TOMRA SORTING SOLUTIONS
SAIMM – Johannesburg
Content

- Introduction
- Sorting Principle
- Sensors
- Sensor Evaluation Procedure
- Applications
  - Coal
  - Chrome Ore
  - Diamonds
- Conclusions
- The TOMRA Story
The global leader in sensor-based sorting

Offering cutting-edge technology for industries where automated sorting and processing are key for value creation.
Our sensor technologies are used in a number of applications across three industries:

### RECYCLING
- E-scrap
- Shredded car scrap
- Municipal waste
- C&D waste
- Industrial waste
- Paper
- Packaging
- Plastics

### MINING
- Industrial minerals
- Ferrous metals
- Base metals
- Precious metals
- Coal
- Diamonds
- Gem stones
- Slag

### FOOD
- Tomato
- Citrus
- Meat
- Radish
- Corn
- Cheese
- Onions
- Potatoes
**Available Sensors within the Electro Magnetic Spectrum**

<table>
<thead>
<tr>
<th>Sensor/Technology</th>
<th>Material Property</th>
<th>Mineral Application</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gamma-radiation</strong></td>
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<td><strong>X-ray</strong></td>
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<td>Ultraviolett (UV)</td>
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<td>Visible light (VIS)</td>
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<td>Near Infrared (NIR)</td>
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<td>Infrared (IR)</td>
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<td>Microwaves</td>
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<td>Radio waves</td>
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<td>Alternating current (AC)</td>
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<tr>
<td>$10^4$</td>
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</table>

**Material Properties**

- **RM** (Radiometric): Natural Gamma Radiation
  - Uranium, Precious Metals
- **XRT** (X-ray transmission): Atomic Density
  - Coal, Diamonds
- **XRL** (X-ray luminescence): Visible Fluorescence under X-rays
  - Diamonds
- **ED-XRF** (Energy Dispersive XRF): X-ray Fluorescence
  - Fe grade thresholds
- **COL** (CCD Color Camera): Reflection, Brightness, Transparency
  - Base/Precious Metals, Ind. Minerals, Diamonds
- **PM** (Photometric): Monochromatic Reflection/Absorption
  - Ind. Minerals, Diamonds
- **NIR** (Near Infrared Spectrometry): Reflection, Absorption
  - Base metals, Industrial Minerals
- **IR** (Infrared cam): Heat conductivity, heat dissipation
  - Base Metals, Industrial Minerals
- **MW-IR** (heating in conjunction with IR): Sulfides & Metals heat faster than other minerals
  - Base/Precious Metals
- **EM** (Electro-Magnetic sensor): Conductivity
  - Base Metals, Magnetite
Rock-by-Rock Scanning

Sample usually about 500 rocks in total:
- 50 rocks of each of the mineral-bearing ore rock types and
- 50 rocks of the different waste rock types.
- The rocks should be in a size range between -80 and 20mm.
- Each rock should have a sample number engraved into it and be packed in a tough plastic bag.
- Each rock should have XRF mineral content values

Each rock scanned by all sensors

The data of all rocks will be presented and compared in a test report with a conclusion drawn recommending the best possible sensor.
Electromagnetic sensor

- The electromagnetic response comprised of two parameters;
  - magnitude and
  - phase
- These responses are a measure of the particle’s
  - magnetic susceptibility and
  - conductivity of the material:

![Magnetite](image_url)
Electromagnetic Sensors

Sensors detect variations in both frequency and amplitude of signal
Rock-by-Rock Comparison

Figure 1: EM Magnitude response vs. Gold content
Colour Image Processing

- High resolution photos are taken of all samples;
  - Colour image processing software to analyse sample
  - Colour classes are defined and measured as a percentage of rock surface
UV-Induced Fluorescence

- Samples are placed under a UV light and photos taken;
  - Analyse in image processing software
  - Zones of fluorescence defined and measured as a percentage of rock surface

True UV Image

Classified Image
NIR Image Processing

- NIR Spectrometer to determine the reflectance intensity at wavelengths:
  - 1 000 nm to 2 600 nm

VIS Spectroscopy  NIR spectroscopy

Fig. 1: Quartz, Calcite, Talc
Rock-by-Rock NIR Comparison

NIR Index Value vs. Au content

- NIR Index Value
- Au (ppm)

Footwall Waste (I) samples
All other samples
Color/NIR Combination

The resolution is low. Objects are detected as one, if they are too close to each other.

Final sorting image. All objects are detected and can be classified by relation (%) of the NIR Classification.
Equipment selection

- Mechanical platform: PRO Secondary
- Little moving parts
- Robust
- Low capex and opex
- Small footprint
- Same platform for all units in the flowsheet
  - Easy to operate
  - Easy to maintain
  - Easier spares handling
XRT Image Processing

- Samples are subjected to high intensity X-rays;
  - X-ray images analysed in image processing software
  - Contrast filters applied to images to enhance differences between zones of varying density
XRT Evaluation

Low-Grade Sulfide Ore

Medium-Grade Sulfide Ore

Massive-Sulfide Ore

Granite Waste

Quartzite Waste
Radiometric Sensor

- Samples were placed on a radiometric scintillation detector to measure any radioactive decay of samples.
- Detectors are used to measure the natural gamma radiation of the uranium ore.
- Detectors consist of a NaI scintillator and a photomultiplier tube (PMT).
- Direct correlation between number of counts (gamma rays) and grade.
Radiometric Sensing
Radiometric Evaluation

