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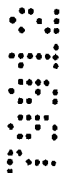
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ABSTRACT

The invention concerns a method of sorting diamond-containing particles on-line from gangue particles. In the method, the particles (12) are subjected to irradiation by an X-ray or thermal neutron beam (20) from a source (18). A detector (22), arranged at a predetermined orientation to the incident beam (20), detects radiation which is elastically scattered by each particle. A diffraction spot pattern is then derived from the detected radiation and is compared, by a computer (24), with a diffraction spot pattern for diamond. A determination is made whether there is correlation between the patterns which is indicative of the presence, in the particle, of diamond. When such correlation exists, the relevant particles are separated from the other particles.



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ON-LINE DIAMOND DETECTION

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The following statement is a full description of this invention, including the best method of performing it known to applicant(s):

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BACKGROUND TO THE INVENTION

THIS invention relates to on-line diamond detection and sorting.

5 The discussion of the background to the invention herein is included to explain the context of the invention. This is not to be taken as an admission that any of the material referred to was published, known or part of the common general knowledge in Australia as at the priority date of any of the claims.

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Diamonds are commonly sorted from associated gangue particles in diamondiferous feed material using X-rays which generate detectable luminescence in diamonds. One serious limitation of this known method arises when the diamond is shrouded with material which is opaque to the luminescence and which accordingly prevents proper detection thereof. Another serious limitation arises from the fact that the luminescence spectrum emitted by an X-radiated diamond is not necessarily distinctive of diamond, since other minerals such as zircon can emit similar luminescence spectra under X-radiation.

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Diffraction is also commonly used in the laboratory for studying lattice structures of crystalline materials. In an X-ray diffraction spectrometer, the crystalline sample is placed in a fixed position in a monoenergetic X-ray pencil beam. Elastically scattered radiation from the lattice planes in the crystalline structure can be detected by scanning an X-ray detector over a range of angles relative to the incident, primary X-ray beam, or by using a stationary, linear array of X-ray detectors at predetermined angular positions.

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The diffraction scattering angles are determined by Bragg's law and depend on the X-ray wavelength, lattice constants for the crystal in question, and the angle between a particular lattice plane and the incident beam. The first two of these variables are readily determinable.

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Radiation scattered inelastically by the crystal in question gives rise to background radiation, but such radiation does not have the specific angular distribution which is characteristic of diffractive scattering by the crystal lattice planes.

It is known that if a sample irradiated with monoenergetic radiation is in polycrystalline form, the elastically scattered radiation forms a concentric ring pattern centred on the axis of the irradiating beam. On the other hand, if the sample is a single crystal, the diffraction spots will only appear at certain angular positions, along the rings of the pattern, relative to the axis of the irradiating beam. Thus in the case of laboratory analysis of a single crystal diamond the diamond must be held with its crystal planes at certain orientations if the radiation detection apparatus is to be correctly positioned to detect the relevant spots.

The orientation of crystallographic planes in a single crystal structure can be measured by a Laue camera in which a continuous X-ray spectrum is used and a scattered diffractive pattern is detected by a two-dimensional detector such as a photographic film. If the spots from one lattice plane give a symmetric pattern centred about the primary irradiating beam, it can be said that the relevant crystal plane is aligned with that beam. Asymmetry in the detected Laue diffraction spot pattern is indicative of the angle between the relevant lattice plate and the incident X-ray beam.

The present invention proposes to use of these phenomena in the on-line detection of diamond-containing particles.

SUMMARY OF THE INVENTION

According to one aspect of the present invention there is provided a method of sorting diamond-containing particles on-line from gangue particles, the method including the steps of:

- subjecting particles which are to be sorted to irradiation by an X-ray or thermal neutron beam;
- by means of a detector arranged at a predetermined orientation to the incident beam, detecting radiation which is elastically scattered by each particle and deriving a diffraction spot pattern from the detected radiation;
- by means of a computer, comparing the derived diffraction spot pattern for each particle with a diffraction spot pattern for diamond to determine whether there is correlation between the patterns which is indicative of the presence, in the particle, of diamond; and
- separating those particles for which there is correlation between the patterns indicative of the presence of diamond from other particles for which there is no such correlation.

Most gangue particles associated with diamond in nature do not include single crystal minerals so there will be no detection of a spot pattern that could be characteristic of diamond in the case of such particles.

In one embodiment, the particles are irradiated with an X-ray beam, possibly monoenergetic. The wavelength spectrum of the X-ray beam and the acceptance waveband of the associated detector are selected such that the detector is capable of detecting spots at diffraction scattering angles characteristic of diamond for those particular X-ray wavelengths. As an alternative to a broad spectrum X-ray beam, it is also proposed to irradiate the diamondiferous particles with a thermal neutron beam.

According to another aspect of the invention there is provided apparatus for sorting diamond-containing particles on-line from gangue particles, the apparatus including:

- an X-ray or thermal neutron source for producing an X-ray or thermal neutron beam;
- means for transporting particles which are to be sorted through an irradiation zone in which the particles are irradiated by the beam;
- a detector arranged at a predetermined orientation to the beam for detecting radiation which is elastically scattered by each particle;
- means for deriving a diffraction spot pattern from the detected radiation;

- a computer for comparing the derived diffraction spot pattern for each particle with a diffraction spot pattern for diamond to determine whether there is correlation between the patterns which is indicative of the presence, in the particle, of diamond; and
- sorting means, operating under the control of the computer, for separating those particles for which there is correlation between the patterns indicative of the presence of diamond from other particles for which there is no such correlation.

BRIEF DESCRIPTION OF THE DRAWING

The invention will now be described in more detail, by way of example only, with reference to the accompanying drawing which diagrammatically illustrates an apparatus used in the method of the invention.

