A RATIONAL EVALUATION OF FIBRE TEXTURES OF THIN SOLID FILMS FROM ELECTRON DIFFRACTION PATTERNS

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A simple algebraic criterion based on reciprocal lattice geometry was established. It allows a straightforward construction of the distribution of intensity peaks on an electron diffraction pattern along layer lines associated with any crystallographic direction. It can be used to determine the fibre texture axis in materials composed of crystals of arbitrary symmetry. The method was applied to the determination of the fibre texture of thin films of PbO.

INTRODUCTION

The anisotropy of crystals influences many physical and mechanical properties of polycrystalline materials with non-uniform distribution of the orientation of their crystallites. X-ray, electron, and neutron diffraction methods are mostly employed for the preferred orientation (or texture) investigations.

A very common type of preferred orientation is the so-called fibre texture characterised by the alignment of crystals with one or several crystallographic directions parallel to some important direction within the sample, whereas all other directions have random azimuthal distribution around this axis. The fibre axes here are the wire axis, the temperature gradient or the normal to the surface of electrodeposited or of thin solid film, respectively [1]. The direct beam perpendicular to the texture axis gives rise to the diffraction pattern similar to the single crystal rotation photograph, i.e. the Debye rings have intensity peaks along layer lines normal to the fibre axis. The sharpness of such peaks depends on the degree of perfection of the texture.

The common and very simple method of determining the crystallographic direction \([uvw]\) along the fibre axis is the evaluation of the length of the translation vector \(t_{uvw}\) from interlayer distance. This length is then compared with the lengths of several translation vectors, calculated from lattice parameters. This method is satisfactory for solids with a simple crystal lattice (e.g. for cubic and hexagonal metals) provided the texture is well defined. Materials, however, used e.g. for construction of modern electrotechnical devices are often deposited in the form of thin solid films and may have a more complex structure and symmetry. In such cases a mere determination of the length of the lattice translation along the fibre axis from the interlayer distance cannot serve as an unambiguous criterion for the determination of the crystallographic direction along the fibre axis, especially in materials with a poorly defined structure.

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More reliable information on the fibre axis can be drawn from the comparison of the measured and calculated distribution of possible diffraction maxima on Debye rings along the layer lines. The present paper gives a simple algebraic criterion based on the reciprocal lattice geometry allowing a rational procedure for the construction of layer lines corresponding to any crystallographic direction associated with the fibre axis in materials of arbitrary crystal symmetry. Emphasis is laid on the electron diffraction texture pattern for which the described procedure is most straightforward and which is a very convenient means for texture studies of thin solid films. The procedure will be demonstrated on the texture determination of thin PbO films.

DETERMINATION OF TRANSLATION PERIOD ALONG THE FIBRE AXIS FROM THE ELECTRON DIFFRACTION PATTERN

Small wavelengths, of the order of $10^{-2}$ Å, used in electron diffraction studies lead to a significant simplification of the diffraction geometry. Diffraction angles are here confined to several degrees of arc and even relatively large reciprocal vectors are small compared to the radius of the Ewald sphere. This is illustrated in Fig. 1, from which it is apparent that the usual Bragg equation

$$(1) \quad \frac{1}{d} = \frac{2}{\lambda} \sin \theta$$

can be simplified to read

$$(2) \quad \frac{1}{d} = \frac{2}{\lambda} \theta_{\text{rad}}.$$

By using a flat film normal to the primary beam, the perpendicular distance $r$ of the diffraction spot from the direct beam is given by

$$(3) \quad r = L \tan 2\theta \mp L \theta_{\text{rad}}$$

where $L$ is the sample-to-film distance. By elimination of $\theta_{\text{rad}}$ using (2) and (3) we get

$$(4) \quad \frac{1}{d} = \frac{1}{\lambda L} r = Kr$$