Real-time material tracking: Testing the suitability of microdot technology for ore tracking

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Synopsis

The ability to conduct real-time material tracking in mines has been a long-standing challenge. Technological innovations such as radio frequency identification technology (RFID) have over the years contributed to the effective tracking of material flow and reporting of metal content. This paper outlines the laboratory procedures and results from testing the suitability of microdot technology as a viable technique for real-time material tracking in mining. The paper clarifies the reasons for conducting the test and presents the material safety data sheet (MSDS) from a South African and Canadian perspective. Microdots from three aerosol systems were immersed in water, heated to 100°C, and crushed into coarse and fine material. These tests were used to ascertain if the technology could withstand mining conditions. A strength, weakness, opportunity, and threat (SWOT) analysis was used to evaluate and compare microdot technology with RFID. It was shown that microdot technology has some potential to track ore parcels because data integrity was retained after exposure to post-blast mining conditions. However, more improvement is required to digitally detect microdots before the technology can be implemented at scale in the mining industry.

Keywords

microdot, technology, radio frequency identification technology, ore tracking, material safety data sheet, core samples, fine samples.

Introduction

Real-time material tracking in production and metallurgical processes remains a challenge. Several technologies, including RFID tags, have been developed over the years to address this problem. This paper outlines the laboratory procedures and results from testing the suitability of microdot technology as a viable technique for real-time material tracking using 10 000, 5 000, and 3 000 microdot aerosol systems. The material safety data sheet is outlined from a South African and a Canadian perspective. Microdots from these aerosol systems were subjected to typical underground conditions including immersion in water, heating to 100°C, and crushing samples from the Bushveld Complex into coarse and fine material. A strength, weakness, opportunity, and threat (SWOT) analysis of microdot technology relative to radio frequency identification (RFID) technology was also developed to decide if microdot technology is suitable for material tracking.

The basis for conducting the tests

Microdots are transparent polyester discs less than 1 mm in diameter. According to Veridot (2016), the discs contain marked lines of text with a unique identification code. The technology is mainly used for asset tracking and identification, including marking and tracking vehicle parts using a unique numbering or identification system. The unique codes are visible using a magnifying lens or an electronic microscope. If microdot technology is determined to be viable for ore tracking, the following may be possible.

- *Tracking material loss*: Integrating microdots with a mine-to-mill optimization process, which will contribute to solving ore loss and routing problems. Material loss and incorrect routing arise when ore flows through ore systems such as orepasses, skips, belts, ore trucks, and hoppers. When the ore reaches the surface, it is stockpiled at different locations or sent to the mill for processing. Discrepancies in terms of quality and quantity estimates arise when reconciling processed and stockpiled ores (actual) with the planned.

- *Improved ore accounting and reconciliation*: Ore accounting involves the measurement and tracking of materials through the value chain from source to the production plant, whereas reconciliation compares production estimates from the mine with estimates from the processing plant (JKMRC, 2008). An effective tracking system will enable better accounting and reconciliation processes. The F1, F2, and F3 system is being practiced by industry and was proposed by Parker (2006).
- *Managing blending and dilution activities*: When the unique microdot identity is linked with the attributes of the ore, it will enable the processing department to better understand the properties of the material being delivered by the mill in real time and ultimately improve the management of blending and dilution activities.

RFID technology

Ore tracking was traditionally made possible with manual innovations, including metal balls, washers, and wooden blocks. More recently, RFID technology has been applied to asset tracking in the mining industry. The technology is also used for safety proximity detection systems to alert miners of moving and static equipment within their area of operation. Tracking explosive initiators (for security purposes) and tracking ore and waste parcels in both surface and underground mines are examples of typical uses. Pilot projects have taken place in South Africa, Australia, and South America (Nozowa *et al*., 2009). In the South African context, the technology is known as the Oretrak system.

The use of RFID technology to track ore parcels throughout the mining process (Figure 1) was demonstrated by JKMRC (2008). In this process, the ore is tagged at the source with markers representing volumes of ore or waste and which are later detected when flowing through the system. The tags may not be detected when material goes to the waste dump. Tagged material that is sent to a long-term stockpile can be detected later on, when it is processed.

Material safety data sheet (MSDS)

The MSDS is defined by the Canadian Centre for Occupational Health and Safety (CCOHS) as a document containing information on the potential hazards of a chemical product and the procedures to be adopted for working safely with such products (CCOHS, 2017).

