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Refraction Index Measurements on AlN Single Crystals

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The refraction index of aluminium nitride has been determined from transmittivity measurements of plane-parallel single crystal plates in the spectral region from 2200 to 6000 Å. AlN crystals were prepared by direct reaction of aluminium vapour with nitrogen at temperatures of 1900 to 2000 °C (1). Monocrystalline halves of twins of deltoid shape with the twinning axis [1010] were used for the measurements (Fig. 1). The c-axis was in the crystal plane and parallel to the longer deltoid edge. The crystal area was 0.5 to 2 mm^2, the thickness 2 to 4 mm. The lattice parameters of the crystals ($a = (3.08 \pm 0.04)$ Å, $c = (4.93 \pm 0.06)$ Å), determined by the method of crystal rotation, agreed with published data (2 to 5).

The transmittivity of the samples has been measured by a double-ray spectrophotometer CF-4, a set of molten quartz plates operating at the Brewster angle was used as polariser. The refraction index has been calculated from the relation which holds for the transmittivity maxima (6)

$$2\,nd = N\lambda\,, \qquad (1)$$

where n is the refraction index, d the sample thickness, and N the interference order. The interference order was determined graphically. In the region where the refraction index is weakly dependent on λ ($\lambda > 4500$ Å) the dependence of N on $\frac{1}{\lambda}$ is practically linear, and in the case of sufficiently thin samples N may be determined precisely from the intersection of this line with the y-axis.

The precision of determining the refraction index was determined by the precision of the thickness measurement. Repeated light- and dark-field microscopic measurements (magnification 900 x) gave the thickness with an error of about 3 %. To eliminate a possible systematic error the shift of interference transmittivity maxima with variations of the incidence angle was also used for the thickness measurement. If the transmittivity maximum of the N-th order is obtained with perpendicular incidence at a wavelength of λ_0 and for incidence at an angle of α for the same order at a wavelength of λ_1, then we may determine the thickness from the interference maximum shift $\Delta\lambda = \lambda_0 - \lambda_1$ according to the formula

$$d^2 = \frac{N^2(\lambda_0+\lambda_1)\Delta\lambda}{4\sin^2\alpha - 8n\left|\frac{\partial n}{\partial\lambda}\right|\Delta\lambda} . \qquad (2)$$

The correctional term ($8\,n\left|\frac{\partial n}{\partial\lambda}\right|\Delta\lambda$) may only be neglected in the region where n depends only slightly on wavelength, its magnitude may be determined graphically. The sample thickness determined by means of this method agreed well with the thickness determined microscopically.

The refraction index for four samples for both polarisations, calculated from relation (1), is shown in Fig. 2. The refraction index of AlN for the line of the Na doublet ($\lambda \approx 5890$ Å) has been measured by means of the immersion method by Lagrenaudie (8) ($n_o = 2.00 \pm 0.06$; $n_e = 2.18 \pm 0.06$) and by Kohn, Cotter, and Potter (5) ($n_o = 2.13 \pm 0.02$; $n_e = 2.20 \pm 0.02$). Our measurements give somewhat higher values for this wavelength ($n_o = 2.17 \pm 0.05$; $n_e = 2.22 \pm 0.05$).

To check our data, we have estimated the magnitude of the refraction index in the region of zero absorption from the ratio of the intensities in the transmittivity maximum and minimum of the sample. The following relation holds here (6):

$$\frac{T_{max}}{T_{min}} = \left(\frac{n^2+1}{2n}\right)^2 \qquad (3)$$

for a plane-parallel sample and zero slit width. We have obtained for $\lambda \approx 4750$ Å from the dependence of this ratio on slit width for a perfectly plane-parallel sample, by extrapolating to zero slit width,

$$n_o \in (2.17 \text{ to } 2.20),$$
$$n_e \in (2.23 \text{ to } 2.26).$$

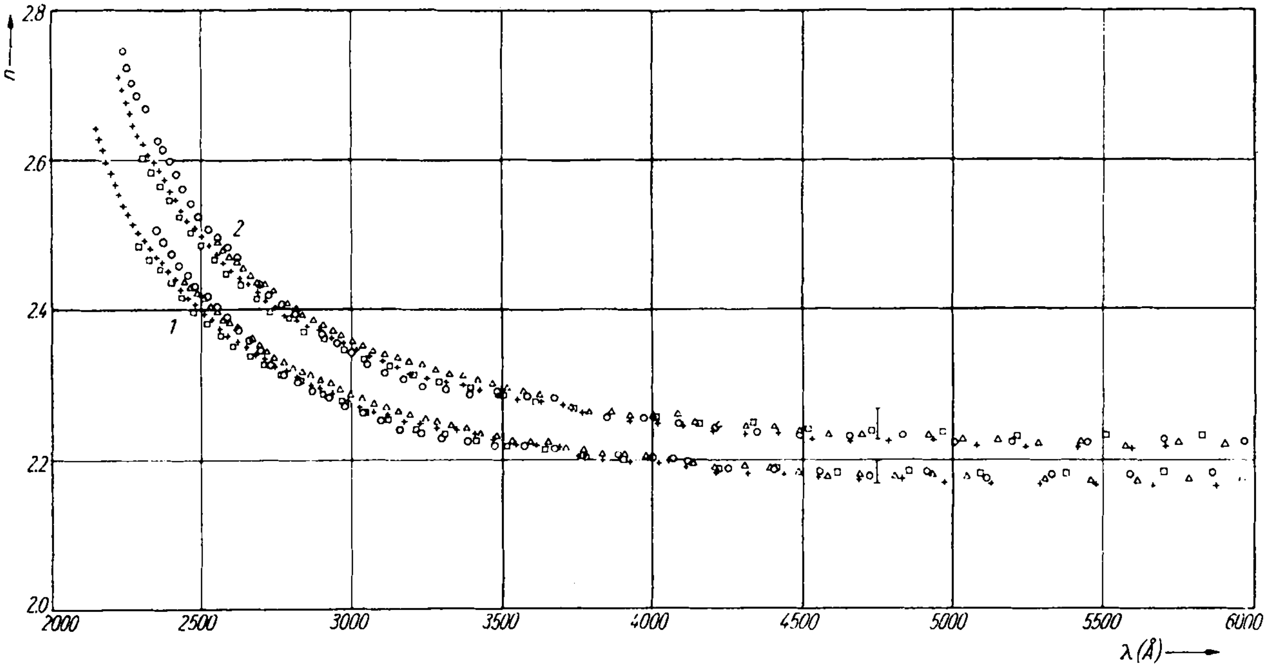

Fig. 2. Spectral dependence of the refraction index of AlN
1 - $\mathfrak{E} \perp c$, ordinary ray (n_o), 2 - $\mathfrak{E} \parallel c$, extraordinary ray (n_e)

These intervals are also shown in Fig. 2. Relation (3) gives rather a lower refraction index, since any deviation from plane-parallelity or imperfection of polarisation will decrease this ratio. This estimate agrees with our measurements. The lower value of the refraction index, given in (5, 7, 8) may be caused by a different content of impurities (mainly oxygen) in the samples measured. A comparison of the refractive index of AlN with corresponding values for isoelectronic substances, α-SiC (n = 2.65) (9) and BP (n = 3 to 3.5) (10), shows that among these substances AlN has the most ionic character.

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