Abstract: An infrared spectral system (10) for identifying target mineral grain particles within a group of mineral grains (12) is disclosed. In an example embodiment, the system (10) comprises a conveyor belt (20) for carrying the group of mineral grains (12), at least one infrared excitation module (16) that includes means (40) for providing infrared radiation to the group of mineral grains (12) on the conveyor belt (20), at least one infrared collection module (32) for collecting the reflected infrared radiation from the group of mineral grains (12) on the conveyor belt (20), processing means (72) for determining the location of target mineral grain particles on the conveyor belt (20), and target particle extraction means for picking the target particles based on the processing means' determined location of target particles. In an example embodiment, the means (40) for providing infrared radiation to the particles on the conveyor belt includes a heater element (46) located within a heater holder (42). In a second example embodiment, particles are presented as a batch to a spectral imaging system (100), and target particles are picked by a robotic system.
INFRARED IMAGING SPECTROSCOPY SYSTEM AND METHOD FOR SORTING PARTICULATE MATERIAL

BACKGROUND OF THE INVENTION

This invention relates to an infrared imaging spectroscopy system and method for sorting particulate material in the size range between 300 micron and 2 mm (-2.0+0.3 mm).

There is a continuous need for analytical techniques to enable discrimination of kimberlitic indicator mineral grains within a group of background mineral grains. South African patent application no. 2004/9204, for example, discloses a system for and method of identifying and sorting such indicator mineral grains using reflectance spectroscopy in the visible part of the electromagnetic spectrum. One of the limitations of such a system is that the visible part of the electromagnetic spectrum can not be used to detect so-called black kimberlitic indicator minerals, and in particular spinel and ilmenite minerals, with the present invention thus aiming to provide a system and method that can detect these minerals.
SUMMARY OF THE INVENTION

In broad terms this invention relates to an infrared imaging spectroscopy system and method for identifying target mineral grain particles within a group of mineral grains.

In one particular version of the invention, the system takes the form of an infrared reflectance spectroscopy system for identifying target particles within a group of particles, the system comprising:

- a conveyor belt for carrying the group of particles;
- at least one infrared excitation module that includes means for providing infrared radiation to the particles on the conveyor belt;
- at least one infrared collection module for collecting the reflected infrared radiation from the group of particles on the conveyor belt;
- processing means for determining the location of target particles on the conveyor belt; and
- target particle extraction means for picking the target particles based on the processing means' determined location of target particles.

Typically, the system includes a feed presentation sub-system comprising at least one vibratory feeder that is arranged to define a monolayer of particles and for feeding the monolayer of particles to the moving conveyor belt.

Conveniently, the system includes spring-loaded roller guides to ensure that the conveyor belt runs true, the roller guides being fixed on one edge and spring loaded on the other, thereby keeping the belt under tension but fixed relative to the one edge as it moves.
Typically, the means for providing infrared radiation to the particles on the conveyor belt includes a heater element located within a heater holder.

Preferably, the heater holder comprises a coolant inlet and a coolant outlet, with a cooling chamber extending between the inlet and the outlet.

In one version of the invention, the system includes a plurality of infrared collection modules to detect reflected infrared radiation in a plurality of bands in the range 3 to 19 microns.

Significantly, the size range of the particles is $-2.0 \pm 0.3$ mm.

Preferably, the target particles are black kimberlitic indicator minerals, including spinel and/or ilmenite minerals.

In another version of the invention, the system takes the form of an infrared spectral imaging system for identifying and sorting target particles within a batch of particles, the system comprising:

- a tray for supporting the batch of particles;
- leveling means for leveling the batch of particles into substantially a monolayer;
- an infrared spectral imaging device to produce a spectral image of the batch of particles;
- a classifier for determining the pixel coordinates of target particles in the spectral image;
- converter means for converting the pixel coordinates to world coordinates of the target particles on the tray; and
target particle extraction means for picking the target particles based on the calculated world coordinates and for transferring the picked target particles to a storage arrangement.

Significantly, the size range of the particles is -2.0+0.3 mm.

