JPN. J. APPL. PHYS. VOL. 24 (1985) NO. 9

A Method for Determining the Activation Rates of PSEE Centers in Scratched Aluminum by Varying the Stimulation Intensity

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(Received May 25, 1985; accepted for publication July 20, 1985)

When metals are deformed, *e.g.*, by abrasion, their photo-stimulated exoelectron emission (PSEE), after showing a momentary increase and decrease, reaches a quasi-stationary state, i.e., it decreases very gradually for twenty or thirty days.[1,2] In view of the two-process model we proposed previously,[3] this quasi-stationary PSEE yield per unit time, N_s, can be written as

$$N_s=\frac{\alpha\beta}{\alpha+\beta}S_0=\frac{1}{\dfrac{1}{\alpha}+\dfrac{1}{\beta}}S_0 \qquad (1)$$

where S_0 is the total number of exo-emission centers, α the rate of emission from exo-active centers, and β the rate of activation of exo-inactive centers.[4] It should be noted that α, being related to the excitation of electrons at energy levels within the band gaps of surface oxides, must depend on the intensity and wavelength of the photostimulation. On the other hand, photostimulation does not seem to have a substantial effect on β, which is related to electron transitions from the bulk metal to vacant levels of the oxide layers.

Under the assumption that α can be either infinitesimally small or infinitely large for varying intensities of photostimulation, we obtain, as the corresponding limiting formulas of eq. (1), the relations

$$\lim_{\alpha\to 0} N_s=\alpha S_0, \qquad (2)$$

$$\lim_{\alpha\to\infty} N_s=\beta S_0. \qquad (3)$$

The physical meanings of these approximations are as follows: (1) When the photostimulation intensity is very low (eq. (2)), nearly all of the emission centers are activated, i.e., filled with electrons. Hence, the PSEE yield depends on the emission rate α. (2) When the photostimulation intensity is very high (eq. (3)), nearly all of the emission centers are inactivated, i.e., unoccupied by electrons. The PSEE yield should then be determined solely by the exo-activation rate β.

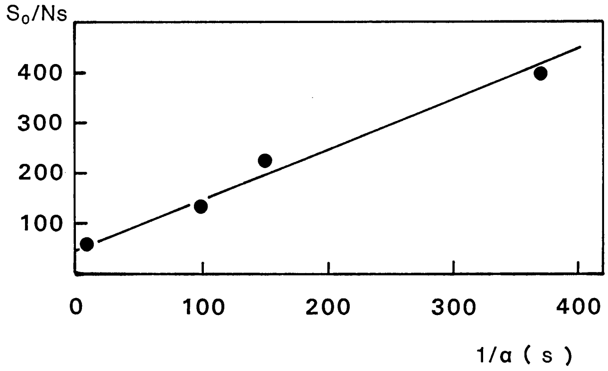

Fig. 1. Relation between ratio of total number of exo-emission sources over stationary PSEE (S_0/N_s) and reciprocal of exo-emission rate ($1/\alpha$).

Equation (3) indicates that β can be determined if the values of N_s and S_0 are known and the value of α can be made sufficiently large. To determine β accurately, it is convenient to transform eq. (1) into

$$\frac{S_0}{N_s}=\frac{1}{\alpha}+\frac{1}{\beta} \qquad (4)$$

It is apparent from eq. (4) that, if the ratio S_0/N_s of the observed values is plotted as a function of $1/\alpha$, a linear relation should be obtained, and that the value of β may be unambiguously determined by extrapolating the line to the point corresponding to $\alpha=\infty$. Our experimental results are shown in Fig. 1, where good linearity is seen between S_0/N_s and $1/\alpha$. Calculation of β from Fig. 1 gives a value of approx. $2.22\times10^{-2}\,s^{-1}$, which seems reasonable.

In connection with the data shown in Fig. 1, a brief description of the experimental procedure is necessary. An Al specimen (99.99% purity) was scratched at room temeprature and at an ambient pressure of 10^{-5} Torr. The intensity of the light of wavelength 340 nm used to stimulate the specimen was changed successively so that the value of α could be varied. The PSEE yield from the specimen in the quasi-stationary state, N_s, was counted using a multichannel analyzer. Further experimental details, including the method of determining α and S_0, have been reported previously.[3,5]

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