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 μ 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 x 10^{16} e.s.u. The threshold wavelength for electronic interband transition is found to be 0.85 μ.

Introduction

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

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

$$\xi' = 2 n K = \frac{4 \pi \sigma}{\omega} = \frac{(4 \pi N e^2/m^*) H}{\omega^3} = \frac{\sigma_0 H^2}{2\pi^2 C^3} \lambda^3 \ldots \qquad (2)$$

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_n are the A-C and D-C conductivities of the metal respectively, where $\sigma = \frac{Kω}{2\pi}$ and $\sigma_n = \frac{Ne^2\tau}{m^*}$

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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 opitcal 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 μ are given in table (1) and represented graphically in fig. (1) with data of previous authors (10-15) 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	5.43	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			

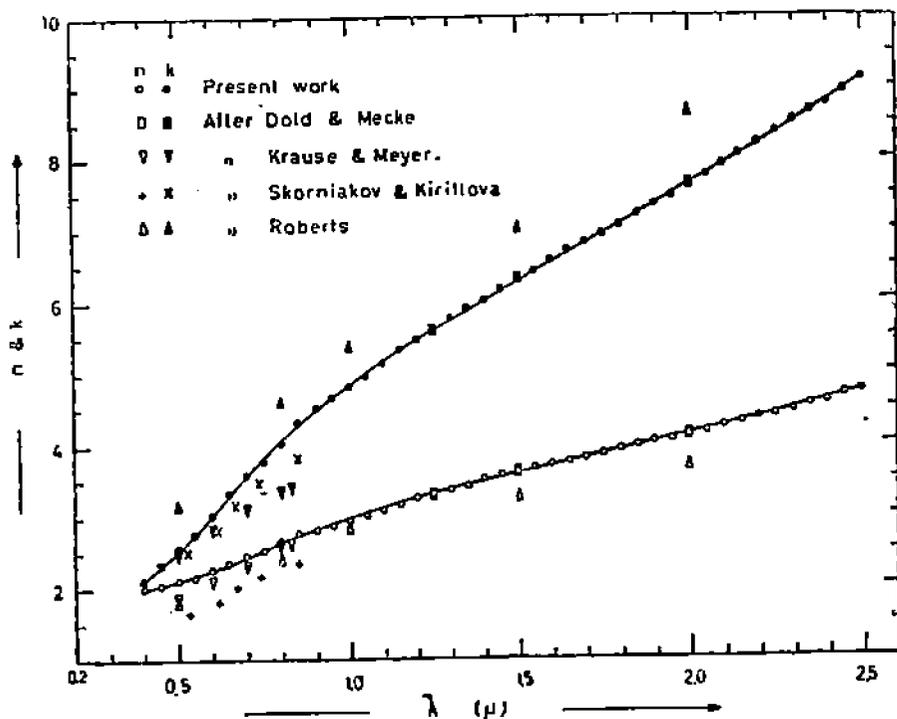* From Johnson and Mattey's Company, London.