Preferably, the target particles are black kimberlitic indicator minerals, including spinel and/or ilmenite minerals.

The invention further provides an infrared imaging spectroscopy method of identifying target particles within a group of particles, the method comprising the steps of:

- presenting the group of particles to at least one infrared excitation module for identification;
- providing infrared radiation to the particles;
- collecting the reflected infrared radiation from the particles;
- processing the reflected infrared radiation to determine the location of the target particles; and
- extracting the target particles.

**BRIEF DESCRIPTION OF THE DRAWINGS**

**Figure 1** is a top view of an infrared (IR) spectroscopy system comprising a plurality of IR optical modules, according to a first embodiment of the invention;

**Figure 2** is a side view of the IR spectroscopy system shown in Figure
1, with only one IR optical module being shown for clarity;

**Figure 3** shows the infrared reflectance spectrum of a conveyor belt used in the system shown in Figures 1 and 2;

**Figure 4** is a bottom view of a heater holder used in the system shown in Figures 1 and 2;

**Figure 5** is a partly cut-away detailed perspective view of one of five IR optical modules used in the system shown in Figures 1 and 2;

**Figure 6** shows a schematic view of an infrared spectral imaging system according to a second, preferred embodiment of the present invention in which spectral imaging is done in a batch process;

**Figure 7** shows a detailed side view of a batch preparation arrangement used in the system shown in Figure 6;

**Figure 8** shows a cross-sectional side view of a tray used in the batch preparation arrangement shown in Figure 7;

**Figure 9** shows a detailed view of a particle picking nozzle using the system shown in Figure 6; and

**Figure 10** shows a top view of the batch preparation arrangement shown in Figure 7.

**DESCRIPTION OF PREFERRED EMBODIMENTS**

In broad terms, the present invention discloses a system and method that uses infrared spectral classification of individual grains in an online,
automated process, for subsequent sorting. In particular, the invention uses the infrared reflectance spectra of the particles being imaged in order to determine whether they are target kimberlitic or non-target grains, and extracts target grains to produce a concentrate. This requires the acquisition of a pure spectrum, originating only from the surface of the single grain without interference from other grains or a background surface, from each mineral grain in the heavy mineral concentrate. A spectral classification algorithm, which allows for the identification of the specific grains of interest here, has been developed, and is described in detail later on in the specification.

To this end the following criteria / guidelines were used in the design of the systems of the present invention:

1. No loss of mineral grains, i.e. no spillage.
2. The grains were not to be damaged.
3. The size range of the grains is -2.0+0.3 mm, divided into sub-ranges varying by at most a factor two in diameter.
4. The goal for the feed rate was 30 grains per second i.e. 1 x 10^5 grains per hour.
5. The goal for the discrimination of the kimberlitic grains was >85% correctly report to the concentrate, and <10% of non-target grains report incorrectly to the concentrate.

A first embodiment will now be described with reference to Figures 1 and 2. An infrared reflectance imaging spectroscopy system 10 for detecting kimberlitic indicator mineral grains, including spinel and ilmenite minerals, within a group of background mineral grains 12 comprises in broad terms a feed presentation system 14 and five infrared (IR) optical excitation and collection modules 16.1, 16.2, 16.3, 16.4 and 16.5. The feed presentation system and IR modules are fitted to a supporting frame 18.

The five IR modules 16.1, 16.2, 16.3, 16.4 and 16.5 are arranged to detect reflected IR radiation in five broad bands in the infrared range from 4 to 19...
microns. These five bands define a low resolution spectrum that can be used to identify, amongst others, spinel and ilmenite minerals.

The system 10 further comprises a conveyor belt 20 for carrying the mineral grains 12, the conveyor belt 20 being arranged to be driven over a pair of pulleys 22 and 24 by means of a suitable motor and associated gearbox drive unit 26. The motor and drive unit 26 is connected to a power supply 28 via an electromagnetic interference (EMI) filter 30 and an inverter 31, the filter 30 being used to reduce noise on the output signal of an IR detector 32 fitted to each IR module 16.

