

UDC 539.23

Matyushin V.M.¹, Velikanov M.V.²

¹ Dr. Sc. Phys.-Math. 3HTY

² RT-314m, ZNTU

STIMULATION OF DIFFUSION PROCESSES IN STRUCTURE COPPER FILM - GERMANY UNDER ATOMIC HYDROGEN

The development of modern technology involves the creation of thin metal films on the surface of solids in order to improve their properties, change their physical, electrical and electrophysical parameters, which is directly related to the processes of mass transfer and doping. Thin metal films can also be effectively used as a source for doping near-surface or bulk crystal layers, including by diffusion of metal atoms from a film. In microelectronics, precision instrument making, machine building is the problem of improving the adhesion of metal films to different surfaces, which is directly related to the processes of mass transfer in the film-sublayer system [1].

For a sharp decrease in the total temperature in the technological system acceleration of diffusion processes under the action of atomic hydrogen (H) can be used [2]. At recombination of hydrogen atoms in a molecule on the surface of solids, relatively high energy (4.5 eV per one recombination event) is released, which, in the case of its transfer to surface atoms, can stimulate diffusion processes in near-surface and volume layers as a metallic film, for example and the rigid body on which this film is applied.

Thus, the study of processes of mass transfer in a heterosystem metal film - a solid, stimulated by the interaction of H, represents a great scientific and practical interest.

The source of molecular hydrogen was an electrolyzer, where molecular hydrogen was obtained by electrolysis in an aqueous KOH solution. Next, molecular hydrogen passed through the formaldehyde dehydration chamber with silica gel to absorb water vapor and enter the working system. The residual pressure was approximately 1 Pa, and the pressure of the atomic-molecular mixture

was 4-20 Pa, depending on the established concentration H. H was formed under the action of a high-frequency discharge. The concentration of H in the working volume was measured by the calorimetric method. The optimum concentration of H in the case of intensive treatment of samples was $\approx 10^{14} - 10^{15} \text{ cm}^{-3}$.

The total temperature of $T_{\text{pr.H}}$ did not exceed 310-320 K. For the processing of samples in H, the following mode was used: $n_{\text{H}} \approx 5 \cdot 10^{14} \text{ cm}^{-3}$, $P_{\text{H}} = 20 \text{ Pa}$, $T_{\text{pr.H}} = 310 \text{ K}$.

As a sublayer were n-type germanium crystals (with $\rho_{\text{V}} = 1 \text{ Ohm} \cdot \text{cm}$) with a dislocation density of 10^2 cm^{-2} and a surface orientation $\langle 111 \rangle$. One side was mechanically and chemically polished (purity class 14). On the prepared polished surface of the plates, a thin metallic film Cu was applied by thermal evaporation in a vacuum of 0.1 to 0.5 μm thickness. The temperature of the underlayer at the same time does not exceed 350 K.

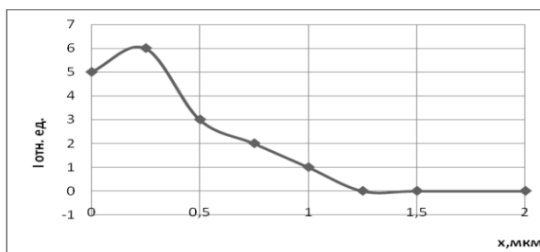


Figure 1 - Graph of diffusion of mussels, such as germanium, which has been previously treated in H

To control the redistribution of film atoms, for example, a secondary ion mass spectrometry (SIMS) method was used [3]. The studies carried out with this technique showed the possibility of obtaining a complete integral distribution of Cu and Ge atoms in the film system - sublayers. With the help of SIMS, the distribution of ionic currents of copper and germanium in germanium specimens with a copper film, initially not treated with atomic hydrogen, and then treated with it, was removed.

The influence of H on the samples resulted in the sputtering of the copper film. The ionic currents of copper and germanium in samples of germanium with copper films treated with H showed that there is a redistribution of the concentration of copper atoms near the film boundary - crystal. Samples with a film thickness of 0.4 μm , processed in H for 5 minutes were investigated. In this case, the processing of copper film is not completely sprayed. In this case, the thickness of the boundary layer of the film - a crystal (where the density of the film is less than its bulk value) was of the order of 0.01 microns. The average density of copper film in this layer was about 80% of its volume density. After this, to detect

the diffusion of copper in a copper film, the curve of the film curvature treated with Y was removed from the film curves for the untreated film and a redistribution of copper on the boundary of the film section - sublayers - was obtained.

From the graph (Fig. 1), the diffusion coefficient was calculated and the dependence of the diffusion coefficient on the depth was constructed. For this purpose, the distribution formula of impurities along the diffusion layer was used in the case of a diffusion source with unlimited power [4]:

$$C_x = C_0 \operatorname{erfc}\left(\frac{x}{2\sqrt{Dt}}\right), \quad (1)$$

where C_0 is the concentration; x – depth of the layer; D – diffusion coefficient; t – the processing time. For the superficial concentration C_0 the highest value is taken on the ordinate axis. $t = 5$ minutes (sample processing time). After that, a plot of the dependence of the diffusion coefficient of copper in the film on the thickness was constructed. As can be seen from Fig. 1 dependence has two sections: the first section (from 0 to 0.27 microns), the diffusion coefficient increases; on the site of 2 to 0.5 microns, falls (due to the appearance of a temperature gradient during the action of atomic hydrogen with a maximum temperature on the surface of the copper film). Such redistribution of copper in the film leads to its seal on the interface of the film-sublayers, which increases the adhesion film to the underlayer.

Consequently, under the action of H in a copper film, a substantial mass transfer occurs in the direction of the interface boundary between the substrate films and abnormally high coefficients of surface self-diffusion, which correspond to effective temperatures in the range from 1173 to 933 K, although the temperature at which processing was carried out in H was not more than 320 K . The main mechanism of mass transfer is the superficial intergranular. The structure of the film at the interface of the section is sealed, which leads to increased adhesion, improvement of its electrophysical (including electrical conductivity) properties, metal crystal contact improvement. In addition, processing in H increases the quality of the metal film as a source for the doping of semiconductor structures.

REFERENCES

1. Borisenko V.E., Vorob'eva A.I., Utkina I.A. Nanoelectronika [Nanoelectronics]. – Moscow: Binom, 2009. – 223 p. (Rus)
2. Matyushin V.M., Zhavzharov E.L. MonografIya «RadikalorekombInatsIyna obrobka mIkrostruktur» [Monograph "Radical recombination of microstructures"], Zaporizhzhia: ZNTU.-2011, 190 p. (Ukr)

3. Veksler V.I. Vtorichnaya ionnaya emissiya metallov [Secondary ion emission of metals]. – M.: Science, 1978. - 302 p (Rus)

4. Gotra Z.Yu. Tehnologiya mikroelektronnyih ustroystv [Technology of microelectronic devices]. Directory. - Moscow: Radio and Communication, 1991. - 528 p. (Rus)