

OPTICAL CONSTANTS AND ELECTRONIC PARAMETERS OF NI

By

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Abstract

The optical constants n and k of Nickel have been measured in the wavelength range $0.4-2.5 \mu$ by analyzing the elliptically polarized reflected light. The electronic parameters such as the density N , relaxation time τ and the effective mass m^* of free electrons are computed giving a Fermi energy E_f of 1.56 e.v. and D.C. conductivity of 0.78×10^{16} e.s.u. The threshold wavelength for electronic inter-band transition is found to be 0.85μ .

Introduction

The electronic parameters of a metal are related to its optical constants, the refractive index n and the absorption coefficient k , in the following dispersion equations, based on the free electron theory (1-3).

$$-\xi'' = K^2 - n^2 = -1 + \frac{4\pi N e^2}{m^* \omega^2} = -1 + \frac{\sigma_0 H}{\pi c^2} \lambda^2 \quad (1)$$

$$\xi' = 2nK = \frac{4\pi\sigma}{\omega} = \frac{(4\pi N e^2/m^*) H}{\omega^3} = \frac{\sigma_0 H^2}{2\pi^2 C^3} \lambda^3 \dots \quad (2)$$

where ξ' and ξ'' are the real and imaginary parts of the dielectric constant of the metal at frequency ω of light used, N is the free electron density, e the electronic charge, m^* the effective mass of the electron and H its collision frequency defined as the reciprocal of its relaxation time τ . σ and σ_0 are the A-C and D-C conductivities of the metal respectively, where $\sigma = \frac{eK\omega}{2\pi}$ and $\sigma_0 = \frac{Ne^2\tau}{m^*}$.

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Experimental Details :

The mirror like surface of opaque nickel film was prepared under vacuum of 10^{-5} mm Hg using spectroscopically pure Ni wires*. The optical measurements were carried out in air at room temperature using Battiés method.(4) The description of the apparatus and method used is given by the author in previous work.(5-9)

Results and Discussion :

The present results of the optical constants n and k of Ni in the wavelength range $0.4 - 2.5 \mu$ are given in table (1) and represented graphically in fig. (1) with data of previous authors (10-16) for comparison.

TABLE 1

λ (μ)	n	k	λ (μ)	n	k
0.40	2.00	2.09	1.50	3.61	6.31
0.45	2.05	2.33	1.55	3.65	6.42
0.50	2.10	2.55	1.60	3.70	6.55
0.55	2.17	2.77	1.65	3.74	6.69
0.60	2.24	3.02	1.70	3.78	6.80
0.65	2.33	3.28	1.75	3.83	6.92
0.70	2.43	3.54	1.80	3.88	7.06
0.75	2.51	3.77	1.85	3.94	7.19
0.80	2.63	3.99	1.90	3.99	7.33
0.85	2.73	4.31	1.95	4.05	7.47
0.90	2.80	4.50	2.00	4.12	7.62
0.95	2.86	4.65	2.05	4.17	7.76
1.00	2.92	4.80	2.10	4.23	7.90
1.05	2.99	4.95	2.15	4.28	8.05
1.10	3.06	5.11	2.20	4.34	8.20
1.15	3.14	5.28	2.25	4.42	8.35
1.20	3.24	5.46	2.30	4.47	8.49
1.25	3.31	5.61	2.35	4.53	8.64
1.30	3.37	5.74	2.40	4.57	8.77
1.35	3.42	5.88	2.45	4.67	8.94
1.40	3.48	6.02	2.50	4.71	9.08
1.45	3.54	6.16			

* From Johnson and Matthey's Company, London.

