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Ultrasonic Influence on the Characteristics of the Interface of the SDS of CdTe/CTO Structures

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ANNOTATION: The effect of ultrasonic treatment on the generation characteristics of the interface between the PDP of CdTe/STO structures obtained by magnetron ion sputtering has been studied.

KEY WORDS: ultrasound, defect, relaxation, generation, layer.

Introduction. As is known, ultrasound (US) affects the defective structure and electrophysical characteristics of semiconductors and semiconductor structures [1–4]. Effects with ultrasonic action appear in the areas of semiconductor structures, where the field of internal stresses is observed [3,4]. Such fields are a factor contributing to the formation and recombination of defects under the influence of ultrasound. It is of great interest to study the effect of ultrasonic action on the CdTe/TeO_2 interface and to study the presence of a highly stressed transition layer [5].

We have studied the effect of ultrasonic treatment on the generation characteristics of the CdTe/TeO_2 interface formed by the oxidation of a p-type CdTe surface with (111) crystallographic orientation and resistivity of 10^2–10^3 Ohm·cm. Oxidation was carried out in the atmosphere in the MSIR system of pure oxygen and argon during the deposition of a layer of cadmium stannate CTO, a mixture of metal oxides, which attract increased attention of researchers and materials scientists due to their low cost and their unique properties. Magnetron ion sputtering was used to obtain transparent layers of In_2O_3 and ITO [6]. Indium tin oxide (ITO) is the material with the highest electrical conductivity and light transmission (R_S=10 ohm/μ and T = 90%). However, there is great interest in using alternative, cheaper coating materials such as Cd_2SnO_4 (CTO) [7]. Optically transparent and electrically conductive thin layers of Cd_2SnO_4 cadmium stannate (CTO) were deposited by reactive magnetron sputtering on a substrate at room temperature.

Methodology. The study of the generation characteristics of the interface was carried out using the method of isothermal relaxation of the capacitance, which makes it possible to determine both the surface generation rate S_g and the generation lifetime rg in the CdTe region adjacent to the interface. To implement this method, test structures of the metal–dielectric–semiconductor type (MPS structures) were formed by vacuum deposition of gold onto the TeO_2 layer.

Results and its discussion. The resulting structures were exposed to ultrasound at a frequency of 2.5 MHz and a power of 0.5 W/cm^2 for 45 min. The relaxation process of the nonequilibrium capacitance of the CdTe/CTO PDP structure was measured at a test signal frequency of 10 kHz, in the dark, at a temperature of 0°C. The state of non-equilibrium depletion was created by switching the voltage applied to the structure from -6 to +6 V (Fig. 1). In this case, the structure was transferred from the state of inversion to the state of a stronger inversion. The choice of this measurement mode is due to the fact that it makes it possible to neglect the contribution of the charge exchange of surface states in the process of relaxation of the nonequilibrium capacitance of the CdTe/HTO SDS structure and to increase the accuracy of measurements and the unambiguous interpretation of the results obtained [8]. On fig. Figure 1 shows the relaxation dependences obtained for one of the investigated CdTe/CTO structures before and after ultrasonic treatment. It can be seen that the ultrasonic action leads to an increase in the relaxation time of the nonequilibrium capacitance of the CdTe/CTO structure, which indicates a decrease in the rate of generation of minority charge carriers. Processing presented in fig. 1 dependences, according to [6, 8], showed that the decrease in the rate of the relaxation process is due to both a decrease in the values of Sg and an increase in the generation lifetime of minority charge carriers. It should be noted that, before ultrasonic treatment, a significant spread of Sg values is observed in the structures under study (from S_g = 2.5 cm/s to S_g = 14.2 cm/s). At the same time, the spread of rg values did not exceed 20% relative to the average value r_g = 0.96 and t = 10^{-6} s. The observed effect of a decrease in the values of S_g as a result of ultrasonic exposure is observed in all the structures under study, regardless of the values of S_g and r_g.

