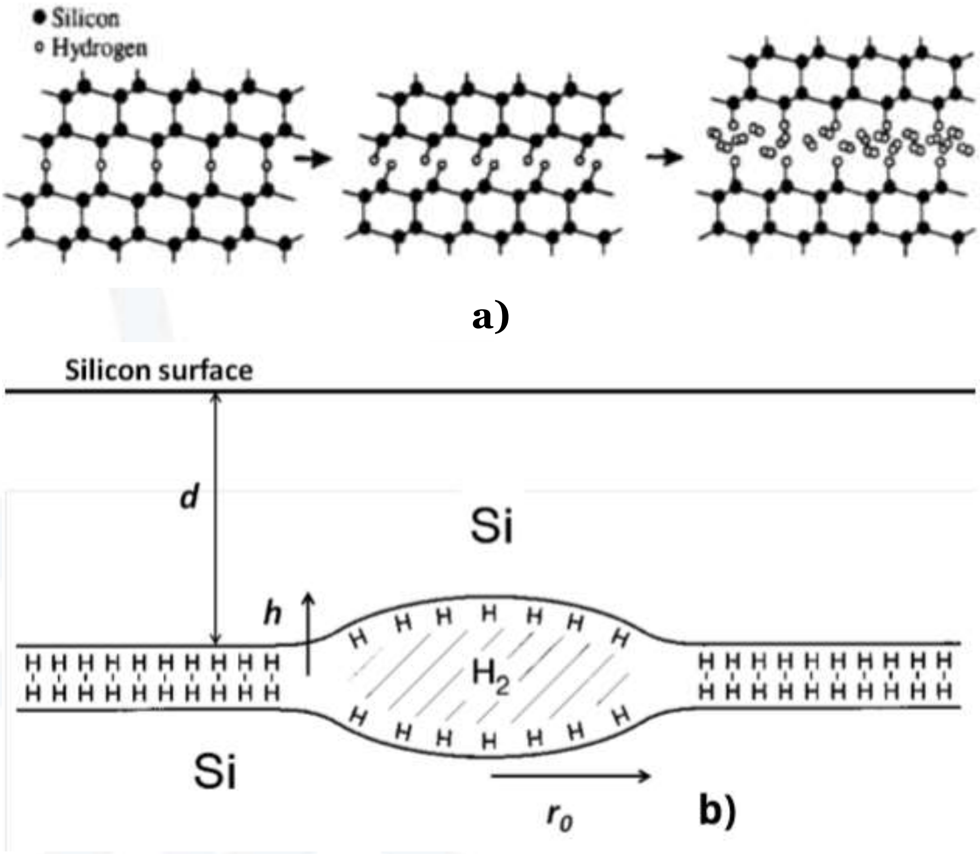

Figure 2. a) a schematic representation of the formation of hydrogen layered defects and their transformation into hydrogen bubbles; (b) Schematic diagram of a bubble of height h and radius r0 formed at depth d from a layered defect as a result of the diffusion of hydrogen from the walls and the surrounding volume.

However, this process is limited by van der Vaals forces acting within a plate defect between two planes coated with hydrogen atoms. parallel elongation of experimental Stress layer defects has been observed by the application of hydrogen ion beams to silicon insulating material technology [15 - 16]. It was also shown in hydrogen-placed silicon that, up to a certain threshold value of the curing time, the accumulation of hydrogen buried in the bulk of the material has a convex shape. On this basis, the lamellar defects grow to a certain critical size *rcrit* in a closed form. It is concluded that the internal energy associated with the interaction of surfaces coated with hydrogen atoms by the internal pressure will be greater than the value of γs. it can be assumed that the surface energy of the corresponding silicon planes, which can be determined by the fission method, is much smaller than γs.