The preferred version for the conveyor belt 20 takes the form of a stainless steel metal belt that is laser welded to form a continuous belt, the metal belt being covered with an IR absorbing paint. Advantageously, such a belt can withstand high temperatures (of the order of a few hundred degrees Celcius, potentially up to 1000 °C), and can also conduct the heat to a cooling station 34.

The IR absorbing paint was sourced from Akzo Nobel, and is available in various colours. Infrared testing showed the gray version to have the best absorption property, as shown in Figure 3, and, in an example embodiment, this was used to coat the belt.

In order to ensure that the conveyor belt 20 runs true, spring-loaded roller guides are fitted. This is important, because if the variation on the edge of the belt 20 is even in the range of only 100 microns, the IR reflection from a mineral grain may be missed by one or more of the optical modules 16, and detected by the others. Typically, therefore, the roller guides are fixed on one edge and spring loaded on the other, thereby keeping the belt 20 under tension but fixed relative to the one edge, as it moves. Two additional roller guides are placed on top of the belt 20 to force it downwards.

With reference now also to Figures 2 and 4, a transformer 36 fitted to the main power supply 28 and is used to power a thyristor drive 38 that in turn
drives a heater 40 fitted to one end of each of the IR modules 16.1 to 16.5. There are five thyristor drives 38 and five heaters 40, one per IR module 16.1 to 16.5, but only one of each is shown in Figure 2.

Each heater 40 provides the required source of IR radiation to the grains travelling beneath the IR detector 32 on the conveyor belt 20. In one version, the heater 40 comprises a heater element in the form of a coiled Kanthal Nikrothal wire, which requires a 12V high current power supply, controlled by the thyristor drive 38. Thus, the transformer 36 takes the form of a 12V, 6OA (12A per thyristor drive) transformer.

The heater 40 is itself held within a heater holder 42, the bottom of which is shown in more detail in Figure 4. The heater holder 42 comprises a water cooled stainless steel structure, with a ceramic disc 44 being provided within the heater holder 42 for supporting the heater coil 46, the heater coil 46 having terminal connections 48 and 50. A water inlet 52 and water outlet 54 is in fluid communication with a cooling chamber within the holder 42. The inlet 52 and outlet 54 themselves are in fluid communication with a water pump and reservoir, which are arranged to supply the cooling water.

A temperature controller 56, connected to the main power supply 28, uses a thermocouple to provide feedback on the current temperature of the heater 40, with the temperature controller 56 being used to control each thyristor drive 38. In addition, the temperature controller 56 provides for the variable setting of the heater temperature, allowing for the optimisation of the feed and detection system parameters. These parameters include:

- belt speed, selected so as to maximise IR irradiance on the mineral grains, and to prevent the belt and grains melting. This also influences the effective integration time of the detector;
- noise level on the IR detector 32;
- signal-to-noise (SIH) of the detector 32; and
- required rate of flow of the cooling water.

As indicated above, an IR detector 32 is fitted at one end of each of the IR
modules 16. Each of the modules 16 has a band-pass filter placed in front of the detector, so as to allow only a specified band of infrared radiation to reach the detector. In one version of the invention, each detector 32 utilises Phase Sensitive Detection (PSD), also known as Lock-In Amplification, to detect a signal buried in noise that is orders of magnitude larger. The technique utilises electronics to "lock-in" to a signal varying with a particular frequency, and through the application of the Fourier Transform and filtering techniques, is able to eliminate signals (i.e. noise) not at the "locked-in" frequency. PSD was implemented as the IR detectors have a 1/f noise response, and the noise is reduced by a factor of 10 if the frequency of the signal being detected is greater than approximately 400 Hz. In order to generate this frequency dependent signal from the static IR reflection, an optical chopper is provided, which, although not shown but with reference to Figure 5, fits in front of a filter 58, and thus within a beam path 60 provided by the reflected IR radiation off the particles on the moving conveyor belt 20.

It should be emphasized that the IR detector described above is just one of a group of different detector arrangements that can be used in the present invention, with possible alternatives being described further on in the specification.

