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*Work supported in part by the U. S. Army Research Office, Durham, North Carolina.

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OPTICAL CONSTANTS OF ALUMINUM IN VACUUM ULTRAVIOLET

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(Received July 16, 1962)

We have obtained the values of the frequency-dependent complex dielectric constant $\epsilon(\omega)$ of aluminum in the photon energy region of 12-17 eV from the characteristic electron energy loss spectra.[1] The values were obtained by utilizing the correlation between the intensity of the electron absorption spectrum of a substance with its optical properties[1,2] from recently obtained inelastic electron scattering data.[3] The importance of this method, applied for the first time in this investigation, is that in this photon energy region the usual optical methods of obtaining the frequency-dependent complex dielectric constant are fraught with many difficulties such as inconvenient light sources, vacuum problems, and surface effects, etc.[4] An advantage of the inelastic electron scattering experiments is that one can in most cases separate the surface effects from the bulk effects by varying the thickness of the material to be studied and/or varying the incident energy of the electrons. The electron energy absorption spectrum arising from the interaction of the incident electrons with the "bulk" of the medium is characterized by $\mathrm{Im}[1/\epsilon^*(\omega)]$, where $\epsilon^*(\omega)$ is the complex conjugate of the frequency-dependent $\epsilon(\omega)$. The Kronig-Kramers[5] dispersion relations were then applied to the electron absorption spectrum, which ranged from 11.1 to 18.3 eV, to calculate $\mathrm{Re}[1/\epsilon^*(\omega)]$ and, hence, $\epsilon(\omega)$ is obtained. The input data were scaled by means of the sum rule,[6] $\int_0^\infty \omega\,\mathrm{Im}[1/\epsilon^*(\omega)]d\omega = (\pi/2)\omega_p^2$, where the plasma frequency ω_p is related to the number of electrons in the medium available to interact with the incident electron beam. In the integration, we take the integrand to be vanishingly small beyond the recorded absorption region. An estimate[7] of the influence of neglecting absorption processes outside the recorded absorption spectrum was made by adding a hypothetical contribution,

$$\int_{\Delta E_0-\delta}^{\Delta E_0+\delta} \omega\,\mathrm{Im}\frac{1}{\epsilon^*(\omega)}d\omega = f\int_{\Delta E_1}^{\Delta E_2} \omega\,\mathrm{Im}\frac{1}{\epsilon^*(\omega)}d\omega,$$

to the sum rule, where ΔE_1 and ΔE_2 are the limits of the recorded absorption spectrum, and $f=5\%$ at $\Delta E_0 = 7$ eV and $f=10\%$ at $\Delta E_0 = 30$ eV. Figure 1 shows the calculated optical properties with and without the hypothetical contribution added separately to the Kronig-Kramers integration.

In this investigation, we found that the optical constants of aluminum can be approximated by a two-parameter Drude-like model (solid curve in Fig. 1) with N, the number of "free" electrons per atom, as 2.6 and τ, the relaxation time, as 1.1×10^{-15} sec. The density N was calculated from $\omega_p^2 = 4\pi e^2N/m$, where the plasma frequency ω_p was approximated as the value of ω at the inelastic electron absorption peak and m is the free electron mass. The relaxation time τ was obtained from the integrated half-width of the absorption line. These two parameters compare quite favorably with the values obtained from optical data[8] in the region between 2200 Å to 5 μ, namely, $N = 2.4$, $\tau = 1.2 \times 10^{-15}$ sec, for which a Drude-type model was used also.

A more complete discussion of the results and a description of the methods used to treat the data, including procedures used to unfold the natural absorption profile, will be communicated elsewhere.

The authors wish to thank Dr. L. Marton, Chief, Electron Physics Section, for his encouragement; Dr. Howland Fowler and Mr. Nils Swanson for permission to use their unpublished data; and Mr. Benjamin Furst for providing the computational program for the unfolding procedure.

*This work was done during the tenure of a National Research Council-National Bureau of Standards Research Fellowship grant.

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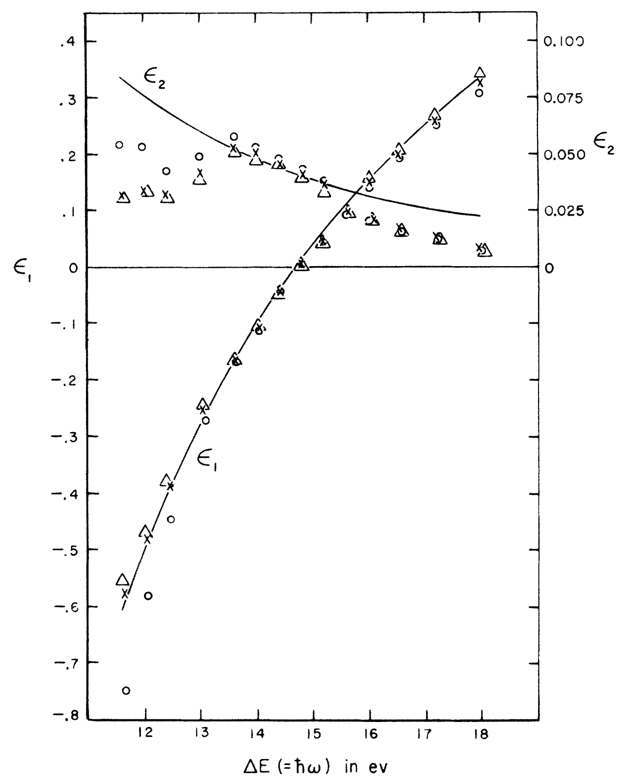

FIG. 1. The real part ϵ_1 and the imaginary part ϵ_2 of the complex dielectric constant for aluminum; ×, from the experimental electron energy loss absorption spectrum; o, from the experimental electron energy loss absorption spectrum plus the 5% contribution at 7 eV; Δ, from the experimental electron energy loss absorption spectrum plus the 10% contribution at 30 eV; ——, the Drude-type model $\epsilon_1 = 1 - \omega_p^2\tau^2/(1+\omega^2\tau^2)$, and $\epsilon_2 = (1/\omega\tau)[\omega_p^2\tau^2/(1+\omega^2\tau^2)]$, with $N = 2.6$ and $\tau = 1.1 \times 10^{-15}$ sec.

FISSION-FRAGMENT TRACKS IN METAL AND OXIDE FILMS*

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Transmission electron microscope studies on the interaction of energetic fission fragments with thin films have yielded some interesting results. The outstanding feature observed in fission-fragment-irradiated thin films[1-4] has been the appearance of tracks which are indicative of the removal of material from a region of the order of 100 Å around the path of the fission fragment. The tracks are thought to be the result of localized heating and vaporization, but it is not understood why the lattice reaches a high enough temperature to cause vaporization. The present study presents a model of track formation and experimental evidence based on observations on Au and Al.

Single crystalline and polycrystalline (100Å average grain size) Au films of approximately 50Å thickness and polycrystalline (100Å average grain size) Al films, 20 and 50Å thick, were irradiated with fission fragments from a U-foil.