Acknowledgements

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ACARP

Queensland Government
Introduction

- Real time is possible
- Further research is necessary
- Once developed it is a “game changer”
  - Detect and mitigate sources
  - PPE becomes second line of defence rather than only protection
- Other uses for the device can be developed
  - DPM, Asbestos, fire detection/ smoke, gas and combinations of them.
Respirable Dust

- Dust is produced when rocks are broken crushed, ground, scraped or impacted.
- The nature of this dust is that there can be a fraction that is invisible, (0.5-10μm), harmful and can remain in the air for long periods of time.

Respirable Crystalline Silica
<10 microns
Rationale for Development

- Current methods “allow” a person to be exposed to silica even though they may be below the total mass limit
- Exposure is unknown for at least 14 days
  - Potentially many days of exposure
- Devices are not able to locate sources
Ring Down Spectrometer

- Originally designed for IED detection
- Configured to detect low concentrations of Methane
- Can be configured to detect any substance with an IR signature
- Silica tests show that it is possible.
Initial proof of concept tests

- Three types of dust samples
  - Pure Silica
  - Metal mine dust
    - Conveyor Dust
    - Rib Side Dust
Silica

Quartz Size Distribution

- Distribution
- Distribution 2
- lower Limit
- Upper Limit
- Cumulative Passing
- Cumulative Passing 2
Conveyor Dust

![Graph showing conveyor dust distribution with different curves and labels for lower and upper limits, cumulative passing, and distribution.]
## Conveyor Dust Analysis

<table>
<thead>
<tr>
<th>Phase</th>
<th>Weight %</th>
<th>Error Of Fit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illite</td>
<td>27.8</td>
<td>0.47</td>
</tr>
<tr>
<td>Albite</td>
<td>16.6</td>
<td>0.34</td>
</tr>
<tr>
<td>Quartz</td>
<td>16.3</td>
<td>0.22</td>
</tr>
<tr>
<td>Muscovite</td>
<td>14.3</td>
<td>0.64</td>
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<tr>
<td>Dolomite</td>
<td>10.4</td>
<td>0.29</td>
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<tr>
<td>Kaolin</td>
<td>8.8</td>
<td>0.56</td>
</tr>
<tr>
<td>Chalcopyrite</td>
<td>2.3</td>
<td>0.09</td>
</tr>
<tr>
<td>Chlorite</td>
<td>1.8</td>
<td>0.26</td>
</tr>
<tr>
<td>Gypsum</td>
<td>1.7</td>
<td>0.16</td>
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</table>
Rib Side Dust

![Ribside Dust Graph](image-url)
### Rib Side Dust Analysis

<table>
<thead>
<tr>
<th>Phase</th>
<th>Weight %</th>
<th>Error Of Fit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illite</td>
<td>20.9</td>
<td>0.47</td>
</tr>
<tr>
<td>Quartz</td>
<td>20.1</td>
<td>0.27</td>
</tr>
<tr>
<td>Muscovite</td>
<td>18.4</td>
<td>0.64</td>
</tr>
<tr>
<td>Albite</td>
<td>16.6</td>
<td>0.35</td>
</tr>
<tr>
<td>Dolomite</td>
<td>11.4</td>
<td>0.30</td>
</tr>
<tr>
<td>Kaolin</td>
<td>7.2</td>
<td>0.59</td>
</tr>
<tr>
<td>Gypsum</td>
<td>2.2</td>
<td>0.17</td>
</tr>
<tr>
<td>Chalcopyrite</td>
<td>1.9</td>
<td>0.09</td>
</tr>
<tr>
<td>Chlorite</td>
<td>1.3</td>
<td>0.27</td>
</tr>
</tbody>
</table>
Experimental Setup

- The device was set up on a test bed
- Dust was placed in front of the cyclone and brushed into the air
- An ambient run was conducted
- A series of measurements taken until the dust was collected
- Repeated for each dust
- Results analysed.
Setup
Laser
Cavity
Detector
Dust Management

Cyclone

Filter
Dust Delivery

Sample Delivery
Results

Dust Measurements

Absorbance $[cm^{-1}]$

$\times 10^{-4}$

Wavenumber $[cm^{-1}]$

Empty Cavity
Quartz
CB
Results

Dust Measurements

Absorbance $[cm^{-1}]$

Wavenumber $[cm^{-1}]$

$\times 10^{-4}$
Outcomes and Questions

- Device “saw” silica dust in real time
- Device discriminates silica from other dusts
- Response was in seconds
- What is the most appropriate wavelength for Silica?
- What is the most appropriate wavelength for Coal?
Testing with Coal

- Next Step
- Doping with silica
- Modified method
- Sample preparation
- Results
- Additional conclusions
Doping with silica

- Samples prepared for testing
- ROM Coal
- ROM Coal +5% respirable Silica
- ROM Coal +10% respirable Silica
Modified method

- Coal Dust is lighter than Silica
- Protection from Respirable Dust
- Control of Sample Size
Sample Preparation
Sample Preparation
Sampling
Results

Coal Spectrum

Absorbance

Wavenumber

1180 1200 1220 1240 1260 1280 1300 1320 1340

$5 \times 10^{-4}$
Results
Results
Results
Selection of Frequencies

- Two Wavelengths are required 7.4microns & 9.4 microns
- One that sees all dust
- One that does not see silica
- Subtracting one from the other would allow the determination of the silica content
New Materials