As is clear from Figure 5, each IR module 16 includes a pair of transverse aluminium tubes 62 and 64 for housing a first mirror 66 and a second mirror 68 for directing the beam path 60 through the module 16 to the IR detector 32. In addition, each IR module 16 is adjustably mounted to the frame 18, with the individual components within each module also all being adjustable so as to facilitate calibration of the system.

Referring back to Figure 2, a data acquisition module 70 is fitted to each IR detector 32, for capturing the analogue signals from the detector 32, with a computer processor/classifier 72 then being used to do the necessary temporal adjustments and to determine the nature of the particles on the conveyor belt 20, in a real time, online manner. The classifier 72 is based
on a large training database, with representative mineral grains being obtained and categorised into separate target and non-target categories by expert mineral sorters.

A number of rudimentary classification methodologies / algorithms are possible. In an example embodiment, it was found that data representation was not necessary, due to the sparse nature of the data, and in fact seemed to reduce the classification performance. The best results were obtained by training and testing a k-Nearest Neighbour (k-NN) classifier with \( k = 3 \), on a variance normalised dataset.

Once a spectrum is classified as a target spectrum, its associated coordinates are added to a list of target coordinates. Thereafter, an extraction system (not shown) is used to extract the target mineral grains. There are a number of possible extraction systems, with, at present, a pneumatic mini-cyclone for mineral grain extraction being envisaged.

It is envisaged that other possible feed presentation system could be used instead of the conveyor belt feed system described above. Two potential other presentation systems are a batch feeding system, and a rotation disc feed system.

In a second, preferred embodiment shown in Figures 6 to 10, an infrared spectral imaging system 100 is shown, in which the material is treated in separate batches of approximately 1 gram each, each batch being placed on a tray 102. The material is first presented to an infrared spectral imaging device 104, in the form of a dense, stationary, monolayer. The spectra from all particles in the spectral image are then sent to a classifier. This returns the pixel coordinates of target particles in the image. The pixel coordinates are then converted to world coordinates of the particles on the tray 102. A robotic picking system 106 is then directed to the target coordinates, to pneumatically pick the target particles up and place them into appropriate concentrate bins 108.
In use, the material in any particular batch is first sieved to size fractions such that the upper diameter is at most a factor two times greater than the lower particle diameter. A batch of material is placed on the flat tray 102 atop a batch or sample preparation assembly 110. Referring to Figure 8, the tray 102 has a tapered rim 112, to keep particles from moving to the edge of the tray 102. A small ridge 114, approximately 300 micron deep, is provided at the bottom of the taper 112, for preventing particles from being pushed up the taper 112 in the preparation process. The surface 116 of the tray 102 has a coating that is absorbing in the appropriate infrared wavelength range.

The area of the surface 116 of the tray 102 required depends on the amount of material being prepared. For 1 gram of material a surface area of approximately 25 cm² is required to avoid masking of particles. Referring to Figure 7, the batch preparation arrangement 110 includes a vibrating stage assembly 118 comprising a spring steel plate 120 and a linear electromagnetic vibrator 122. The electromagnetic vibrator 122 is used to produce the required vibration in the steel plate 120. The spring steel plate 120 is supported on a leveling mechanism comprising four bolts 124A, 124B, 124C and 124D, which in turn are fitted to a base plate 126 and secured in position by means of nuts 128A to 128H. A similar arrangement is used to mount the bolts 124C and 124D in position.

The vibrating stage assembly 118 is arranged to distribute the particles into a uniform monolayer by applying a low amplitude (approximately 0.5 mm), high frequency (50 Hz) vibration to the tray 102. The vibrator 122 is switched off after a fixed time. With an accurately machined and leveled tray 102, a uniform monolayer is achieved within a fixed time of approximately 30 seconds.

In the example embodiment, an infrared spectral imaging device 104 is employed. Various embodiments for the infrared spectral imaging system are described further on in the specification. Referring to Fig. 6, the
spectral imager is positioned over the sample tray 102 by means of a conveyer 134.