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^{22} 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 optiacl 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 $\varepsilon^{\cdot}/\lambda$ is represented against λ giving a threshold wave length of 0.85 μ for interband transition. Theoretical values of $\varepsilon^{\cdot}/\lambda$ 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].
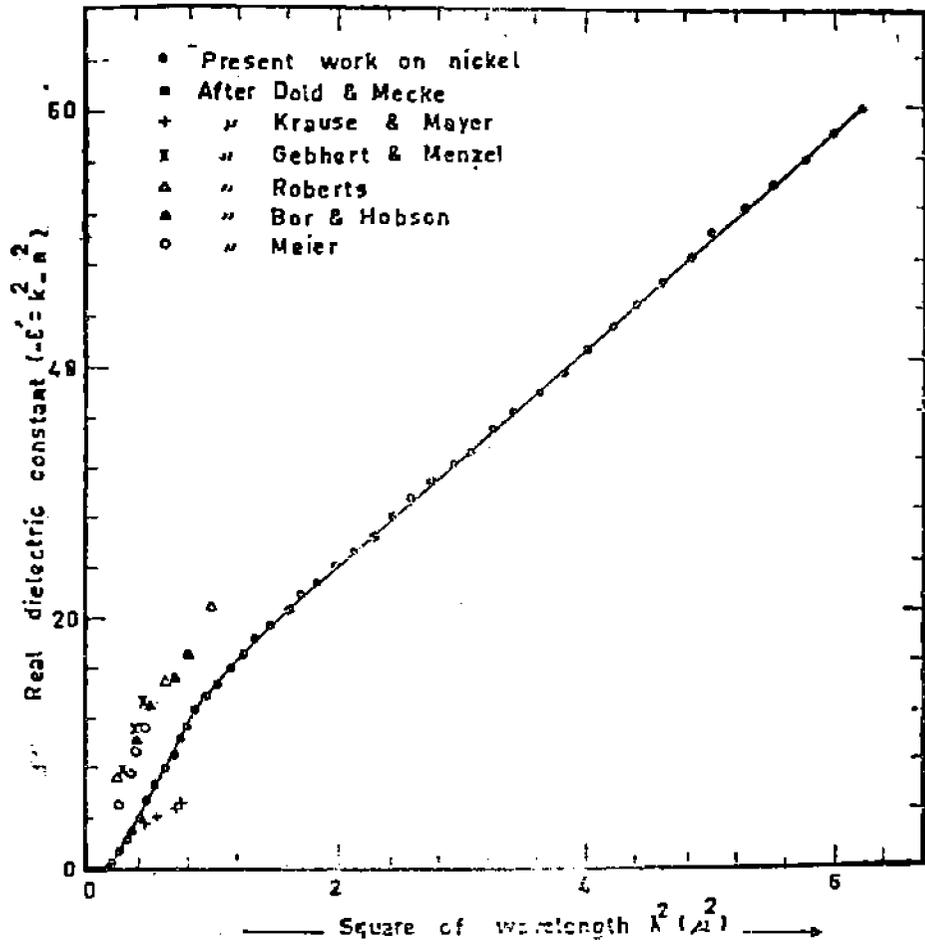
Fig. 2 — The real dielectric constant (ϵ') versus square of wavelength (λ^2) together with data of previous authors.