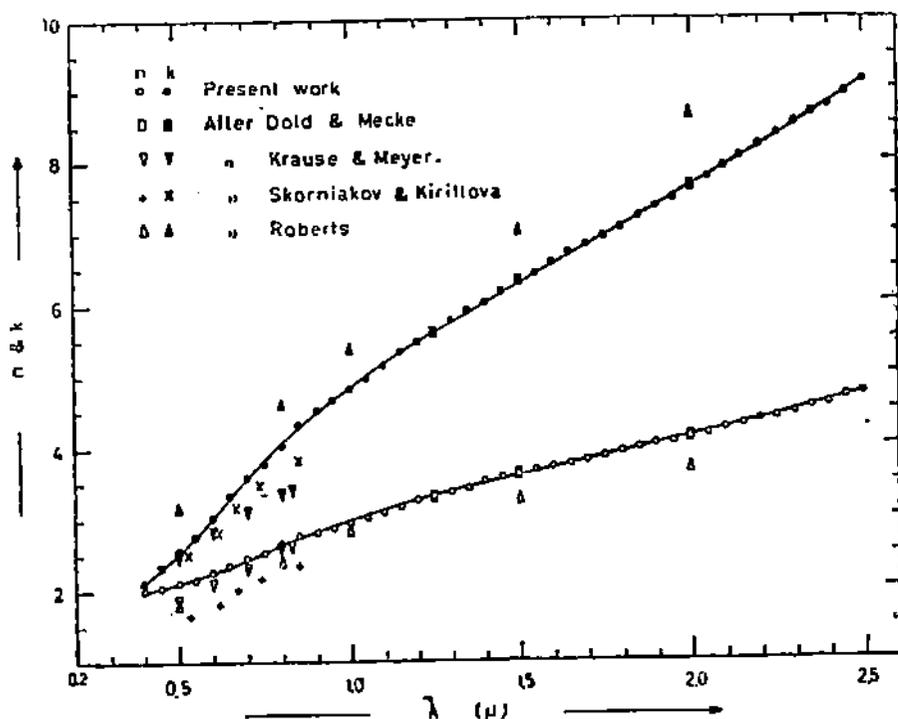


Fig. 1 - The refractive index (n) and absorption coefficient (k) versus wave length (λ).

Fig. (2) represents the relation between $(k^2 - n^2)$ and λ^2 giving a straight line according to eq. (1). Considering only the slope of the straight line in the infrared region and taking $m^* = 9.1 \cdot 10^{-28}$ gm, the number of free electrons/cm³ can be calculated giving a value of 0.96×10^{23} electrons/cm³ corresponding to a Fermi energy $E_f = 1.56$ e.v., effective number of free electron per atom $n_e = 0.11$, and an optical effective mass $m^*/m = 9.09$. This may be due to the existence of different types of free electrons of different mass and mobility. The electronic structure of Ni has a total 10 electrons in the 3d and 4s states which may overlap, thus the value of n_e refers to s-electrons since the contribution of the d-electrons to relaxation is negligible.

The effect of the interband transition appears in Fig. (3) where ϵ'' / λ is represented against λ giving a threshold wave length of 0.85μ for interband transition. Theoretical values of ϵ'' / λ are given also for comparison showing that the present results can not be explained by a single free electron term but it is necessary to involve several types of free electrons as expected by Robert⁽¹⁶⁾.