The spectral image is stored in memory of a control PC as a three-dimensional array, often referred to as a datacube. This represents the two spatial dimensions and one spectral dimension. The processing of the datacube is described further below.

The signal processing algorithm consists of the following steps:

1. **Identify calibration points and sample region in image:**
   Calibration points on the tray surface are identified automatically using a template matching technique. Similarly, the borders of the sample region are determined automatically by identifying the tapered tray edge in the image, which may be coated with a material of contrasting infrared absorbance.

2. **Determine central pixel of particles in images**
   With the sample region identified, the datacube is truncated so that only this region of the image is processed further. A grey-scale image is extracted from the datacube, by averaging over particular spectral bands. The image is then convoluted with a matched filter, with circular geometry, and diameter corresponding to the centre of the size fraction in the batch. Pixels corresponding to the centres of particles are then identified by finding local maxima, above a certain threshold, in the convoluted image. The spectra at each of these central pixels are then sent on to the pre-processing and classification algorithm. The method is robust in situations where the particles are densely packed, and may in some cases be touching. By choosing the threshold conservatively, it is ensured that at least one spectrum per particle in the image is sent on for further processing.
3. **Data pre-processing**

Pre-processing involves the following steps:

3.1. Detector response and dark current correction:

\[ I = (I_M - I_B) (I_S - I_B), \]

where

- \( I_M \): measured spectrum
- \( I_B \): dark current spectrum, which is used to correct for the dark current at all pixels across the line scan
- \( I_S \): detector response (signal obtained from perfect reflector, e.g., InfraGold)
- \( I \): corrected spectrum

4. **Spectral classification**

The classifier is based on a large training database, acquired using the spectral imaging system described above. Representative mineral grains were obtained and categorised into separate target and non-target categories by expert mineral sorters.

Classification of the spectra can then be accomplished using a number of potential classifiers, applied in this derived feature space. In the current embodiment for Kimberlitic mineral sorting, both linear discriminant and nearest neighbour methods have been implemented.

If a spectrum is classified as a target spectrum, its associated pixel coordinates are added to the list of target coordinates.

**Target extraction system**

Target extraction is by means of a robotic pneumatic picking system 106. In an example embodiment, the system 106 comprises a nozzle 140 that
can be placed at an (x,y) position on the plane of the tray surface 116 to an accuracy of 100 micron, and a z (i.e. height above tray 102) accuracy of 100 micron. A schematic of the nozzle 140 is shown in Figure 9, and comprises a stainless steel body 142 terminating in a 0.5 mm diameter circular aperture 144, covered by a small aperture steel gauze 146. The nozzle 140 is used to extract particles between 300 and 2000 micron in a pick-and-place procedure.

Spatial coordination of the robotic system is achieved by means of at least three calibration points on the edge of the tray. These are of a nature that can be detected by the spectral imager, and by a laser displacement meter attached to the robot. This defines a transformation between image and robotic coordinates of the target particles.

Particles are placed into one of any number of concentrate bins 108, situated near to the sample preparation assembly 110. The pneumatics of the system are designed to allow for the application of a reverse pressure, to ensure particles are placed into the bins 108. The bins 108 may be at least a few centimetres deep, to avoid grains being blown out of the bin 108 by the reverse air blast. The robot cycle time is rated at approximately one second, allowing for one pick-and-place movement per second.

It is envisaged that the following is a list of potential implementations of the infrared spectral imaging system. These include typical hyperspectral and multispectral acquisition systems, as well as ideas that are relevant to a laboratory based spectroscopy imaging system.

(1) Whiskbroom scanning system: A scanning mirror collects the reflected radiation from each point in a line off the tray, while the scanner is moved forward in the perpendicular direction. The infrared bands of interest are then detected by means of one of the following wavelength selection methodologies:

   (a) a series of reflection and transmission band-pass filters
are used with individual single element detectors;
(b) a prism or grating is used to disperse the radiation, and individual detectors are appropriately positioned;
(c) a prism or grating is used to disperse the radiation, and fibre optics are appropriately positioned, with the ends of the fibres being coupled to individual detectors;
(d) a prism or grating is used to disperse the radiation onto a linear array detector; or
(e) a linear variable filter and linear array detector may be used.

