B6, 2001

1 Define anisotropy

A material is said to be anisotropic with regard to a given physical property if the value of this property depends on the direction along which it is measured.

2 Neumann's principle

This principles states that the symmetry of a physical property must include the symmetry elements of the point group of the crystal; it can be higher but never lower.

3 Light propagation in zircon

We consider the propagation of light normal to (013) in zircon. The refractive indices are $n_o = 1.923$ and $n_e = 1.967$.

The zircon is tetragonal, *ie* shows uniaxial indicatrix. The two polarisation

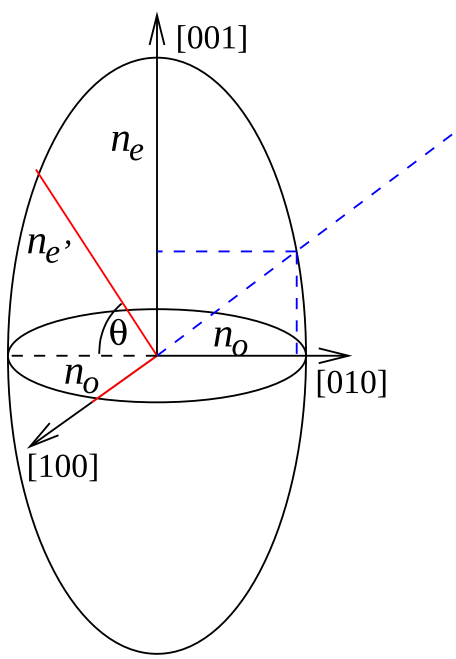

Figure 1: The indicatrix for zircon showing the light direction (blue) and the corresponding permitted vibration directions (red).

directions $[uvw]$ must belong to (013), *ie* [100] and $[0\bar{3}1]$.

Clearly, the index associated with [100] is n_o. We calculate $n_{e'}$, using θ as defined in figure 1: in the ellipse defined by the axis $y//[010]$ and $z//[001]$, $n_{e'}$ has coordinates:

$$y = n_{e'} \cos\theta \quad (1)$$

$$z = n_{e'} \sin\theta \quad (2)$$

The ellipse has for equation:

$$\frac{y^2}{{n_o}^2} + \frac{z^2}{{n_e}^2} = 1$$

so $n_{e'}$ verifies:

$$\frac{(n_{e'} \cos\theta)^2}{{n_o}^2} + \frac{(n_{e'} \sin\theta)^2}{{n_e}^2} = 1$$

Numerical solution: $\theta = 16.80^o$, $n_{e'} = 1.928$.

We therefore have as permitted directions, and indices:

$$[100]: \quad n_o = 1.923$$

$$[0\bar{3}1]: \quad n_{e'} = 1.928$$

The retardation to obtain yellow is given as being 350 nm. For the light propagating along $[0\bar{3}1]$, the birefringence is:

$$\Delta n = 5 \times 10^{-3}$$

so that the required thickness is:

$$t = \frac{350 \times 10^{-9}}{5 \times 10^{-3}} = 70 \times 10^{-6}\,\text{m} = 70\,\mu\text{m}$$

When using cross-polarisers, no light can pass through the analyser if it remains entirely in the direction of the polariser. If we consider a monochromatic light, this is the case when the retardation is an integer number of times the wavelength λ (equivalent to a phase change of 2π. In white light, for a given retardation (*i.e.* thickness), the component whose wavelength is an integer number of times the retardation is blocked by the analyser as it undergoes no net change in polarisation. It is therefore subtracted from the white light, to produce complementary colours. Yellow is the first to appear as it corresponds to the subtraction of violet (short wavelength).