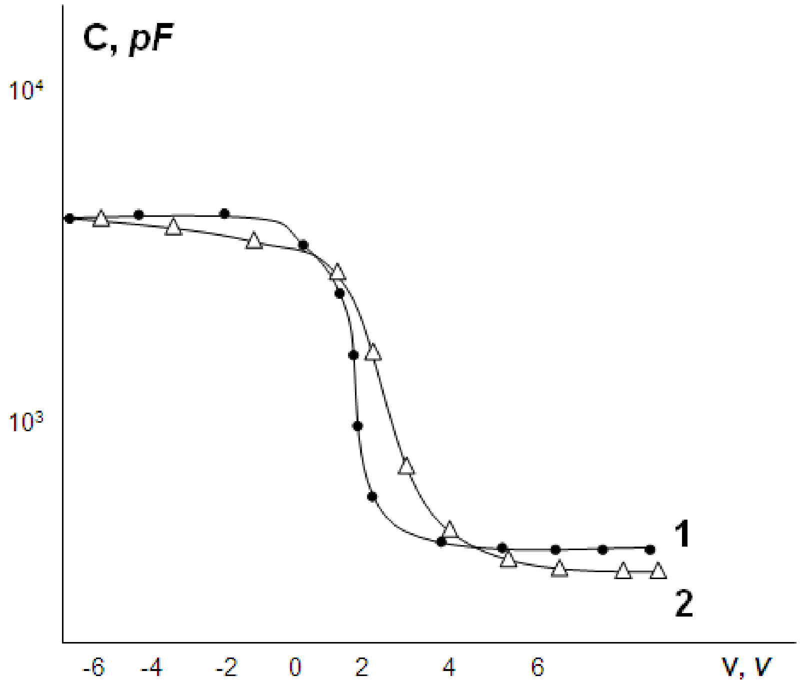

Fig. 1. Relaxation dependences of the nonequilibrium capacitance of the CdTe/CTO SDS structures under study: 1-before exposure to US; 2-after exposure to US.

In this case, in addition to a decrease in the surface generation rate, ultrasonic treatment also leads to a decrease in the scatter of Sg values (from S_g = 0.5 cm/s to S_g = 2.5 cm/s). The values of r_g in the CdTe region adjacent to the interface change to a much lesser extent as a result of ultrasonic treatment. Thus, the average value of T_g after ultrasonic treatment was 1.6×10^{-6} s, and the scatter of r_g values did not exceed 15%.

According to [5, 9], the value of Sg is related to the concentration of surface generation centers (surface states). However, studies carried out using the method of high-frequency capacitance-voltage (C-V) characteristics showed that ultrasonic exposure does not lead to any noticeable changes in the type of C-V dependences of the structures under study (Fig. 2), which indicates the absence of changes in the density value surface states (N_{SS}).