In the formation of interface bubbles in bonded silicon plates, expressions for *rcrit* t were obtained when the bubble cores occurred at the interface between the two plates. It should be noted that in this case the expression describing the elastic energy of the bubble is strongly related to the ratio of the bladder radius r and the plate thickness d (or the thickness of the silicon layer on the resulting bubble). The critical bubble nucleus radius was defined as a function of the ideal hydrogen gas pressure in the bubble. The pressure inside the bladder was assumed to be constant. The following expression is obtained for *dr*:

$$rcrit = \{16\, \gamma_{\mathrm{p}} E d_1^3 / [9\alpha\, (1-v^2)\Delta p^2]\}^{1/4}, \qquad (1)$$

Here, the difference between the pressure inside the Δp -layer defect and the pressure in the outer atmosphere, the E-Young modulus, the ν -Poisson ratio, is *α* 1-order coefficient depending on the details of the a-calculation. Note that expression (1) applies to cases where the thickness of the silicon layers on both sides of the layered defect 96 is equal. If the thickness of the upper silicon layer on the layered defect is much lower than the thickness of the substrate, expression (1) is transformed into the following form.

$$rcrit = \{32\, \gamma_{\mathrm{p}} E d_1^3 / [9\alpha\, (1-v^2)\Delta p^2]\}^{1/4}, \qquad (2)$$

where d1 is the thickness of the top layer (or the depth at which the bubble is formed). As can be seen from expressions (1) and (2), the critical radius for the nucleation of a hydrogen bubble decreases with decreasing plate thickness. In other words, the formation of bubbles of smaller radius in thin films is more preferable. A similar effect is observed with an increase in pressure within the lamellar defect. Experimentally, the manifestation of this effect is that the surface of the thinned plate becomes more convex after joining [1-2].

If the radius of the layered defect is much smaller than the thickness of the silicon layer (i.e., the hydrogen bubble nucleation occurs at a greater depth than r), the critical radius of hydrogen bubble nucleation is the formation of interface bubbles in bonded silicon plates.

$$rcrit = 32\,\gamma_p E\beta^3/[9\alpha f(1-\nu^2)\Delta p^2], \qquad (3)$$

where $\beta\sim2{,}5$ is the value indicating the maximum value of the hydrogen bubble in the silicon wafer relative to the thickness of the hydrogen transfer standard used in silicon technology, i.e. $r \le d/\beta$. From the condition $r=d/\beta$ the geometric parameter f ~ 2 is selected. This condition allows us to adjust the dependencies obtained for $r \le d/\beta$ ((3)) and $r > d/\beta$ (expression 1). Expression (3) shows that the critical radius of formation of small bubbles does not depend on the thickness of the upper silicon layer. In addition to the expressions (1) and (3) in the formation of interface bubbles in bonded silicon wafers, the pressure inside the bubble is thought to be proportional to the concentration of H_2 molecules desorbed on the silicon surface between the added wafers. $r > rcrit$ was expressed for bubble growth kinetics. However, the resulting expression has several unknown parameters that do not allow quantitative analysis of foam growth without the necessary adjustment of the parameters, but allow us to determine, for example, *Si/Si* and Si/SiO_2 allows us to explain many of the experimental features observed at the tumor boundaries [4-5].

The process of anisotropic growth of the bladder due to the increase in pressure of gas molecules in it is described as exfoliation of silicon and other crystals as a result of hydrogen implantation with increasing temperature H_2. The anisotropy of the voltage in the region of accumulation of H_2 molecules at the implanted sites occurs because the surface energy of the planes weakened by the formed *(Si-H)-(H-Si)* bonds is much less than the compression and shear energy of cast silicon. In this case, the bubble grows by evaporating adjacent hydrogen atoms bound to silicon and forming an H_2 molecule in the bubble. The pressure inside a bubble is proportional to the number of molecules. molecules are also considered to be ideal gases here. By minimizing the total free energy expression relative to the bubble height h and its radius r_o, the exfoliation of silicon and other crystals as a result of hydrogen implantation obtained the corresponding geometric parameters of the bubble depending on the temperature. In this case, as in the case of the critical bubble nucleus radius [7], the result depended on the ratio between the size of the bubble and its depth *d*. The resulting phrase is as follows:

$$r0 = (1/4\pi)\,\{3kTN0/[\gamma p-(3/4)\,p0kTf(T)\ln(3TN0/4\pi\gamma p)]\}, \qquad (4)$$