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 (— ξ' + ·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. λ > 1.7, the value of the relaxation time is computed giving a value of 3.2 x 10⁻¹⁵ sec. Fig. (5) shows that the straight line does not pass through the origin, which agrees with
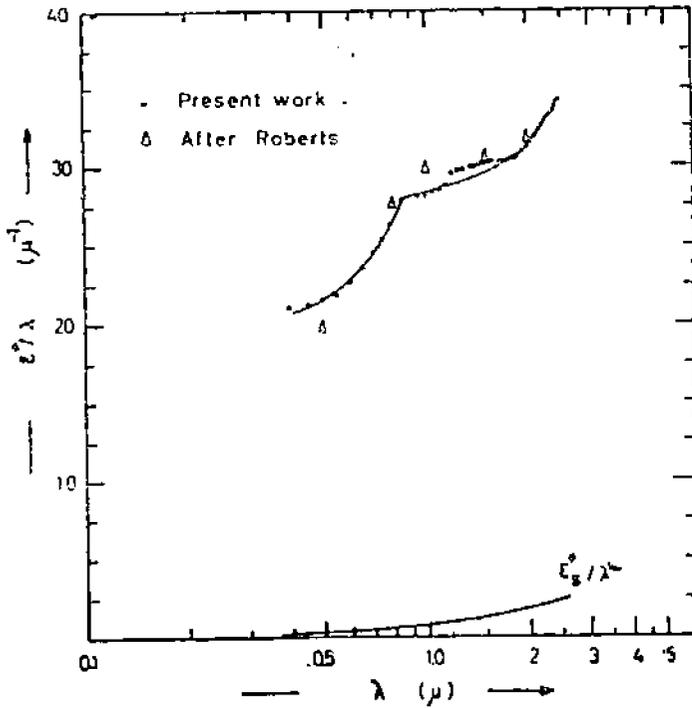
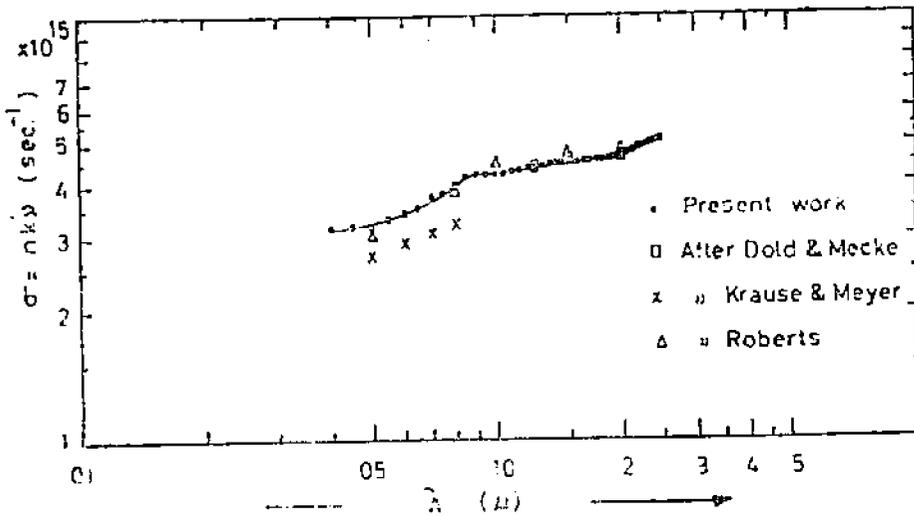Fig. 3 ε'' / λ.   versus λ.

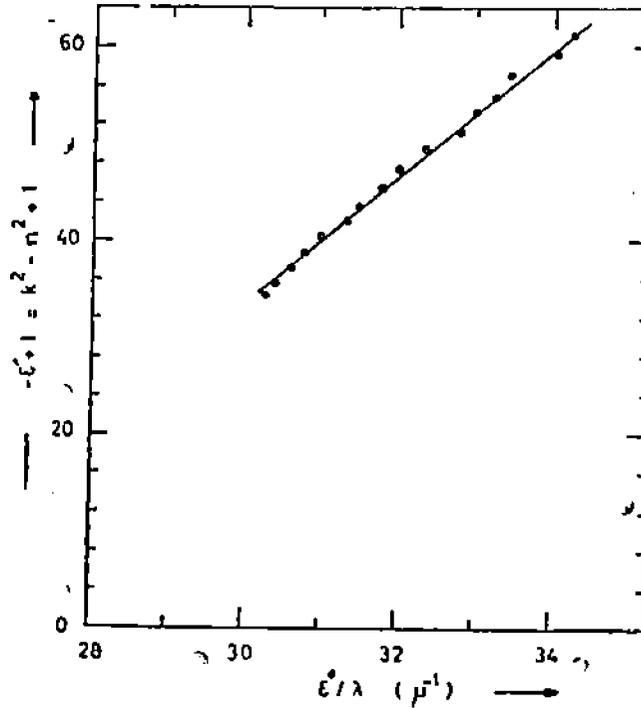Fig. 4   Dispersion curve for the conductivity σ

Fig. 5 -- The argand diagram.

Beatti and Conn ([17]). Since $\sigma_0 = \dfrac{Ne^2\tau}{m^*}$, 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_s and m*/m obtained in the present work are given in table (2) with data of previous authors for comparison.

Author	N x 10⁻²² cm⁻³	$n_c =$	F_f e.v.	τ x 10¹⁵ sec	σ_0 x 10⁻¹⁶ 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	2.88	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

Acknowledgement :

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