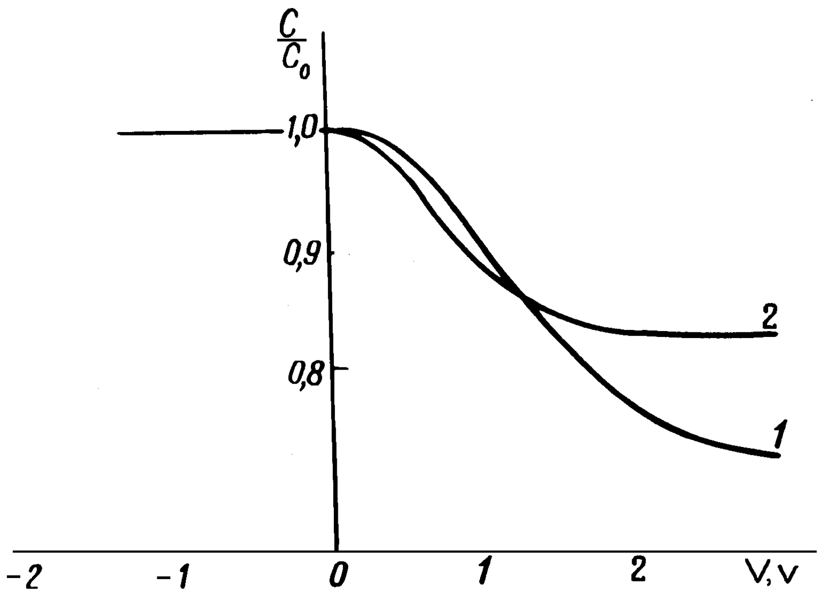

Fig.2. High-frequency capacitance-voltage characteristics of the CdTe/CTO SDS structures under study, normalized to the capacitance of the dielectric C_o (C_o = 524 pF): 1 before exposure to ultrasound; 2 - after exposure to ultrasound.

Moreover, it was found that in the studied structures before ultrasonic treatment, despite the significant spread of S_g values, the N_{SS} values differ by no more than 22%. In this case, no correlation was found between the density of surface states and the values of S_g. A significant scatter in the values of S_g at close values of N_{SS} for CdTe/CTO structures fabricated in the same technological cycles was previously discovered in [10, 11].

This, according to the authors of [12, 13], is a consequence of the fact that the values of Sg are determined not only by the value of N_{ss}, but also by the presence of local spatial inhomogeneities of the surface charge distribution at the CdTe/TeO_2 interface and the fluctuations of the surface potential associated with them. In this case, the decrease in S_g values as a result of ultrasonic exposure can be explained by the fact that it leads to a rearrangement of the stressed layer at the interface, which occurs in such a way that it leads to smoothing of local inhomogeneities in the distribution of the surface charge. The physical mechanism by which US causes structural changes in cadmium telluride layers, especially in the transition layer of TeO_2 oxide. Since ultrasound leads to an increase in the mobility of free cadmium and tellurium atoms in imperfect crystallites on the surface of CdTe films, especially Te atoms. As a result, nuclei are formed in the CdTe base on the film surface and in the spaces between grains of cadmium telluride, as well as the influence of oxygen in the structures of the dielectric layer of TeO_2 oxide. It is obvious that the nuclei are formed in those spaces between grains, near which the necessary process for the occurrence of structural transformations is reached, where the recrystallization of cadmium telluride begins from its surface [15]. This causes the experimentally observed decrease in the texture of the base layers of cadmium telluride after ultrasonic treatment. Since during recrystallization the growth of the base layer is carried out on the cadmium telluride layer, this leads to a decrease in the deformation of the crystal lattice and, accordingly, to a decrease in the lattice period. Since, after ultrasonic treatment, the mixed hexagonal and cubic modification on the CdTe surface, which are formed due to surface imperfections during film growth [14], transforms into a cubic one [15]. Based on these processes, the surface generation channels associated with surface potential fluctuations are eliminated. This is supported by the fact that ultrasonic treatment leads both to a decrease in the value of Sg and to a decrease in the spread of its values. At the same time, the rearrangement of the defect structure stimulated by ultrasound practically does not change the total number of defects in the transition layer and, therefore, does not affect the value of N_{ss}.

An increase in the values of rg as a result of ultrasonic processing of the structures under study indicates that, in the CdTe region adjacent to the interface, a rearrangement of the defect structure is also observed, leading to a decrease in the number of generation centers. However, the effects associated with the influence of ultrasonic exposure on the generation characteristics of this region are much less pronounced, which may be due to the absence of internal mechanical stress fields in it, which facilitate the rearrangement and rearrangement of defect centers.

Conclusion. Thus, as a result of the studies carried out, it was established that the ultrasonic action leads to a change in the generation characteristics of CdTe of the CdTe/TeO_2 interface formed during the thermal oxidation of the surface. The observed changes are due to the rearrangement of the defective structure of the interface and the silicon region adjacent to it, stimulated by ultrasound. The presence of internal mechanical stresses is a factor contributing to the processes of rearrangement of the defect structure; therefore, the effects of ultrasonic action at the interface between the CdTe/CTO SDS structures are more pronounced than in the CdTe bulk.

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