Journal of Surface Analysis Vol.14, No. 4 (2008) pp. 312-315
T. Iyasu et al. Database construction of Secondary electron emission - Monte Carlo approach combine d with supplementary experiment

Special lecture, Korea-Japan Symposium

Database construction of Secondary electron emission - Monte Carlo approach combined with supplementary experiment –

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(Received: December 06, 2007; Accepted: January 07, 2008)

A novel approach is proposed to derive a theoretical curve, $\delta_{th}(E_P)$, from the equation

$$\delta_{th}(E_P) = k\int_0^\infty \left(\frac{\mathrm{d}E}{\mathrm{d}z}\right)_{E_P} \cdot e^{-\alpha z}\mathrm{d}z$$

for construction of a database of the secondary electron emission (k, α), where $\delta(E_P)$ and $(dE/dz)_{E_P}$ are the secondary yield and energy dissipation in depth, respectively, for incident electrons of primary energy, E_P, α is the absorption coefficient of the secondary electron and k the secondary emission coefficient of the specimen. This approach is based on the uses of the theoretical energy dissipation in-depth $(dE/dz)_{E_P}$, and experimental $\delta_{ex}(E_P)$ or a set of δ_m and E_m where δ_m is the maximum secondary yield obtained at primary electron energy E_m. Comparing the theoretical $\delta_{ex}(E_P)$ with the experimental $\delta_{ex}(E_P)$ or a set of δ_m and E_m, one can obtain the best-fit value of α and, then, k.

Since data-sets of δ_m and E_m have been reported for a wide variety of materials so far, the proposed approach enables us to derive the α-and k-values for the materials of practical interest, filling up the deficiency of reliable data on the secondary emission.

This approach has been applied to materials of practical interest and the 1st database of (k, α) is reported in Table 1. The result has revealed that dependencies of both the k- and α-values upon atomic number Z are very close to that of the work function, providing another subject worth while being studied intensively.

1. Introduction

Secondary electron emission was discovered more than a century ago, so many people believed that nothing new to be studied further about the secondary electron emission. However, recently the secondary electron emission has been attracting renewed attention from industry. Particularly, those who are involved in plasma display panel(PDP) manufacturing have been trying to understand quantitatively the secondary electron emission in oxide material such as MgO which has been used as cathode material in the PDP.

An approach which is presented in this seminar is rather simple and practical, but it enables the secondary electron emission to be described quantitatively to meet the strong requirement from the industry.

2. Model

The model of the proposed approach is based on the equation as follows:

$$\delta(E_P) = k\int_0^\infty \left[\frac{dE}{dz}\right]_{E_P} \cdot e^{-\alpha z}dz \quad (1)$$

