JOURNAL OF THE PHYSICAL SOCIETY OF JAPAN VOL. 17, SUPPLEMENT B-II, 1962
PROCEEDINGS OF INTERNATIONAL CONFERENCE ON MAGNETISM AND CRYSTALLOGRAPHY, 1961, VOL. II

Measurement of Differential Cross Section of 30 kV Electrons for Plasmon Excitation in Al

HIROSHI WATANABE
Hitachi Central Research Laboratory, Kokubunji
Tokyo, Japan

The absolute value of differential cross section $\sigma_1(\theta)$ of 30 kv electrons which have excited a plasmon in Al films was measured by making use of the Möllenstedt type electron velocity analyser. The absolute value decreases with the increase of specimen thickness t due to the effect of multiple scattering. To eliminate the effect of multiple scattering, the value of $\sigma_1(\theta)/t$ at $t=0$ was obtained by extrapolating the film thickness to zero.

The value of differential cross section thus obtained, which is free from the effect of multiple scattering, is compared with the theoretical value given by Ferrell (Phys. Rev. **101** (1956) 554). The agreement is satisfactory.

Ferrell[1] has calculated the differential cross section of electrons which have excited a plasmon in a solid film of unit thickness. The result is given by

$$\sigma_p(\theta)=\frac{d(1/\lambda)}{d\Omega}=\frac{1}{2\pi a_0}\frac{\theta_E}{\theta^2+\theta_E{}^2}G^{-1} \qquad (1)$$

where $d(1/\lambda)$: differential inverse mean free path for one plasmon excitation, $d\Omega$: differential solid angle into which the electrons are scattered, a_0: Bohr radius, $\hbar\omega_p$: plasmon energy, θ_E: $\hbar\omega_p/2E$, θ: scattering angle. G^{-1} represents the reduction ratio of plasmon production as the scattering angle increases[3]. In Fig. 1 G^{-1} is given as a function of scattering angle.

Marton *et al*[2] measured the angular dependence of 24 ev eigen-loss inelastic scattering of 20 kv electrons passing through thin gold films. Their experimental result of scattered intensity vs scattering angle was compared with eq. (1) without G^{-1} factor, and the agreement was less satisfactory. The reason for it was attributed by Ferrell[1] to the incomplete separation of the no-loss beam from the characteristic loss peak, and to the multiple scattering in the film.

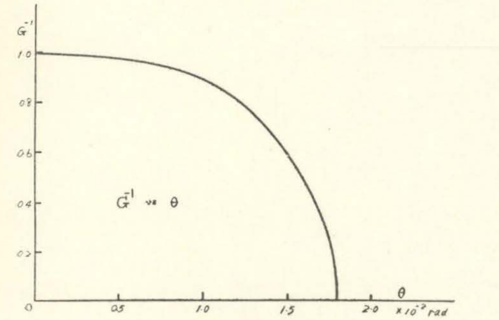

Fig. 1. G^{-1} vs. θ for Al, 30 kv.

In the present experiment the absolute value of differential cross section was measured for the plasmon excitation ($\hbar\omega_p=15$ ev) of 30 kv electrons in Al evaporated films of various thicknesses. The energy spread of the no-loss beam is so small that the 15 ev eigen-loss peak is completely separated. To eliminate the effect of multiple scattering the logarithmic value of $\sigma_1(\theta)/t$ is plotted against the film thickness t. The value of $\sigma_1(\theta)/t$ at $t=0$ is obtained by extrapolating the film thickness to zero, and this extrapolated value is the differential cross section free from the effect of multiple scattering.

Experimental procedures

The ray diagram is schematically shown in Fig. 2. The electrons scattered into the objective aperture are focussed onto the fine slit plane and then the energy is analysed by the analyser lens.

The intensity $I_i(\alpha)$ of electrons scattered into the aperture subtending a semi-angle of α is given by

$$I_i(\alpha)=I_0\int_0^{\alpha}2\pi\sigma_i(\theta)\sin\theta d\theta \qquad (2)$$

I_0: intensity of the incident beam,
$\sigma_i(\theta)$: differential cross section of scattering process denoted by i,
$i=0, 1, 2, \cdots$: elastic process, one-plasmon excitation, two-plasmon excitation$\cdots$.

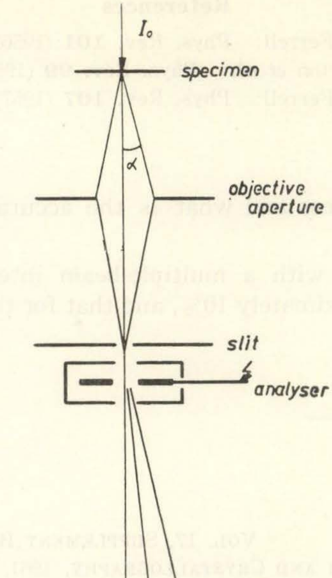

Fig. 2.

The energy loss spectra for evaporated Al films of different thicknesses are recorded on photographic plates, and the relative intensities of I_0 and $I_i(\alpha)$ are photometrically measured for various aperture angles α. $\sigma_i(\theta)$ is obtained by graphical differentiation of $I_i(\alpha)/I_0$ curve by α as follows;

$$\sigma_i(\theta)=\frac{1}{2\pi\sin\theta}\times\frac{d}{d\alpha}\left(\frac{I_i(\alpha)}{I_0}\right) \quad (3)$$

The experimental value of $\sigma_1(\theta)$ depends upon the thickness of the specimen film. The dependence is empirically expressed by

$$\sigma_1(\theta)=\sigma_p(\theta)te^{-\mu t} \quad (4)$$

where μ is a constant. In this experiment $\sigma_1(\theta)/t$ is plotted against t, and the value of $\sigma_1(\theta)/t$ at $t=0$ is compared with $\sigma_p(\theta)$ in eq. (1).