$$h =(NDkT/d)^{1/2}, \text{ uchun } r_o \ll d \qquad (5)$$

$$h =(NDkT/r0)^{1/2}, \text{ uchun } r_o \gg d \qquad (6)$$

where $D=(1-v^2)/E$; H_0 is the number of molecules left in the bubble at the initial time corresponding to the local hydrogen density exceeding the concentration of hydrogen bound to Si on the bubble surface (called the solubility limit at T = 0); f (T) is the thermodynamic fraction of hydrogen leaving the bubble walls; H is the total number of hydrogen molecules in the bubble at $T>0$ after some of the hydrogen atoms have evaporated from the *Si* surfaces: $N=\rho s(\pi r_0^2)f(T)$, where ρ_s is the surface density of the hydrogen atoms. Expression. (4) is a basic expression that shows how the radius of a hydrogen bubble changes with increasing temperature. The critical temperature at which the hydrogen bubble opens is also determined in the purification of silicon and other crystals as a result of hydrogen implantation:

$$kTef(Te)ln(3TeN0/4\pi\gamma p) \approx 4\gamma p/3\rho s, \qquad (7)$$

From the expressions obtained (5) and (6) it can be seen that the height of the correct bubble h does not depend on the radius of the bubble if the bubbles are large and the ratio $h/r_0 \ll 1$. For small bubbles, h/r_0 is even smaller. In fact, in practice, several bubbles grow at the same time. In this case, some bubbles may be absorbed by others and the separation temperature may exceed T_e [6-5].

From an experimental point of view, it is important to determine the conditions for surface swelling. That is, the conditions for reaching the maximum height of the bubble *h*. It can be assumed that the distortion of the layer on the bubble occurs when the height *h* is comparable to the bubble radius r_0 [7]. This gap is caused by the strong curvature of the plate surface. In other words, in this case the bending energy increases relative to the elastic energy. Calculating the bending energy of the shell is very problematic. [8] gave an approximate expression for the bending energy based on the measurements. In this case, the bubble dimensions are also calculated by minimizing r_0 and h, in addition to the surface energy of the bubble, the elastic energy of the volume and the free energy of hydrogen gas are expressions for the total free energy that takes into account the bending energy.

In this case, the expression for the ratio of the bubble parameters has the following form:

$$h/r_0 = (NDkT/\pi d^3)^{1/2}, \qquad (8)$$

and the swelling temperature of the layer is characterized by the following expression:

$$kTblist \approx c(\pi d^3/ND), \qquad (9)$$

where c is the number constant (approximately 10^{-2}). Expression (9) shows that the swelling temperature is strongly related to the depth of hydrogen implantation d.

Comparing the expressions (9) and (7), it can be assumed that for a small d, the bubbles can also open before growth.

That is, located at shallow depths, we have a surface that develops at low temperatures. Finally, it should be noted that theoretical or experimental studies may be hampered because the values of the quantities have not been determined by anyone. For example, the absolute value separation temperature in expression (7) depends on the evaporation energy of the two hydrogen atoms of the silicon surfaces of the microcavitation, namely: $f(T)\sim exp(-/\Delta kT)$. The chemical energy of the two hydrogen atoms on the surface of the reconstituted silicon is not clearly known.

The chemical sorption energy of the two hydrogen atoms on the reconstituted silicon surface is not clearly known. According to available data, this value can vary from 0.2 to 1 eV. Furthermore, the results obtained in the exfoliation of silicon and other crystals as a result of hydrogen implantation do not take into account the kinetics of the separation process. On the other hand, the separation time is one of the defining parameters of the hydrogen separation process [8]. In this case, it is necessary to remove the barriers for the diffusion of kinetic hydrogen atoms, as well as barriers for the formation of hydrogen molecules, impurities from the silicon surfaces. In disordered regions, hydrogen atoms can form *Si-H* bonds that differ from their equilibrium thermodynamic geometry.

Thus, in the exfoliation of silicon and other crystals as a result of hydrogen implantation, the process of bubble formation was considered only due to the evaporation of H atoms into the region where H_2 molecules were formed. A thermodynamic model of the splitting of a silicon wafer as a result of the lateral growth of hydrogen bubbles in hydrogen immobilization in a silicon *p-n* junction was considered, which depends on the effective activation energy of hydrogen dissociation and hydrogen diffusion [13].

So far, despite the success of the theoretical analysis of the motion of hydrogen in silicon, a number of questions remain regarding its properties in damaged silicon. One of the main unresolved issues related to this mechanism is the crystallization and role of silicon films irradiated with high doses of hydrogen ions, which play a very important role in this process.

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