DETERMINING THE EXISTENCE OF MISORIENTATION IN A CRYSTAL

BACKGROUND OF THE INFORMATION

This invention relates generally to determining the existence of misorientation in a crystal (this includes determining the non-existence of misorientation). Though the invention has general applicability, it is particularly applicable to gemstones, especially diamonds; without limiting the scope of this invention, the remainder of this specification relates to diamonds.

Various stones give problems in the diamond industry, amongst which can be listed polycrystals, bicrystals, twinned crystals, strained crystals, crystals with inclusions, cracked stones, coateds, and crystals with growth bands.

The present invention is primarily concerned with polycrystals (a bicrystal is a special case of a polycrystal) and twinned crystals. In each case, there is misorientation—one or more volumes of the crystal have a different crystallographic orientation to the remainder. A polycrystal grew from more than one seed or nucleus and there is no crystallographic orientation relationship between the differently orientated volumes. During the growth of a twinned crystal, the orientation changed; although one or more volumes have a different orientation, there is an orientation relationship. A twinned crystal is considered to be a type of single crystal. The formation of a maccle is the type of twinning that occurs in diamonds. A maccle is a form of twinned crystal in which the lattice of one part of the stone is apparently rotated 180 degrees about the [III] direction to form a twin boundary on the (III) plane. Physical rotation does not actually occur—the twinning occurs during growth. FIGS. 1*a* to 1*d* of the accompanying drawings shows stone shapes resulting from the maccle transformation.

In this specification, the terminology is as explained above, which is the crystallographic terminology. In the diamond industry, bicrystals are called twins.

The existence of two different orientations within a stone can cause problems during manufacture. In many cases, the only option is to manufacture solely by polishing, i.e. the stone cannot be sawn or cleaved using conventional procedures.

Polycrystals and twinned crystals (and particularly twinned crystals) are probably the most difficult stones for inexperienced sorters to master because of the many types and the different techniques used in their identification. Stone shape often indicates a stone might be a polycrystal or twinned but manual classification is only complete when a line at the boundary between misoriented regions of the crystal has been identified. In nearly all cases, the boundary extends to the surface of the stone.

In order to distinguish between a polycrystal or twinned crystals and a non-twinned single crystal, a sorter often needs to look into the bulk of the stone. Knowledge of refraction effects at the stone surface helps the sorter work out the position of internal features. Experience helps the sorter to distinguish between a line indicating misorientation and trails (i.e. growth pattern) on the surface of a stone. It would be very difficult to build a machine which sorted polycrystals or twinned crystals using even the external features because of the variety of ways that a polycrystal or twinned crystal is identified. It is unlikely that optical image processing could allow a machine to distinguish between e.g. a herringbone maccle line and normal trails.

A technique which gives bulk orientational information or contrast would have the advantage that an orientation difference is common to all polycrystals and twinned crystals. However, unless flats were polished on each stone, any optical technique which involved using internal information would require the refractive index of the stone and surrounding medium to be matched. Immersion in a matched refractive index liquid would present engineering problems. Also, all known liquids having refractive indices approaching that of diamond (2.4) are toxic. In addition, it may be desirable to make a distinction between polycrystals and twinned crystals to prevent polycrystals being sorted as twinned crystals.

GB 1 547 371 discloses an X-ray technique for identifying specific diamonds, where a record is made of a diamond using an X-ray beam which is carefully oriented in relation to the crystallographic orientation of the diamond, to produce an X-ray topograph; the diamond can be recognised again even if it has been re-cut, because it will produce a similar topograph.

GB-A-2 107 560 discloses the use of a Laue diffraction pattern as a manufacturing control to ensure that the orientation of a single crystal turbine blade is such that a crystallographic plane is parallel to a planar prepared surface, the equipment being carefully oriented relative to the prepared surface.

THE INVENTION

According to the invention, X-ray imaging is used without pre-orientatating the crystal.

The imaging is made by Laue photography, but it is not necessary that a permanent image be made. The images produced by Laue photography are termed Laue spots, and each Laue spot is produced by a transmitted or reflected diffraction beam by all those lattice planes for which the Bragg condition is fulfilled, the X-ray beam usually containing X-radiation of different wave lengths. There is a good description of the Laue method in "Elements of X-Ray Diffraction", 2nd Edition, by Cullity, from page 92.

Using the invention, one can distinguish between non-twinned single crystals and twinned crystals or polycrystals. Not only the presence but also the position of twinning (i.e. the boundaries, which are also termed composition planes) can be estimated or even precisely located. There is no need to pre-orientate the sample, i.e. to pre-orient any crystallographic plane of the crystal with respect to the axis of the X-rays; nonetheless at some orientations of the stone, the position of the misorientation could be hard to detect, e.g. if the boundary is normal to the axis of the X-ray beam. There is no need to polish a planar surface on the sample or to remove surface defects in general—the surface need not be optically clear.

According to a first technique, the presence of a twinned crystal or polycrystal can be detected by counting the number of spots within a certain area, say within a cone having a certain half-angle. The incident beam should be such that it intersects both orientations (if two are present) while carrying out the method. With a twinned crystal, some Laue spots appear to be produced from the whole crystal (rather than from a part of it) because some planes of atoms are common to