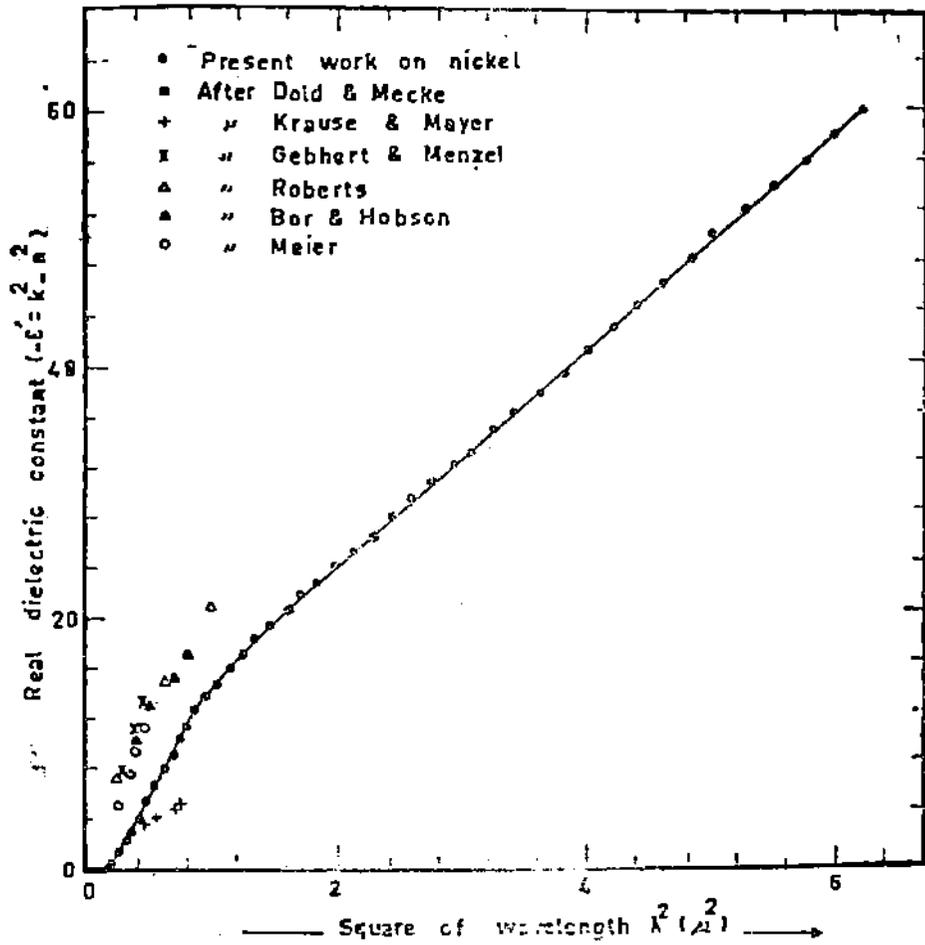


Fig. 2 — The real dielectric constant (ϵ') versus square of wavelength (λ^2) together with data of previous authors.

The Dispersion curve for the conductivity σ is represented in fig. (4) showing that σ is not a critical function of λ . This may be due to the small value of n_{hr} above the transition region. Also this curve supports the idea that there are three different types of free electron in Ni.

The relation between $(-\xi' + 1)$ and ξ' / λ is represented in fig. (5) giving a straight line according to eq. (1) and eq. (2). From the slope of the straight line taken for wavelengths far from the transition region, i.e. $\lambda > 1.7$, the value of the relaxation time τ is computed giving a value of 3.2×10^{-15} sec. Fig. (5) shows that the straight line does not pass through the origin, which agrees with

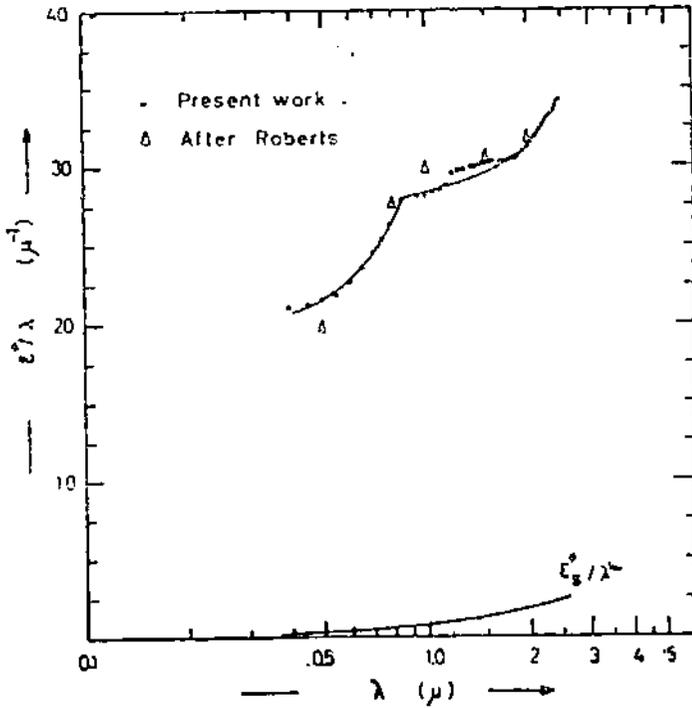


Fig. 3 $\epsilon''\lambda$ versus λ .