From a South African perspective, the MSDS is based on the South African Hazardous Chemical Substance Regulations of 1995. Section 9A of the Act discusses the handling of hazardous chemical substances. The Act requires that every person involved in manufacturing, importing, selling, or suppling any hazardous chemical substance shall provide the recipient of that substance with an MSDS as per the guidelines of the International Organization for Standardization (ISO) 1 1014 or ANSIZ400.1.1993. The categories of information required on an MSDS from a Canadian and South African perspective are outlined in Table I.

The South African regulation requires extra information, namely ecological, disposal, transportation, regulatory and other information.

MSDS of the Veridot system

The microdot technology developed in South Africa, known as the Veridot system, has been used in the mining industry to identify copper cathode and aluminium ingots during transportation at mines (Peterson, 2015).

Holomatrix (Pty) Ltd developed the Veridot MSDS and provides additional information such as that pertaining to fire-fighting and accidental release measures. Although the product information is available, the MSDS further instructs that recipients have the sole responsibility to take due precautions regarding the use of the product.

Testing the suitability of microdots for ore tracking

Figure 2 outlines the procedures for testing the microdot technology as a possible real-time ore tracking solution. The four stages in this approach are the determination of the distribution of the microdots over an area, immersion of samples with microdots in water for 24 hours, heating at 100°C, and crushing into coarse and fine samples. This approach was chosen to simulate mining conditions as far as possible.

The microdot aerosol systems [10 000 (A), 5 000 (B), and 3 000 (C)] are depicted in Figure 3 and observed after every stage of the test.

Estimation of the number of microdots over a given area

To estimate the number of microdots that are likely be in a given area, microdots were sprayed on a white sheet of paper with