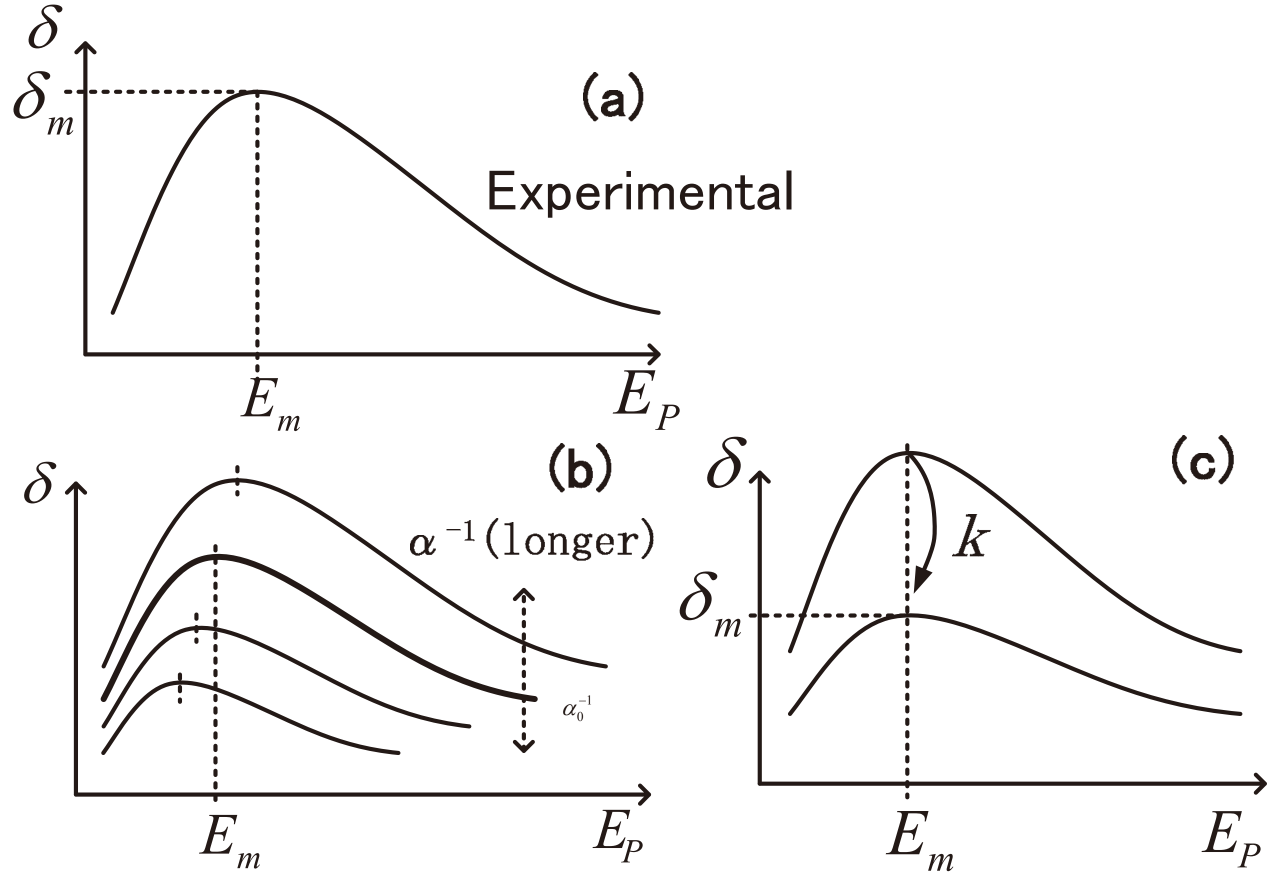


Figure 1 Procedure to derive α - and k -value is experimental data, (b) and (c) are decisions of α and k , respectively.

where $\delta(E_P)$; secondary electron yield for an electron beam impinging on a specimen at primary energy, E_P

k ; secondary electron emission coefficient

α ; absorption coefficient of secondary electrons

$(dE/dz)_{E_P}$; energy dissipation in-depth, z, of incident electrons with primary energy, E_P.

With respect to these physical quantities, (1) experimental data on $\delta(E_P)$ have been reported so far, and (2) $(dE/dz)_{E_P}$ can be obtained from Monte Carlo calculation with considerable accuracy.

The question remained is, therefore, how to obtain the set of (k, α). If the data set of (k, α) is once provided, one can easily describe quantitatively the secondary electron emission for a specimen of any material and any shape, under any boundary conditions of practical use.

3.Procedure to derive *k* and α

A procedure to derive k and α from the experimental $\delta_{ex}(E_P)$ -curve is demonstrated in Fig.1 where a typical $\delta_{ex}(E_P)$-curve is depicted. As primary energy increases, the maximum, δ_m, at primary energy E_P equal to E_m, and then it gradually decreases. There have been reported quite a few experimental measurements on (δ_m, E_m) for number of materials so far.

Concerning the theoretical $\delta_{th}(E_P)$ -curve, $\delta_{th}(E_P)$ are plotted for different α -values by keeping k -value constant (Fig.1 (b)). The both δ_m and E_m of the $\delta_{th}(E_P)$ -curve increase for smaller α -values. This tendency leads us to determining the α -values from the comparison of

Table 1

Database of secondary emission (α_0^{-1}, k) obtained by the proposed approach(1) for materials of practical interest

	α_0^{-1} / nm	k / eV	experiment	
			δ_m	E_m (eV)
Be	1.1	0.017	0.5	200
Mg	1.9	0.012	0.95	300
Al	1.3	0.014	1	300
Si	1	0.024	1.1	250
Ti	0.5	0.046	0.9	280
Fe	0.5	0.048	1.3	400
Co	1.1	0.011	1.2	600
Ni	0.8	0.017	1.3	550
Cu	1.1	0.011	1.3	600
Ga	1.2	0.017	1.55	500
Ge	1.2	0.013	1.15	500
Zr	0.4	0.093	1.1	350
Ag	1.4	0.01	1.5	800
Cd	0.5	0.047	1.1	450
Sn	0.9	0.024	1.35	500
Sb	1.4	0.014	1.3	600
Ba	1.4	0.015	0.8	400
W	0.4	0.07	1.4	650
Pt	0.4	0.086	1.8	700
Au	0.7	0.022	1.4	800
Hg	0.6	0.036	1.3	600
Pb	0.5	0.048	1.1	500
Bi	0.8	0.027	1.2	550
Th	1.3	0.012	1.1	800