(2) Dual mirror scanning system: Similar to (1), except that instead of the scanner being moved, another scanning mirror is employed to scan the first mirror in the perpendicular direction.

(3) Push-broom scanning system: The scanner images the length of the tray, and is moved forward in the perpendicular direction. Wavelength selection for the infrared bands of interest is performed by one of:
(a) a prism or grating is used to disperse the radiation onto a focal plane array (FPA) detector;
(b) a prism or grating is used to disperse the radiation onto a series of linear array detectors mounted on top of one another. The number of array detectors corresponds to the number of bands of interest;
(c) a series of linear array detectors corresponding to the number of bands of interest are mounted on top of one another, each seeing through a transmission band-pass filters corresponding to an infrared band of interest; or
(d) a series of linear array detectors corresponding to the number of bands of interest are mounted on top of one another, each seeing through a portion of an infrared linear variable filter corresponding to an infrared band of interest.
(4) **Scanning mirror, push-broom scanning system**: Similar to (3) above except that instead of the scanner being moved in the perpendicular direction, a scanning mirror is employed to scan the tray in that direction.

(5) **Staring array system**: A focal plane array detector is employed to image the entire tray or a portion of the tray. If a portion of the tray is being imaged, then the entire tray image is constructed by step-scanning i.e. imaging in sequence portions of the tray and subsequently constructing an image of the entire tray. The wavelength selection is performed by either:

(a) a series of filters is positioned in front of the detector before an image is acquired. Each filter corresponds to an infrared band of interest. A filter wheel may be used to rotate through the different filters;

(b) a tuneable filter may be use to select the infrared band of interest. The filter may be, but is not limited to a variable filter (linear of circular), an acoutso-optical filter, a liquid crystal tuneable filter or a Fabry-Perot tuneable filter;

(c) an interferometer such as in a fourier transform infrared (FTIR) spectrometer may be used to acquire the entire infrared spectrum over the infrared wavelength region of interest or a portion of this wavelength range;

(d) a multi-colour (multi-band) quantum well infrared photodetector (QWIP) camera maybe used, with each of the bands corresponding to one of the infrared bands of interest; or

(e) a series of QVVIP cameras may be used, each corresponding to a single band of interest or to a multiple of the bands of interest. The individual images taken would then need to be correlated in order to identify the signals from each of the grains on the tray.

In (a) and (b), multiple cameras may be needed to cover all of the
infrared bands of interest as the technology may not support a single detector or tuneable filter working for all bands. A strategy similar to (e) may then need to be followed.

(6) **Single point mapping** : The tray may be mapped by visiting each point of the tray and acquiring the infrared signal. This may be possible by either :

(a) using a FTIR spectrometer microscope attachment to map the tray, thereby acquiring the full infrared spectrum;

(b) using a FTIR spectrometer microscope attachment to acquire the full infrared spectrum from each mineral grain of interest only. The mineral grains of interest may be identified by other imaging techniques, an example of which is (5,c) above, and may include a visible hyperspectral scanning system or an colour image camera. The mapping system then only needs to visit specified points of interest instead of mapping the entire tray;

(c) using a fibre optic attached to a mechanical scanner to map the entire tray. The fibre optic would then collect light from every point of the tray and the wavelength selection would be performed by one of the methods described in (1) above;

(d) using a fibre bundle, with each of the fibres attached to an individual detectors and transmission filter, as in (1)(a) above, to map the entire tray;

(e) modifying (c) or (d) above to only visit points of interest i.e. identified grains on interest, instead of mapping the entire tray. The grains of interest would be identified by other imaging means, such as visible hyperspectral imaging ; or

(f) using a line of fibres to collect light from the entire length of the tray, and then employing one of the methods in (2)
(7) Wavelength selection in the radiation source: An alternative idea to the above (1)-(6) is to employ the above imaging or scanning systems, but to remove the wavelength selection methods. The wavelength selection is now performed by illuminating (either by scanning, or illuminating simultaneously) the entire tray with lasers corresponding to the infrared bands of interest, or with other infrared light sources which correspond to the infrared bands of interest. One may also use a broadband radiation source and filter this with transmission band-pass filters, to illuminate the tray. In other words, the necessary filtering takes place at the light source and not at the point of detection.