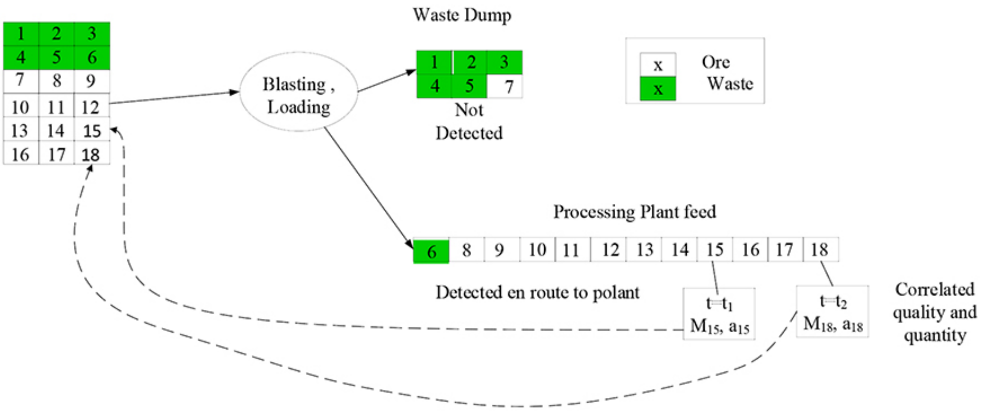


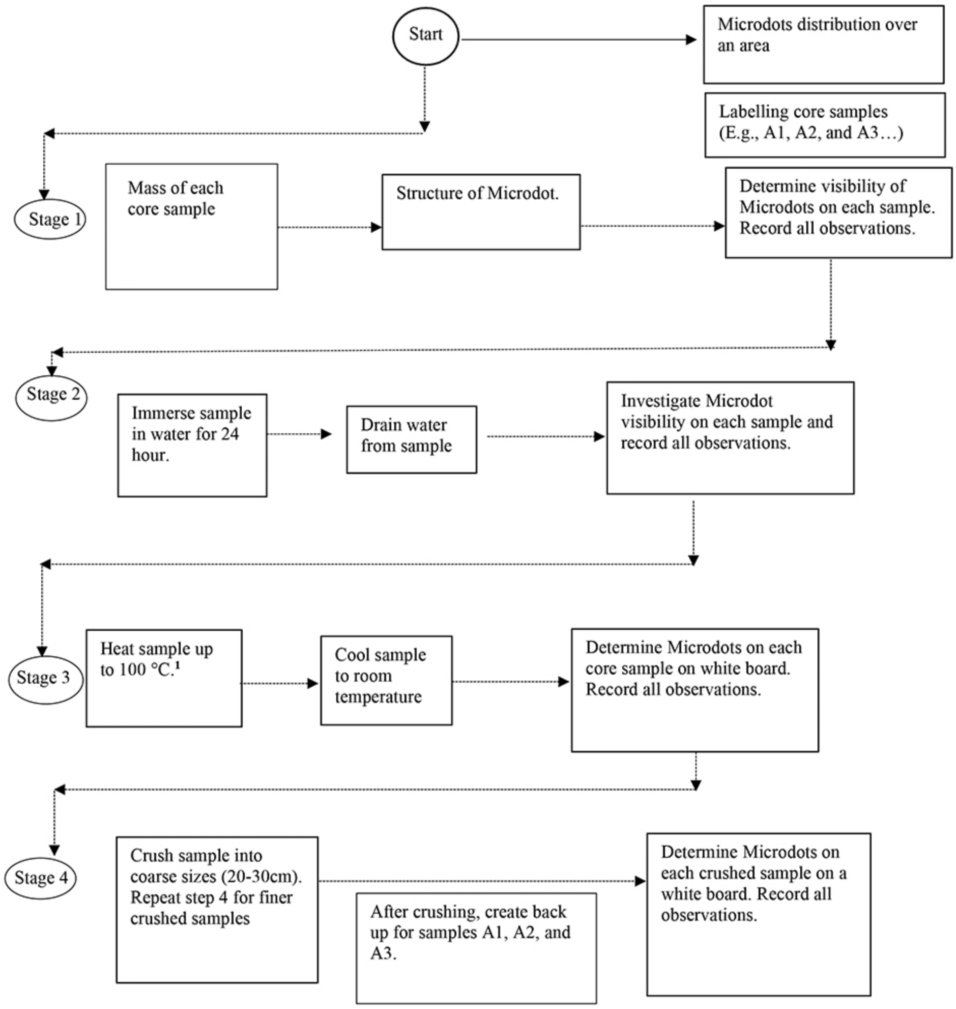
Figure 1—Tracking ore parcels from source to destination (adapted from JKMRC, 2008)

Table I

MSDS from South African and Canadian perspective

No.	MSDS based on CCOHS	MSDS based on South Africa Hazardous Chemical Regulation, 1995, under Occupational Health and Safety act 1993
1	Product information: which includes the product name, manufacturer and suppliers' names, and addresses as well as emergency phone numbers	Product and company identification
2	Hazardous ingredients	Composition of ingredients
3	Physical data	Hazard identification
4	Fire or explosion hazard data	First-aid measures
5	Reactivity data: information on the chemical instability of a product and the substances it may react with	Handling and storage
6	Toxicological properties: health effects	Exposure control/personal protection
7	Preventive measures	Physical and chemical properties
8	First-aid measures	Stability and reactivity
9	Preparation information in terms of who is responsible for the preparation and date of preparation of the MSDS	Toxicological information
10		Ecological information
11		Disposal considerations
12		Transport information
13		Regulatory information
14		Other information

(Cudjoe, 2020)



[1] Although the Microdot technology can survive explosive temperatures up to a maximum of 1200°C, laboratory limitations allowed the test to be conducted to a maximum of 100 °C. Further work is needed to test the effect of heat above 100 °C, dust and wet surface on microdots.

Figure 2—Procedure for testing microdots (Cudjoe, 2020)

Figure 3—Veridot aerosol (10 000, 5 000, and 3 000) **systems and their codes** (Cudjoe, 2020)

Table II

Distribution of microdots on 2.5 cm x 2.5 cm area

Microdots distribution						
Square area = 2.5cm x 2.5cm			**Square area in cm^2 = 6.25**			
Sheet	Box 1	Box 2	Box 3	Average		Average of sheets 1 and 2
1	7	9	4	6.7	7	5.5
2	5	4	4	4.3	4	

Source: (Cudjoe, 2020)

Table III

Estimate of microdots around each sample

Area around specimen (cm^2)	Average number of microdots	Square area in cm^2	No. of microdots around sample
315.31	6	6.25	303.0
316.01	6	6.25	303.4
315.31	6	6.25	303.0
315.31	6	6.25	303.0
315.31	6	6.25	303.0
316.01	6	6.25	303.4
315.31	6	6.25	303.0
315.31	6	6.25	303.0
315.31	6	6.25	303.0

(Cudjoe, 2020)

dimensions 2.5 cm × 2.5 cm. All three aerosol systems (10 000, 5 000, and 3 000)[2] were used. Table II gives an estimation of the average number of microdots within the 2.5 cm^2 area and Table III estimates the number of microdots on a sample area.

