Sensor properties of metal–Ga oxide–GaAs structures

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Sensitivity of Pd-Ga_xO_y-n-GaAs structures with the tunnel thin natural oxide depends on the method of forming of Pd-electrode. Pd metal films obtained by thermal evaporation on a cold GaAs substrate are dense enough and the Pd-Ga_xO_y-n-GaAs samples have a low response to gas (e.g. hydrogen). Structures which are not subjected to thermal annealing also have relatively low response (table, and Fig. 1a). After annealing the continuous Pd film becomes dispersed, the forward (I_f) and reverse (I_{rev}) currents increase significantly in hydrogen environment (Fig. 1b). Curves 1 and 3 are *I-U* dependencies measured in air and curves 2, 4 are dependencies measured in hydrogen. The further increase of annealing temperature at constant annealing time (20 min) results in decrease of response for direct ($I_н/I_f$) and reverse ($I_н/I_{rev}$) currents. If the annealing temperature is high or the annealing time is more than 20-30 minutes the Pd film reacts with oxide film and semiconductor strongly. The reaction products do not have catalyst properties. The lowering of annealing time to 5 minutes at 673 K leads to essential increase of sensitivity to H_2 of Pd-oxide film-GaAs structures. We suppose that during the dissociative adsorption of hydrogen, a part of hydrogen atoms (H) reaches the Pd-dielectric interface by diffusion and forms the electrical dipoles. The dipole field impact on work function of Pd, decreasing the parameter. Therefore the contact potential difference decreases and band bending changes that defines MOS-structures electrical characteristics in H_2/air gas mixture.

Increase of a response to hydrogen after thermal annealing is explained by change of structure and chemical composition of Pd-electrode and dielectric film. According to X-ray diffraction analysis data after annealing at 673 K for a long time the concentration of PdO increases what is lead to catalytic activity decrease. When annealing time is reduced to 5 min, pure Pd electrode can be formed and its catalytic activity is increased. After annealing the arsenic oxides (volatile component) disappear and the dielectric film material is gallium oxide. Both these effects change band bending at Ga oxide-GaAs interface and have influence on response.

Sensors based on GaAs exhibit a small capacitance response on exposure to H_2 unlike Pd-SiO_2-Si structures. The maximum capacitance change of Pd-oxide film-GaAs structures does not exceed 27 % what is much less than capacitance response of Pd-Si structures for which capacitance increases in ten times at the same hydrogen concentration. The effect is explained by high density of surface states at Ga oxide-GaAs interface and *C-U* characteristic has low slope as a result.

It should be noted the structures have sensitivity to CO and NH_3 gases.

Table. Response of forward and reverse currents and capacitance of Pd-n-GaAs structures on exposure to H_2 ($5 \cdot 10^5$ ppm) at 300 K as a function of annealing temperature T_{an}; τ_r and τ_{red} – response and reduce time. The voltage is pointed in parentheses (V) at which the maximum response is observed

№ of sample	T_{an}, K	t_{an}, min	$(I_H/I)_f$	$(I_H/I)_{rev}$	$\Delta C/C$, %	τ_r, s	τ_{red}, min
1	Before anneal		4 (0.15)	1.5 (-0.15)	21	8	7
2	Before anneal		2 (0.1)	1.3 (-0.15)		2	5
3	473	20	24 (0.1)	10 (-O.3)		60	10
4	473	20	27 (0.15)	3.7 (-0.2)		44	12
5	473	20	25 (0.15)	5.0 (-0.15)	27	45	14
6	573	20	267 (0.25)	128 (-0.1)		40	12
7	573	20	620 (0.15)	185 (-0.1)		90	13
8	573	20	450 (0.15)	180 (-0.15)	24	120	23
9	623	20	331 (0.1)	158 (-0.1)		110	21
10	623	20	525 (0.15)	100 (-0.15)	21	130	27
11	673	20	3 (0.2)	1.5 (-0.1)		150	15
12	673	20	11.5 (0.1)	2 (-0.1)		90	9
13	673	20	8.0 (0.15)	1.5 (-0.15)	0	110	16
14	673	5	1528 (0.1)	126 (-0.1)		140	27
15	673	5	1980 (0.15)	125 (-0.15)	22	140	29

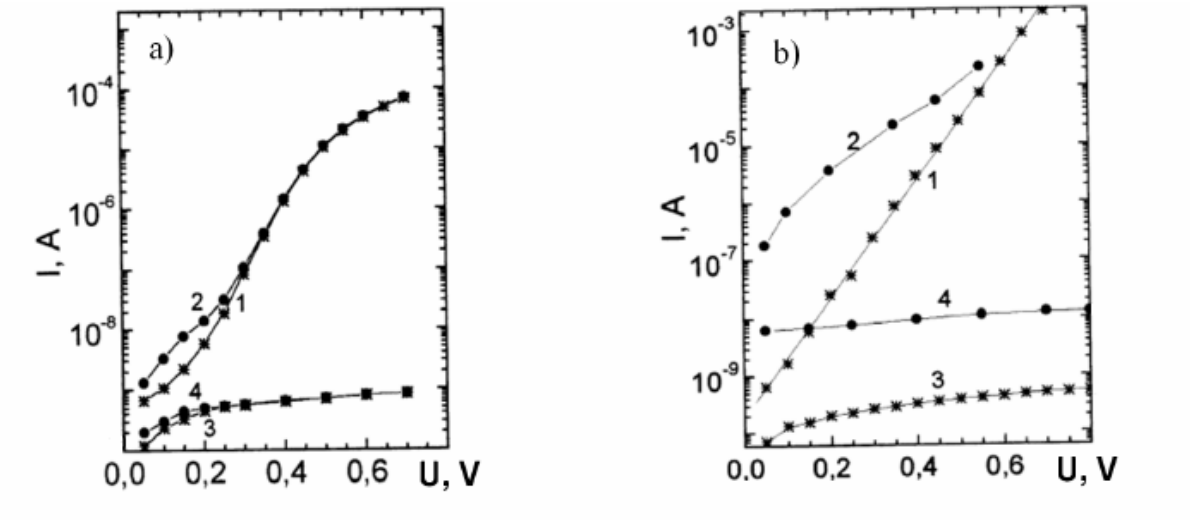

Fig. Forward (1, 2) and reverse (3, 4) current-voltage characteristics of Pd-n-GaAs structures before (a) and after (b) anneal (673 K, 5 min): 1, 3 – air; 2, 4 – H_2 ($5 \cdot 10^3$ ppm)