JPN. J. APPL. PHYS. VOL. 22 (1983), NO. 10

An Improved Method for Determining the Emission Rate and Source Population of PSEE

Hidemi SHIGEKAWA and Shin-ichi HYODO

Department of Applied Physics, The University of Tokyo, Bunkyo-ku, Tokyo, 113

(Received July 18, 1983; accepted for publication August 20, 1983)

In a previous paper[1)] we reported a storage effect observed in photostimulated exoelectron emission (PSEE) from scratched aluminum, showing that factors relevant to PSEE characteristics such as the number of total emission sites or the emission rate of exo-active sites could be experimentally determined. Actually, however, the procedure to determine these factors is rather time-consuming. The purpose of the present communication is to describe an improvement on this point.

Let S_0 be the total number of electron emission sites, $S'(t)$ the number of exo-active sites filled with electrons and $S''(t)$ the number of empty sites. (Hence, $S_0=S'(t)+S''(t)$.) Let $N(t)$ be the emission yield from a specimen observed at time t. From a previous paper $N(t)$ can be written as $N(t)=\alpha S'(t)$, where α denotes the rate of emission from the exo-active sites photostimulated. Also, we define β as the rate of filling the empty sites with electrons by thermal excitation. The rate β should depend on the specimen temperature, but is considered to be independent of photoillumination.

In a previous experiment,[1)] to determine S_0, α and β, we observed the transient response of PSEE when the illumination focussed on specimens was suddenly turned off or on. In the present experiment we did the same, but by changing the light intensity, since the yield of PSEE is known to be greatly influenced by the intensity of photostimulation or by its wavelength.[2,3)]

We assume that at $t<0$ α is equal to α_1 and at $t\geqq 0$ α becomes equal to $\alpha_2(<\alpha_1)$, when the light intensity is diminished at $t=0$. The rate equation, then, can be expressed for $t\geqq 0$ as

$$\frac{\mathrm{d}S'(t)}{\mathrm{d}t}=-\alpha_2 S'(t)+\beta(S_0-S'(t)) \qquad (1)$$

Taking the initial condition of eq. (1), that is,

$$S'(0)=\frac{\beta}{\alpha_1+\beta}S_0 \qquad (2)$$

into account, we can solve eq. (1) as

$$S'(t)=\frac{\beta S_0}{\alpha_2+\beta}+\frac{(\alpha_2-\alpha_1)\beta S_0}{(\alpha_1+\beta)(\alpha_2+\beta)}\exp\left[-(\alpha_2+\beta)t\right] \qquad (3)$$

Equation (3) indicates that the emission yield $N(t)$ will increase in accordance with $\alpha_2\cdot S'(t)$ after dropping from $\alpha_1\cdot S'(0)$ to $\alpha_2\cdot S'(0)$ at $t=0$. This behavior is well demonstrated in Fig. (1), where the observed PSEE yield from a scratched Al specimen (illuminated by light 300 nm in wavelength) is plotted as a function of time.* It is apparent that the ratio $N(0_-)/N(0_+)$, the ratio of yields just before and after $t=0$, should be equal to α_1/α_2. In Fig. 2, where the observed yield is plotted on a logarithmic scale, a good agreement may be noticed between eq. (3) and this observation. It is possible to determine $(\alpha_2+\beta)$ from the slope of the line in Fig. 2.

*The experimental details are similar to those described earlier.[4)]

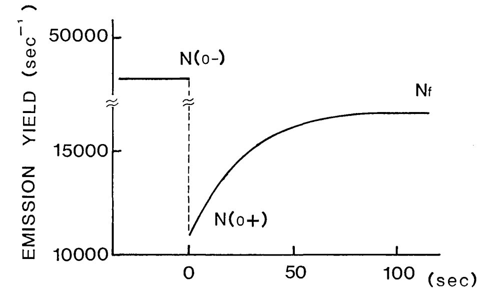

Fig. 1. Change in the emission yield resulting from decreasing the photoemission probability from α_1 to α_2. N_f: Stationary yield.

Next, let us take the time origin, $t=0$, as the moment when the light intensity is increased and consequently α increases from α_2 to α_1. The number of exo-active sites will change with time ($t\geqq 0$) in a way which may be written as

$$S'(t)=\frac{\beta S_0}{\alpha_1+\beta}+\frac{(\alpha_1-\alpha_2)\beta S_0}{(\alpha_1+\beta)(\alpha_2+\beta)}\exp\left[-(\alpha_1+\beta)t\right] \qquad (4)$$

As in the case of eq. (3), eq. (4) indicates the possibility of determining $(\alpha_1+\beta)$ from the slopes of experimental plots. The values of α_1, α_2 and β can be readily obtained from values for the quantities α_1/α_2, $(\alpha_2+\beta)$ and $(\alpha_1+\beta)$. Since the stationary yield of PSEE under intense illumination should be equal to $\alpha_1\beta S_0/(\alpha_1+\beta)$, the total number of emission sites, S_0, can be also estimated.

The method proposed here is much faster than the previous one which requires many runs of experiments in which the period of intermission of photoillumination is varied to determine PSEE factors. Since the PSEE yield gradually decays and the other factors related to PSEE, such as the surrounding conditions, cannot be taken to be precisely constant, this fast method is believed to make possible the acquisition of more reliable data on PSEE.

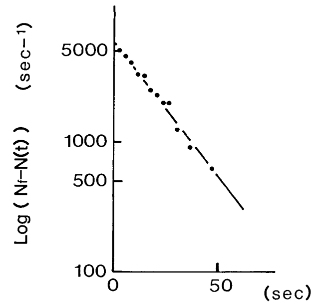

Fig. 2. Observed values of $[N_f-N(t)]$ as a function of time after decreasing the intensity of light ($\alpha_1\rightarrow\alpha_2$).

References

1) H. Shigekawa and S. Hyodo: Jpn. J. Appl. Phys. **21** (1981) 1278.
2) L. Grunberg and K. H. R. Wright: Proc. Roy. Soc. **A232** (1955) 403.
3) T. Smith: J. Appl. Phys. **46** (1975) 1553.
4) H. Shigekawa, R. Iwatsu, M. Okada and S. Hyodo: Jpn. J. Appl. Phys. **22** (1983) 42.