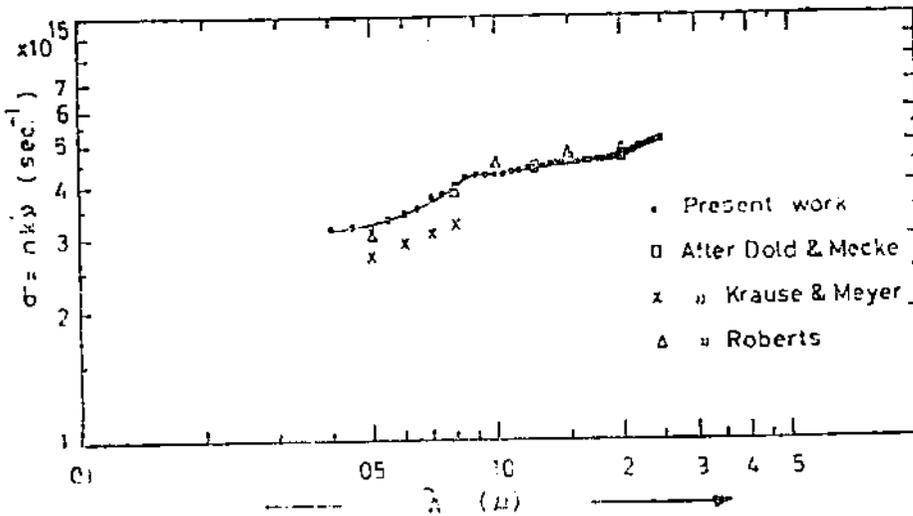


Fig. 4 Dispersion curve for the conductivity σ

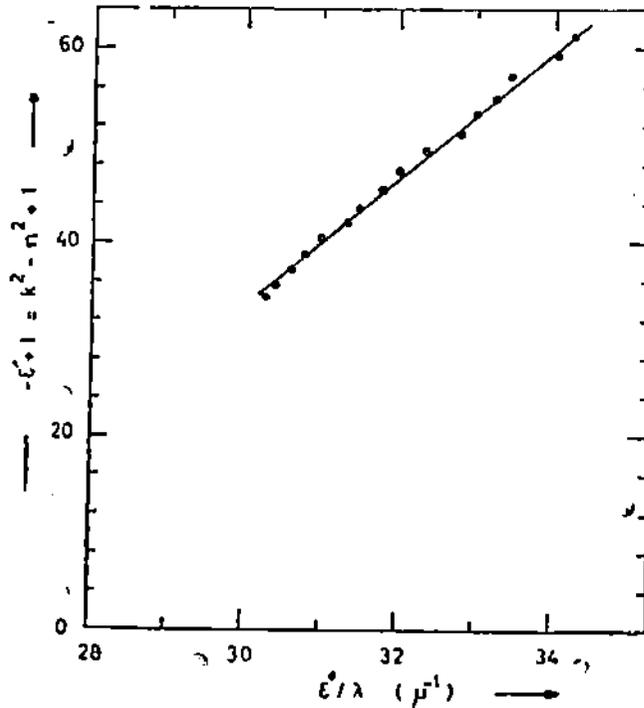


Fig. 5 -- The argand diagram.

Beatti and Conn (17). Since $\sigma_0 = \frac{Ne^2\tau}{m^*}$, the value of the D.C. conductivity σ_0 is calculated using the present values of τ and N giving $\sigma_0 = 0.78 \times 10^{10}$ e.s.u. The microscopic parameters N , n_c , E_f , τ , σ_0 and m^*/m obtained in the present work are given in table (2) with data of previous authors for comparison.

Author	$N \times 10^{-22}$ cm ⁻³	$n_c =$	E_f e.v.	$\tau \times 10^{15}$ sec	$\sigma_0 \times 10^{-10}$ e.s. u.	m^*/m
Present work	0.96	0.11	1.56	3.23	0.78	9.09
Dold & Mecke (10)	1.37	0.15	2.10	8.30	2.83	6.64
Shklyarevskii (18)	0.40	0.045	0.94	7.20	0.76	22.75
Beattie & Conn (17)	1.30	0.14	1.90	10.20	3.16	7.00
»	0.82	0.09		5.0	1.02	11.98

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