MEASUREMENT OF CONCENTRATION OF ATOMIC OXYGEN IN DISSOCIATED GASES

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In [1, 2] we described the experimental results of interaction of atomic oxygen with chemical detectors. In the present paper we describe the effects of interaction of atomic oxygen with silver.

The concentration of atomic oxygen is measured by using the change in electrical resistance of thin silver films due to oxidation.

The experiments were carried out on the apparatus described in [2, 3]. Atomic oxygen was obtained by means of a high-frequency discharge. We constructed special detectors consisting of 20 mm × 10 mm Micarta plates 1.5 mm thick, on the surface of which a thin film of pure silver was deposited in vacuum. The detectors were mounted in a special holder with spring contacts sealed into the cone of a ground-glass joint.

The experiments were conducted with initial molecular oxygen pressures of $2 \cdot 10^{-3}$-10^{-3} mm Hg in the discharge space. We investigated the electric current flowing through the detector (1 in Fig. 1) when atomic particles acted on it. The voltage U_R (Fig. 1), recorded from a constant resistor with R = 160 Ω (2), was applied to the input of a KSR-4 recording potentiometer (3). The detectors were calibrated for absolute atomic oxygen concentration by the electronic spin resonance method.

The detector calibration apparatus consisted of a Varian E-3 radiospectrometer (1 in Fig. 2), a vacuum pump connection with a leak (2), a VIT-2 vacuum gauge (3), a KSP-4 recording potentiometer (4), and a high-frequency generator (5). The calibration experiments were conducted in the following way. A quartz glass tube (7) of diameter 9 mm was mounted in the resonant cavity of an ESR radiospectrometer. A fore-vacuum of 10^{-6} mm Hg was created in the tube, and then the required O_2 fluxes were established by means of the leak and continuous pumping. The top of the tube terminated in a ground-glass joint in which the investigated silver detectors (8) were mounted in a special holder with contacts. The dissociation of O_2 was effected by a high-frequency generator. For the calibration experiments we constructed silver detectors with equal initial electrical resistance. A plot for different concentrations of atomic oxygen was obtained.

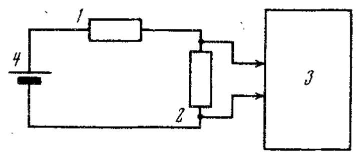

Fig. 1

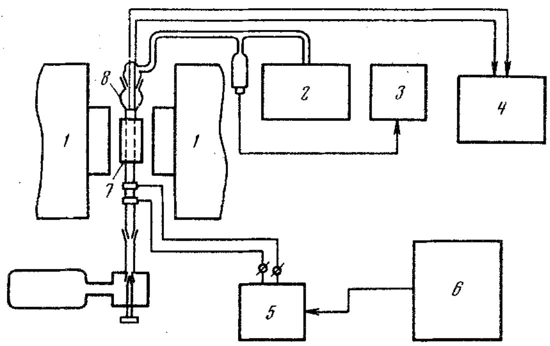

Fig. 2

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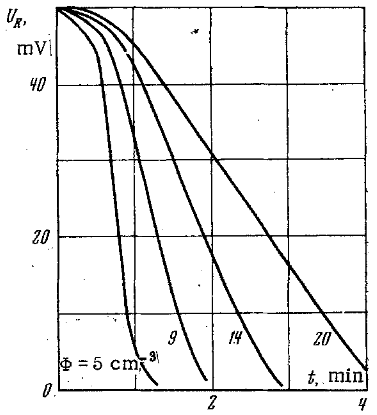

Fig. 3

The concentration was measured with the radiospectrometer and in our experiments was $n_0 = 10^{13}$-10^{15} cm^3 [4]. It should be noted that in the experiments the gas flow was free-molecular and the annihilation coefficient for atomic oxygen particles was $\eta = 0.009$ on the surface of the quartz tube [3] and $\eta = 1.0$ on the silver surface [5]. Hence, the O concentration at the working surface of the detector was assumed equal to the concentration within the resonant cavity of the radiospectrometer. The empirical relationship $\Delta U_R/\Delta t = f(n_0)$ was the calibration curve. The value of $\Delta U_R/\Delta t$ was obtained from a treatment of the experimental curves obtained on the tape of the recording potentiometer.

The estimated measurement error for this method was 30% of the measured value.

We carried out control experiments to determine the properties of silver detectors. Figure 3 shows the relationship $U_R(t)$ for different $\Phi = C \cdot 10^{-13}$ cm^{-3}, where C is the O concentration.

As Fig. 3 shows, U_R is a linear function of the exposure time t over a large portion of the $U_R(t)$ curve for a constant O flux on the detector. Figure 1 shows that $U_R = iR$. Thus, the $U_R(t)$ curves reproduce the variation of the current i through the detector.

In these experiments we used detectors with the same initial electrical resistance $R_g = 100$ Ω. The value of R_g can be altered by changing the thickness of the deposited silver layer. The resistance is monitored continuously with an ohmmeter during evaporation. Unfortunately, the thickness of the silver film on the working surface of the detectors cannot be determined from the resistance of the latter, since the conductivity of these films [6] does not correspond to the conductivity of massive specimens. Hence, the optimal values of the initial resistances R_g for the detectors were chosen empirically on the basis of maximum sensitivity of the latter to minimum O fluxes and stability of R_g after evaporation. It should be noted that a reduction of R_g led to a reduction of the sensitivity of the detectors, and an increase in R_g led to an increase in sensitivity, but the resistance was less stable after evaporation in the latter case.

A test of the effect of temperature conditions on the stability of the detectors showed that heating to 423°K did not lead to any appreciable changes in the initial resistance R_g.

To determine the effect of composition of the gas on the results of O measurements by silver detectors we conducted experiments with different gases. We found that O_3, O_2, H_2, N_2, NO, CO, CO_2, Ar, propane, butane, and methane had no appreciable effect on the detector, i.e., for them

$$U_R(t) = \text{const} = U_{R_g}.$$

We note in conclusion that the results of the described experiments confirm that detectors based on thin silver films can be used to measure the concentration of atomic oxygen in dissociated gases. The procedure for measurement of atomic oxygen with these detectors is as follows:

1) preparation of a series of silver detectors with $R_g = 100$ Ω;

2) obtention of the relationship $U_R(t)$ for each detector;

3) construction of the experimental $U_R(t)$ curve and determination of $\Delta U_R/\Delta t = \tan \alpha$, where α is the angle of slope of the linear part of the curve of $U_R(t)$;

4) determination of the absolute O concentration in the gas from the calibration curve.

The described method of O measurement is more selective and more convenient than that used in [7, 8]. It is intended to use this method to investigate the diurnal altitude variation of O in the atmosphere.

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