- Step 1 Miniaturisation
  - Graphite composite
  - 3D Printed
  - Maintaining vacuum
  - Testing
- Step 2 Further Miniaturisation
Step 1 miniaturisation
Minaturisation
Assembly
Vacuum Testing

- Atmospheric pressure
  - 100kPa = 750 torr
  - 2.2kPa = 16.6 torr
Initial sealing
Leak chasing
New Prototype
New Prototype
New Prototype
Initial Dust Measurements

Dust Measurements (7.4 um)

- Silica Dust
- Room Air
- Coal with 5% Silica
- Coal with 10% Silica

Absorption (Arb. Val.) vs Time (Approx 30s)
Initial Dust measurements

![Graph showing dust measurements over time for different materials: Room Air, Silica Dust, Coal with 5% Silica, and Coal with 10% Silica. The graph illustrates the absorption (Arb. Val.) over time (approx 30s).]
Initial Dust measurements

**Dust Measurements (7.4 um)**

- Silica Dust
- Room Air
- Coal with 5% Silica
- Coal with 10% Silica

**Dust Measurements (9.4 um)**

- Room Air
- Silica Dust
- Coal with 5% Silica
- Coal with 10% Silica
### Dust Analysis

<table>
<thead>
<tr>
<th>Sample Date</th>
<th>Oxide</th>
<th>Coal Ash</th>
<th>Ash Content* %</th>
</tr>
</thead>
<tbody>
<tr>
<td>24th August, 2017</td>
<td>SiO₂</td>
<td>53.98</td>
<td>13.58</td>
</tr>
<tr>
<td></td>
<td>TiO₂</td>
<td>1.41</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Al₂O₃</td>
<td>30.33</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fe₂O₃</td>
<td>5.56</td>
<td></td>
</tr>
<tr>
<td><strong>Sample Type</strong></td>
<td><strong>MnO₄</strong></td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td><strong>1 coal sample</strong></td>
<td>MgO</td>
<td>0.89</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CaO</td>
<td>2.15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Na₂O</td>
<td>1.06</td>
<td></td>
</tr>
<tr>
<td></td>
<td>K₂O</td>
<td>1.83</td>
<td></td>
</tr>
<tr>
<td><strong>Sample Preparation</strong></td>
<td>P₂O₅</td>
<td>0.92</td>
<td></td>
</tr>
<tr>
<td><strong>40 mm Glass Disk.</strong></td>
<td>SO₃</td>
<td>0.58</td>
<td></td>
</tr>
<tr>
<td><strong>Crushing in WC Mill</strong></td>
<td>Cr₂O₃ &lt;0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ashing at 815 °C</strong></td>
<td>ZrO₂</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SrO</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CuO</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ZnO</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NiO</td>
<td>&lt;0.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BaO</td>
<td>&lt;0.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PbO</td>
<td>&lt;0.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>L.O.I.</td>
<td>1.09</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>100.03</td>
<td></td>
</tr>
</tbody>
</table>

**Note:**

(i) L.O.I. = loss on ignition at 1,050°C.
(ii) ND = not determined

*This sample was ashed at 815 °C before analysis. Back-calculation required for results on a whole-basis.
Cumulative dust analysis
Dust sampling points
Post analysis Filter
Test Setup
Circulating Fan
Laser Setup

- **Laser 1:**
  - Wavelength = 7.32um;
  - Pulse Rate = 166667Hz;
  - Pulse Width = 40ns;

- **Laser 2:**
  - Wavelength = 9.34um;
  - Pulse Rate = 156250;
  - Pulse Width = 40ns;
Test Conditions

- Both lasers were operating simultaneously, and the wavelength data was multiplexed in the data stream. The saved data was analysed (demultiplexed) after each run to produce the figures shown in this section.

- The flow rate was set to 2.2 l/min for both the personal dust sampler and the prototype.
Test Setup

- Four, 4-hour data runs performed:
  - **Background**: 4 Hrs data with no dust in system
  - **Run 1**: Coal dust plus 5% silica dust: 4 Hrs data with a coal-dust mixture in system – The dust was 5% of the coal dust. Chamber velocity 4.8m/s
  - **Run 2**: Coal dust plus 5% silica dust: 4 Hrs data with a coal-dust mixture in system – The dust was 5% of the coal dust. Chamber velocity 3.5m/s.
  - **Run 3**: Coal dust plus 10% silica dust: 4 Hrs data with a coal-dust mixture in system – The dust was 10% of the coal dust. Chamber velocity 3.5m/s.
Results

4 Hr data run showing Coal-Silica Dust at 7.32um

4 Hr data run showing Coal-Silica Dust at 9.34um
Two long duration runs
Conclusions

- Using two wavelengths allows discrimination between coal and silica.
- The unit is very responsive to changes in dust concentrations.
- The cumulative exposure to respirable dust can be calculated.
- The unit was continuously run for 18hrs.
Conclusion

- Real time appears possible
- Further research is necessary
- Once developed it is a “game changer”
  - Detect and mitigate sources
  - PPE becomes second line of defence rather than only protection
- Other uses for the device can be developed
Thank you for the opportunity to present our work.

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President and CEO
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