From Table III it can be estimated that six microdots fell within the 2.5 cm^2 area, whereas an average of 303 microdots was estimated on the sample area.

Stage 1 - Basic measurements of samples and structure of Microdots

Samples of anorthosite rock from the Bushveld Complex were obtained and labelled as indicated in Figure 4:

- Samples A1, B1, C1[3]
- Samples A2, B2, C2[4]
- Samples A3, B3, C3[5].

Sample mass, diameter, and length were recorded. The results appear in Table IV.

Figure 4—Anorthosite rock samples from the Bushveld Complex (Cudjoe, 2020)

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[2] Number of microdots in the aerosol can.

[3] Coated with 10 000 microdots.

[4] Coated with 5 000 microdots.

[5] Coated with 3 000 microdots.

Table IV

Basic measurements of samples

Sample	Mass 1 (g)	Mass 2 (g)	Mass 3 (g)	Average mass (g)	Diameter (cm)	Length (cm)
A1	986	986	986	985.9	4.7	20
A2	992	992	992	991.9	4.8	20
A3	986	986	986	985.6	4.7	20
B1	1000	1001	1001	1000.5	4.7	20
B2	999	999	999	999.0	4.7	20
B3	994	994	993	993.6	4.8	20
C1	998	998	998	997.8	4.7	20
C2	995	995	995	994.6	4.7	20
C3	934	934	934	934.4	4.7	20

(Cudjoe, 2020)

Figure 5—Microdot shape and codes (Cudjoe, 2020)

Table V

Microdots visibility on core samples

Core sample	Code	Visibility	Comment on microdots distribution
A1	10 000 microdots= ZAVDTATHVX	Yes	Very Good - microdots are distributed on the sample
B1		Yes	Very Good
C1		Yes	Poor - Few microdots seen on the sample
A2	5 000 microdots = ZAVDT97N7AN3	Yes	Very good
B2		Yes	Poor
C2		Yes	Good
A3	3 000 microdots = ZAVDANVULC	Yes	Very good
B3		Yes	Very good
C3		Yes	Good

(Cudjoe, 2020)

To understand the structure of the microdots, thin section cores were made at the School of Geoscience at the University of the Witwatersrand (Cudjoe, 2020) and sprayed with 10 000, 5 000, and 3 000 microdots aerosol systems. These microdots were viewed under an electronic microscope (Olympus 93X4L).

Microdots are hexagonal shaped discs ranging from 0.3 mm to 1 mm in diameter (Figure 5). Examination of the codes in Figure 5 and their respective barcodes (Figure 3) shows that the microdots are from 10 000, 5 000, and 3000 microdot aerosol systems. The visibility of microdots on core samples (prior to immersion in water, heating, and crushing) using 10 000, 5 000, and 3 000 microdot aerosol systems was determined. The results are presented in Table V.

From the results in Table V, microdots are generally visible by the naked eye although the unique codes could not be determined. The microdots distribution was classified as follows:

Table VI

Results after immersing samples in water for 24 hours

Sample	Code	Visibility	Comment
A1	ZAVDTATHVX (10 000)	Yes	Water has no influence on microdots distribution on sample the microdots stick to sample; microdots were visible under the microscope; codes were still readable
A2	ZAVDT97AN3 (5 000)	Yes	
A3	ZAVDANVULC (3 000)	Yes	
B1	ZAVDTATHVX	Yes	Water did not affect microdots distribution; microdots stick to the surface of the sample; microdots are visible under microscope; codes are still readable.
B2	ZAVDT97AN3	Yes	
B3	ZAVDANVULC	Yes	

Cudjoe (2020)

Table VII

Results of microdots visibility after heating samples at 100°C

Sample	Code	Visibility	Comment
A1	ZAVDTATHVX	Yes	There was no influence of heat on microdots. Microdots still stick to the surface of samples. microdots were visible with the naked eye after heating and codes were visible using the microscope.
A2	ZAVDT97AN3	Yes	
A3	ZAVDANVULC	Yes	
B1	ZAVDTATHVX	Yes	The heat did not have any influence on microdots; the microdots still stick to the sample surface; microdots were readable under the microscope.
B2	ZAVDT97AN3	Yes	
B3	ZAVDANVU	Yes	

Cudjoe (2020)

➤ *Very good* – Microdots are present and evenly distributed around sample
➤ *Good* – Microdots are present but concentrated on one side of the sample
➤ *Poor* – Microdots are present but not clearly visible.