DESCRIPTION OF AN EMBODIMENT

The drawing shows a hopper 10 which feeds diamondiferous particles 12 onto the upper run of a endless conveyor belt 14 which conveys the particles towards and over a discharge roller 16. Located above the belt is an X-ray tube 18 which directs a broad spectrum, X-ray pencil beam 20 downwardly onto particles on the belt. The particles are transported in single file on the belt so that the pencil beam 20 is directed onto a single stream of moving particles 12.

Alternatively, the particles could be spread across the width of the belt with the pencil beam 20 scanning across the belt, possibly by means of a rotating collimator disposed in front of the X-ray tube exit window. In yet another alternative embodiment in which the particles are spread across the belt, the beam 20 could be fanned in a plane at right angles to the plane of the belt.

The numeral 22 indicates a two-dimensional electronic detector which is arranged at a predetermined orientation relative to the primary, incident beam 20 to detect X-rays which are elastically scattered by the particles 12. The output of the detector 22 for each particle is fed to a computer 24 which translates the detected radiation into a Laue diffraction spot pattern.

The computer then compares the derived Laue diffraction spot pattern with a known, electronically stored pattern for diamond. The known diamond diffraction spot pattern is derived from detailed knowledge of the single crystal diamond structure and of the orientations of the lattice planes therein. The comparison is performed iteratively in accordance with a predetermined algorithm in an attempt to fit the known pattern to the instantaneously derived pattern. If sufficiently close correlation is achieved, the particle in question is identified as a diamond or having a diamond inclusion.

In response to a positive identification of a diamond or diamond inclusion, the computer 24 triggers a separation device 26. In this case the device 26 is illustrated as an air blast device which issues a short duration blast of air to deflect the relevant particle out of the stream of particles discharged over the roller 16. Several such devices, spaced laterally apart from one another, may be provided in situations where the particles are presented across the width of the belt 14 rather than in single file.

The deflected particles, i.e primarily diamonds or particles with diamond inclusions, collect in a bin 28 while the remaining gangue particles collect in a bin 30.

As an alternative to the use of a X-ray beam to generate a diamond-distinctive Laue spot pattern, it is within the scope of the invention to irradiate the particles 12 with a thermal neutron beam produced by a thermal neutron source. It is envisaged that this could in fact give greater sensitivity since a neutron beam can be more effectively elastically scattered by the diamond crystal lattice planes.

The underlying principles of the method of the invention could also be used to detect diamonds in other applications, such as in the analysis of individual parcels or in or on human bodies. It will be appreciated that the penetrative power of the X-ray or thermal neutron beam will enable diamonds to be detected even if they are embedded in other materials which would normally be opaque to X-ray generated luminescence.

In the illustrated embodiment, the detector 22 detects X-rays which are forwardly scattered by the particles 12. In the case of thermal neutrons, it is preferred to detect backscattered radiation.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:-

1. A method of sorting diamond-containing particles on-line from gangue particles, the method including the steps of:
 - subjecting particles which are to be sorted to irradiation by an incident X-ray or thermal neutron beam;
 - by means of a detector arranged at a predetermined orientation to the incident beam, detecting radiation which is elastically scattered by each particle and deriving a diffraction spot pattern from the detected radiation;
 - by means of a computer, comparing the derived diffraction spot pattern for each particle with a diffraction spot pattern for diamond to determine whether there is correlation between the patterns which is indicative of the presence, in the particle, of diamond; and
 - separating those particles for which there is correlation between the patterns indicative of the presence of diamond from other particles for which there is no such correlation.
2. A method according to claim 1 wherein the particles are irradiated with a broad band X-ray beam and the waveband of the X-ray beam and an acceptance waveband of the associated detector are selected

such that the detector is capable of detecting diffraction spots at diffraction scattering angles characteristic of diamond for X-ray wavelengths in the X-ray waveband.

3. A method according to claim 1 wherein particles which are to be sorted are passed through the X-ray or thermal neutron beam.
4. A method according to claim 3 wherein the particles are passed on a conveyor belt through the beam.
5. A method according to claim 4 wherein the particles are arranged in single file on the belt and are irradiated by a pencil beam of X-radiation.
6. A method according to claim 4 wherein the particles are spread across the belt and are irradiated by a pencil beam of X-radiation scanned across the belt.
7. A method according to claim 4 wherein the particles are spread across the belt and are irradiated by a fanned beam of X-radiation.
8. A method according to any one of the preceding claims wherein the particles are irradiated by a substantially monoenergetic beam of X-radiation.
9. An apparatus for sorting diamond-containing particles on-line from gangue particles, the apparatus including:

- an X-ray or thermal neutron source for producing an X-ray or thermal neutron beam;
 - means for transporting particles which are to be sorted through an irradiation zone in which the particles are irradiated by the beam;
 - a detector arranged at a predetermined orientation to the beam for detecting radiation which is elastically scattered by each particle;
 - means for deriving a diffraction spot pattern from the detected radiation;
 - a computer for comparing the derived diffraction spot pattern for each particle with a diffraction spot pattern for diamond to determine whether there is correlation between the patterns which is indicative of the presence, in the particle, of diamond; and
 - sorting means, operating under the control of the computer, for separating those particles for which there is correlation between the patterns indicative of the presence of diamond from other particles for which there is no such correlation.
10. A method of sorting diamond-containing particles on-line from gangue particles, substantially as herein described with reference to the accompanying drawing.

11. An apparatus for sorting diamond-containing particles on-line from gangue particles, substantially as herein described with reference to the accompanying drawing.

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