It is also envisaged that fibre optic technology may be used to generate the required IR radiation, either using fiber optic filtering or hollow fibre waveguides to produce the required wavelength.

In broad terms, therefore, the present invention discloses a system and method that uses IR reflectance spectral classification of individual grains in an online, automated process, for subsequent sorting and extracting. In particular, the invention uses the IR reflectance spectra of the particles being imaged in order to determine whether they are target kimberlitic or non-target grains, and extracts target grains to produce a concentrate. Although the invention has primarily been described above with reference to 5 specific bands in the infrared range between 4 and 19 micron, so as to define a spectrum, alternative embodiments involving the acquisition of higher or lower resolution spectra are also possible.

One of the primary advantages of the present invention is its ability to do online, real time classification and extraction of target mineral grains, with the feedrate goal being one hundred thousand grains per hour.
CLAIMS

1. An infrared reflectance spectroscopy system for identifying target particles within a group of particles, the system comprising:

   a conveyor belt for carrying the group of particles;

   at least one infrared excitation module that includes means for providing infrared radiation to the group of particles on the conveyor belt;

   at least one infrared collection module for collecting the reflected infrared radiation from the group of particles on the conveyor belt;

   processing means for determining the location of target particles on the conveyor belt; and

   target particle extraction means for picking the target particles based on the processing means' determined location of target particles.

2. The system of claim 1, wherein the system includes a feed presentation sub-system comprising at least one vibratory feeder that is arranged to define a monolayer of particles and for feeding the monolayer of particles to the conveyor belt.

3. The system of either claim 1 or claim 2, which includes spring-loaded roller guides to ensure that the conveyor belt runs true, the roller guides being fixed on one edge and spring loaded on the other, thereby keeping the belt under tension but fixed relative to the one edge as it moves.

4. The system according to any one of the preceding claims, wherein
the means for providing infrared radiation to the particles on the conveyor belt includes a heater element located within a heater holder.

5. The system according to claim 4, wherein the heater holder comprises a coolant inlet and a coolant outlet, with a cooling chamber extending between the inlet and the outlet.

6. The system according to any one of the preceding claims, which includes a plurality of infrared collection modules to detect reflected infrared radiation in a plurality of bands in the range 3 to 19 microns.

7. The system according to any one of the preceding claims, wherein the size range of the particles is -2.0+0.3 mm.

8. The system according to any one of the preceding claims, wherein the target particles are black kimberlitic indicator minerals, including spinel and/or ilmenite minerals.

9. An infrared spectral imaging system for identifying and sorting target particles within a batch of particles, the system comprising:

   a tray for supporting the batch of particles;

   leveling means for leveling the batch of particles into substantially a monolayer;

   an infrared spectral imaging device to produce a spectral image of the batch of particles;

   a classifier for determining the pixel coordinates of target particles in the spectral image;

   converter means for converting the pixel coordinates to
world coordinates of the target particles on the tray; and

target particle extraction means for picking the target particles based on the calculated world coordinates and for transferring the picked target particles to a storage arrangement.

10. The system according to claim 9, wherein the size range of the particles is -2.0+0.3 mm.

11. The system according to either one of claims 9 or 10, wherein the target particles are black kimberlitic indicator minerals, including spinel and/or ilmenite minerals.

12. An infrared imaging spectroscopy method of identifying target particles within a group of particles, the method comprising the steps of:

   presenting the group of particles to at least one infrared excitation module for identification;

   providing infrared radiation to the particles;

   collecting the reflected infrared radiation from the particles;

   processing the reflected infrared radiation to determine the location of the target particles; and

   extracting the target particles.