Stage 2 – Samples immersed in water

Samples were immersed in water for 24 hours. The results are shown in Table VI.

From Table VI it can be perceived that water has no influence on the visibility of microdots since they were still visible on all the samples when observed under the microscope.

Samples were placed in an oven and heated to a maximum of 100°C[6] and then allowed to cool to room temperature. Observations made in this stage are depicted in Table VII.

The results in Table VII confirm that the data integrity of microdots is not affected by water and heat. This is shown in the images in Figures 6, 7, and 8.

Stage 4 – Crushing samples to coarse and fine sizes

This stage involves crushing samples into coarse and fine sizes using the Rocklab crushing machine[7]. Microdots were visible with the naked eye and the codes were readable under a microscope after crushing to coarse sizes. Figure 9 depicts the visibility of microdots on coarse crushed samples. The results of the visibility check conducted on samples are depicted in Table VIII.

Table VIII shows that crushing has no impact on the microdot visibility. Coarse particles were further crushed into smaller sizes (<1 mm to >3.35 mm)[8]. Samples were further screened to classify them in sizes >3.35 mm, 2–3.35 mm, within 1 mm and 2 mm, and less than 1 mm as depicted in Figure 10.

The visibility of microdots on fine samples is shown in Table IX.

SWOT analysis of microdots in relation to RF tags

A SWOT study was undertaken to evaluate the effectiveness of microdots as a viable tracking solution in comparison to current tracking technologies in South Africa's mining industry.

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[6] Maximum blasting temperature ranges from 1270°C for tin and tungsten powders to 2520°C for aluminium, magnesium, and titanium powders (Cashdoller and Zlochower, 1990). Microdots would therefore not be able to withstand explosives that generate heat exceeding 1200°C.

[7] Coarse sizes range from 2 cm to 3 cm, and fine sizes ranges from 3.35 mm to less than 1 mm.

[8] Coarse sizes range from 2 cm to 3 cm, and fine sizes ranges from 3.35 mm to less than 1 mm.

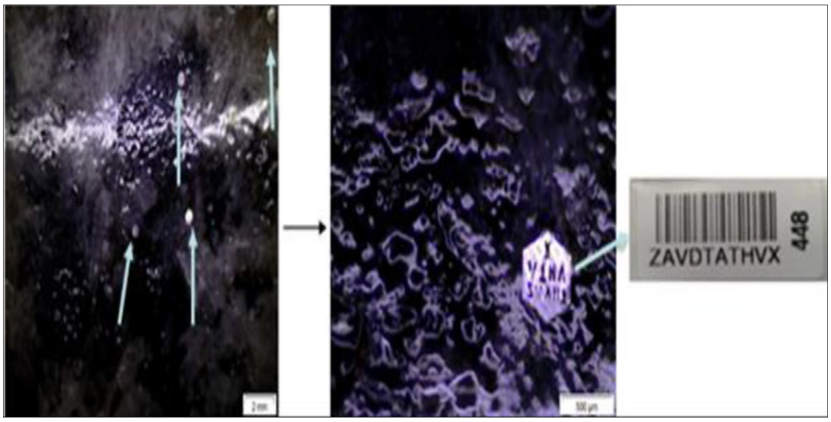

Figure 6—Microdot (10 000) _visibility after subjection to water and heat (Cudjoe, 2020)

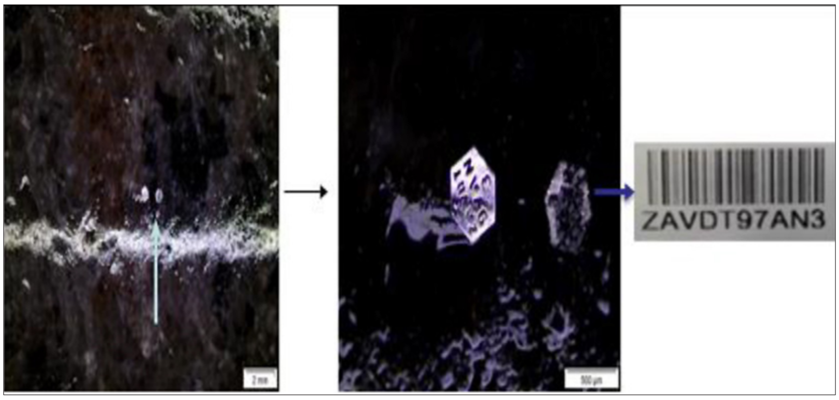

Figure 7—Microdot (5 000) visibility after subjection to water and heat (Cudjoe, 2020)