Experimental result and discussion

Fig. 3 shows the $\sigma_1(\theta)$. $(\sigma_1(\theta)/nt)_{t=0}$ vs. θ is compared with eq. (1) in Fig. 4, where n means the number of Al atoms in unit volume.

The theoretical curve without the G^{-1}-factor is somewhat higher than the experimental one at large angles. This discrepancy is attributed to the G^{-1}-factor. The theoretical curve including the G^{-1} correction is given as the dashed line in Fig. 4. The agreement is satisfactory.

The discussion on $\sigma_2(\theta)$ will be given in the future.

The author expresses his thanks to members of the discussion group of electron

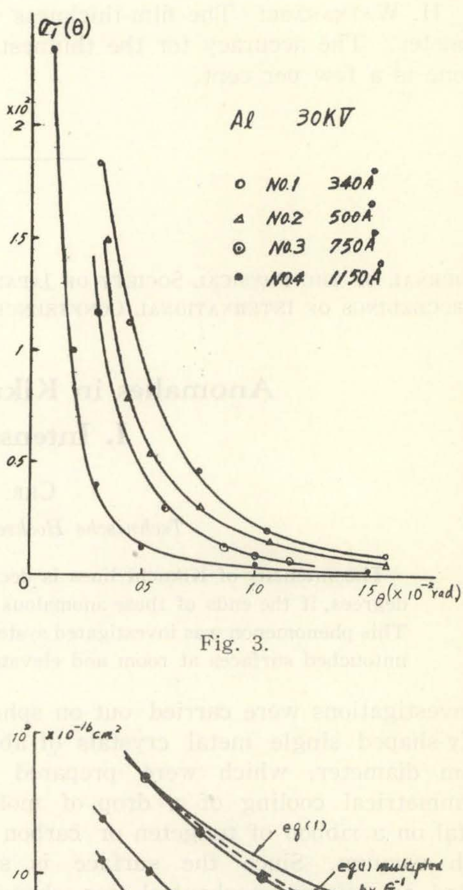

Fig. 3.

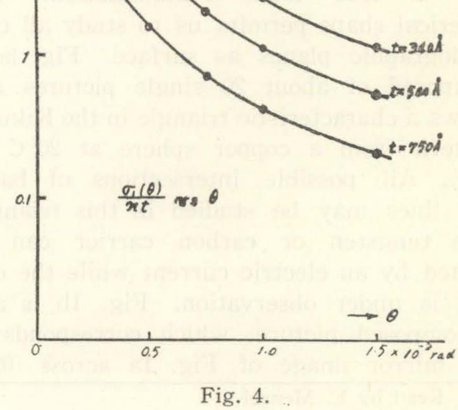

Fig. 4.

energy loss problem for helpful remarks. He is indebted especially to Prof. Fujimoto of University of Tokyo for his valuable suggestions.

References

1 R. A. Ferrell: Phys. Rev. **101** (1956) 554.
2 L. Marton *et al.*: Phys. Rev. **99** (1955) 495.
3 R. A. Ferrell: Phys. Rev. **107** (1957) 450.

DISCUSSION

L. MARTON: How do you measure the film thickness and what is the accuracy of your thickness measurements?

H. WATNANABE: The film thickness was measured with a multiple-beam interferometer. The accuracy for the thinnest film is approximately 10%, and that for thicker one is a few per cent.

JOURNAL OF THE PHYSICAL SOCIETY OF JAPAN VOL. 17, SUPPLEMENT B-II, 1962
PROCEEDINGS OF INTERNATIONAL CONFERENCE ON MAGNETISM AND CRYSTALLOGRAPHY, 1961, VOL. II

Anomalies in Kikuchi Reflection Diagrams
I. Intensity Anomalies*

CHR. MENZEL-KOPP
Technische Hochschule, Darmstadt, Germany

The intensity of Kikuchi lines is decreased or increased in an angular region up to 2 degrees, if the ends of these anomalous regions are directions of simultaneous reflections. This phenomenon was investigated systematically on copper single crystal spheres having untouched surfaces at room and elevated temperatures.

Investigations were carried out on spherically-shaped single metal crystals of about 5 mm diameter, which were prepared by asymmetrical cooling of a drop of molten metal on a ribbon of tungeten or carbon in high vacuum. Since the surface is subjected to neither mechanical nor chemical treatments, it has high crystalline quality and is free from contamination. The spherical shape permits us to study all crystallographic planes as surface. Fig. la is composed of about 20 single pictures and shows a characteristic triangle in the Kikuchi pattern from a copper sphere at 20°C (60 kev). All possible intersections of bands and lines may be studied in this triangle. The tungsten or carbon carrier can be heated by an electric current while the crystal is under observation. Fig. 1b is also a composed picture, which corresponds to the mirror image of Fig. la across (022), taken at about 900°C. The Kikuchi-lines of higher indices are relatively less pronounced than those of lower indices. The diagram becomes simpler without losing sharpness. Both advantages, the spherical shape and the observation at elevated temperature, were utilized in the systematic investigation of the appearance of intensity anomalies in the Kikuchi reflection-diagram.

By intensity anomalies, we mean the decrease or increase in intensity of reflection lines in a large range of angle up to 2°. Fig. 2a~d show four examples of decrease, Fig. 2e one of increase of Kikuchi-lines in a copper reflection diagram. This phenomenon of decrease was first observed in transmission with a convergent electron beam from PbI_2[2), and then studied together with the increase in greater detail on mica and explained as the effect of simultaneous reflection[3)]. This was later confirmed for PbI_2 and interpreted in terms of the dispersion surface[4)]. In reflec-

* Read by E. Menzel.