Sample Types - (<0.1) Avg Counts/Area

- Conglomerate
- Dyke
- Grit
- Mica Quartzite
- Quartzite
- Shale
- VQ

Counts per Area

Sample
Sensor Comparison & Selection

Comparison of Gold retention

![Graph showing comparison of gold retention for different sorting methods.](image)

- Au retained (by mass percentage) by EM sort
- Au retained (by mass percentage) by (Black) Colour sort
- Au retained (by mass percentage) by (High Density) X-Ray Contrast Filter sort
- Au retained (by mass percentage) by NIR Index Value sort
- Au retained by a 'Perfect' sort
Dry Coal XRT Sorting

- Size Range: -120+20mm; -50 +12mm
- Feed Rate: 100-150 t/h; 60 t/h
- Working width: 1,200mm
Snap-Shot XRT Images of Coal and Stone
XRT Coal Sorting Plant
## Sorting Performance

### 60tph -50+12.5mm

<table>
<thead>
<tr>
<th>Sample Mass Kg</th>
<th>air dried mass %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IM [%]</td>
</tr>
<tr>
<td>Feed Measured</td>
<td>40.44</td>
</tr>
<tr>
<td>Feed Calculated</td>
<td>19.50</td>
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<tr>
<td>Product Measured</td>
<td>12.96</td>
</tr>
<tr>
<td>Tailings Measured</td>
<td>6.54</td>
</tr>
</tbody>
</table>

Yield: 66%

### Graphs

- **Graph 1:**
  - Bars for Feed, Product, Tailings
  - Red: C.V. [MJ/kg]
  - Black: Ash [%]

- **Graph 2:**
  - Bars for Product, Tailings
  - Yellow: S [%]
# Sorting Performance

## 120tph -100+60mm

<table>
<thead>
<tr>
<th>Sample</th>
<th>Mass Kg</th>
<th>air dried mass %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>IM [%]</td>
</tr>
<tr>
<td>Feed</td>
<td>25.24</td>
<td>2.4</td>
</tr>
<tr>
<td>Feed</td>
<td>86.70</td>
<td>2.8</td>
</tr>
<tr>
<td>Product</td>
<td>58.32</td>
<td>3.4</td>
</tr>
<tr>
<td>Tailings</td>
<td>28.38</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Yield 67%
XRT Sorting - LG Chromite Ore

Chromite

Waste

Color image

X-Ray grey image

Chromite

Waste

X-Ray classified image
70 tons per hour at +90% availability
-60mm +20mm
The feed grade into the XRT sorter averages approximately 32% chrome and the process upgrades the saleable product to 36% or better at 97% efficiency
XRT Diamond Detection

Diamond X-Ray Simulation

Gravel | Diamonds
--- | ---

Gravel | Diamonds
--- | ---
XRT Diamond Detection

Alluvial Gravel, Size Range -25+8mm

Boart Quality Diamonds

Coated Diamonds (20% Gypsum)
XRT Image Processing

Raw Data Image

Classified Image

11 Boart Diamonds and 2 Gravel Particles, -16+8mm

Alluvial DMS Sinks, -25+8mm
XRT Image Processing

Results:

- 100% of the gravel particles were classified correctly
- 100% of the Diamonds were classified and recovered
- The yield was 7.6g/ejection at 15t/h on a 600mm belt
- The concentrate was 24.7% Diamonds by weight (average)
GEM Large XRT
High Tonnage Belt Sorter

Standard Features
• HMI Touch Panel for operator control and storage of pre-set conditions, and monitoring data with fault finding capabilities
• Complete DE-XRT sensor system
• Separation system, high speed air ejector system with air receiver, filters and pressure regulator
• Stainless steel frame, cabinet and internal chutes conforming to local authority requirements
• X-ray system, comprising water cooled X-ray tube, adjustable solid state X-ray generator and water cooling circuit complete with filter, regulator and flow switch for X-ray tube interlocking

Specifications
<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size Range</td>
<td>8..65mm, max size ratio 1:3</td>
</tr>
<tr>
<td>Feed Rate</td>
<td>Up to 80T/hr</td>
</tr>
<tr>
<td>Dimensions (No Feeders)</td>
<td>4 975mm (L) x 1 685mm (W) x 3 075mm (H)</td>
</tr>
<tr>
<td>Dimensions (With Feeders)</td>
<td>7 899mm (L) x 1 685mm (W) x 3 218mm (H)</td>
</tr>
<tr>
<td>Electric Power</td>
<td>Single and Three Phase (approx. 15kW)</td>
</tr>
<tr>
<td>Compressed Air</td>
<td>30 Normal Cubic Metre/Tonne blasted</td>
</tr>
<tr>
<td>Ejection System</td>
<td>High Speed Air Ejection System</td>
</tr>
<tr>
<td>Availability</td>
<td>40 weeks from receipt of order</td>
</tr>
</tbody>
</table>
Basic Diamond Flowsheet

Liberation

Concentration

Recovery

Gyratory / Jaw

AG Mill Scrubber

Cone

HPGR

Size Range [mm]

DMS

Pan

Jig

XRL

XRT

Grease

Hand

TOMRA SORTING SOLUTIONS MINING
Conclusions

- Sensor Based Sorting is a technology gaining significance in the mining industry
- Proven technology (over 200 sorters in mining)
- Recover value from low-grade dumps and marginal ore bodies
- Physical sorting process – no chemicals, heat
- Placing sorter between mine and mill has numerous benefits
- Mill the Ounces, not the Waste!!
- Tremendous opportunity for
  - Dry Beneficiation of Coal
  - Diamonds
  - Chromite Ore
  - etc
THANK YOU FOR YOUR ATTENTION!