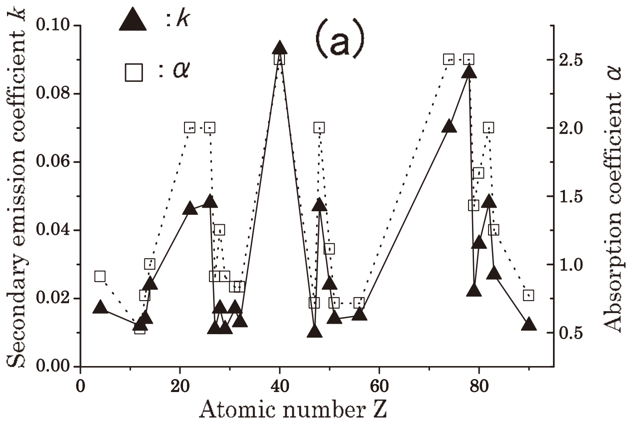
the $\delta_{th}(E_P)$-curve (Fig.1 (b)) with the $\delta_{ex}(E_P)$-curve(Fig.1 (a)), as follows; first, one can obtain the best fit value of α by finding the α-value that leads the E_m-value of the $\delta_{th}(E_P)$-curve to coincide with that of the $\delta_{ex}(E_P)$-curve, as shown in Fig.1 (b). Once the best fit value of α, α_0, is obtained, it is quite easy to obtain the best fit value of k, k_0, by simply comparing the $\delta_{ex}(E_P)$ -curve with $[\delta_{th}(E_P)]_{\alpha_0}$-curve given by

$$\left[\delta_{th}(E_P)\right]_{\alpha_0} = k\int_0^\infty \left[\frac{dE}{dz}\right]_{E_P} \cdot e^{-\alpha z} dz \qquad (2)$$

as depicted Fig.1 (c).

4.Result and Discussion

Table 1 is the first data for the construction of database of (k, α) thus obtained by the procedure mentioned above. It is worthy to note that this database allows us to describe quantitatively the secondary electron emission from the specimen of material listed



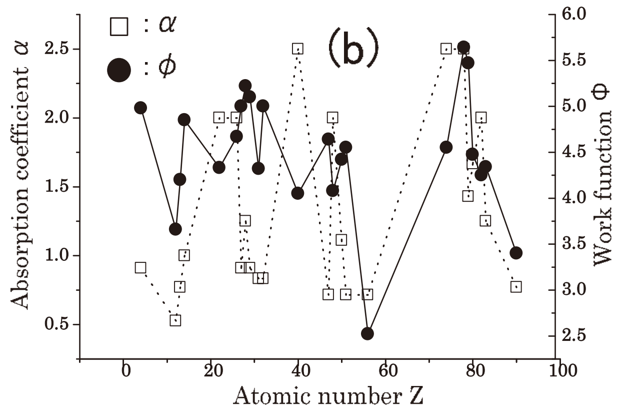


Fig. 2 (a) Correlations of α and k with atomic number, Z and (b) correlations of α and work function Φ with atomic number, Z

in Table 1 for given boundary condition; surface topography , angle of incidence, primary energy , probe size of primary beam, etc.

The k - and α -values are plotted as a function of atomic number, Z in Fig.2 (a). To our surprise, it has been found that the feature shown in Fig.2 (a) bears a close resemblance to that of work function shown in Fig.2 (b). This suggests that both the k and α are such material constants of physical importance, that are closely correlated to the electronic configuration as discussed for the work function.

5. Summary

1. A novel approach is proposed to derive the secondary emission coefficient,*k*, and absorption coefficient, α, for describing the secondary electron yield

$$\delta(E_P) = k\int_0^\infty \left[\frac{dE}{dz}\right]_{E_P} \cdot e^{-\alpha z} dz$$

2. Application of this approach to number of materials of practical interest has led to the 1st database of (k, α). This database enables the secondary electron emission from a specimen of given material to be described quantitatively under various boundary conditions, surface topography, angle of incidence, primary energy , probe size of primary beam, etc.
3. α vs Z-plots and *k* vs Z-plots have revealed that these two plots have a common feature bearing a close resemblance to the work function vs Z-plots. This strongly suggests that both the k and αshould be such physical quantities that are closely correlated to the electronic configuration and, this will be another subject very well worthy to be studied further.

6. Acknowledgement

The present work had been performed for partial fulfilment of doctorate thesis(2) of one of the authors(T.I.)

7. Reference

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