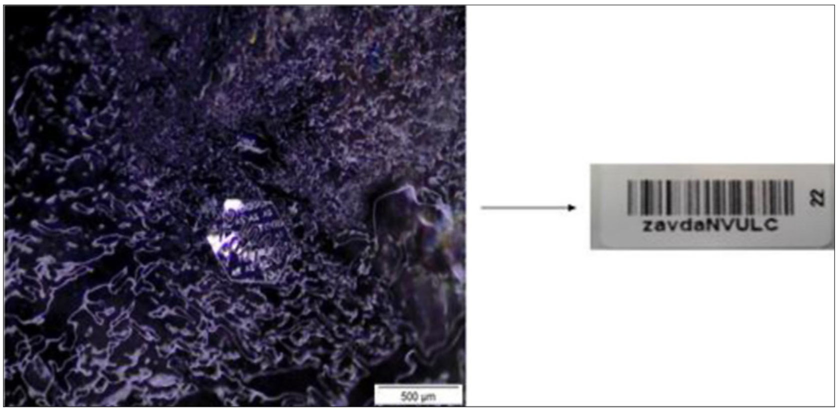

Figure 8—Microdot (3 000) visibility after subjection to water and heat (Cudjoe, 2020)

Table VIII

Results of microdot visibility check on coarse samples

Sample	Code	Visibility	Comment
A1	ZAVDTATHVX	Yes	Microdots are still visible under the microscope; codes ate still readable; visibility was slightly impaired by dust; microdots still stick to samples.
A2	ZAVDT97AN3	Yes	
A3	ZAVDANVULC	Yes	

Cudjoe (2020)

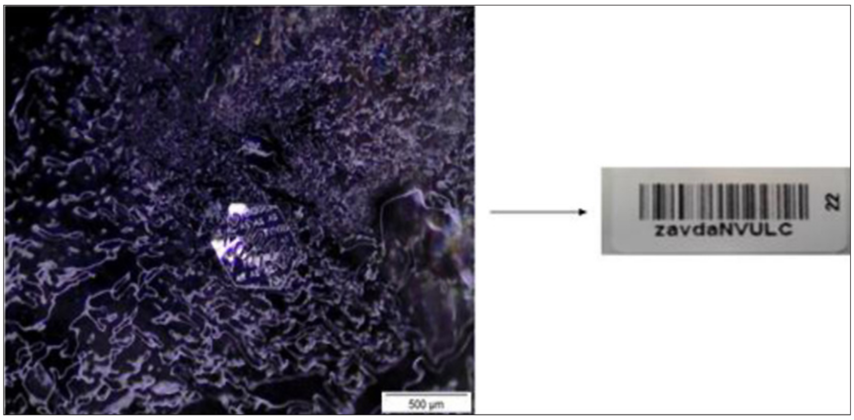

Figure 9—Microdots on coarse samples (Cudjoe, 2020)

Figure 10—Screened samples into various fine sizes (Cudjoe, 2020)

Table X is a SWOT diagram of the microdot technology in comparison to RF tags. Although there are a number of strengths identified (data integrity is retained after subjection to heat, water, and crushing), the potential hazard due to the propellant of the aerosol system (being flammable) makes it inappropriate in the coal industry. This is because the coal industry is faced with frequent spontaneous combustion issues. The technology is also inappropriate for an underground mine because of mine ventilation issues.

Conclusion

This paper describes laboratory testing conducted to determine the potential of microdot technology for real-time tracking using core and broken ore samples from the Bushveld Complex. The MSDS was discussed based on the Canadian Centre for

Table IX

Visibility of microdots in fine samples

Size distribution	Mass (g)			Visibility	Comments
Sample A1 sprayed with 10 000 microdots					
3.35	67.600	67.600	67.600	Yes	Four microdots were seen on four different broken particles; Codes on the microdots couldn't be read due to dust cover.
2	195.500	196.900	197.000	Yes	Three microdots were seen on samples and codes were readable
1	120.700	120.700	119.006	No	The particles are small and hence difficult to identify microdots through a microscope
<1	150.006	150.009	151.003	No	
Sample sprayed with 5 000 microdots					
3.35	86.000	85.600	85.700	Yes	Four microdots were seen on four different particles. Codes on microdots were readable under a microscope
2	205.300	205.000	205.300	Yes	Five microdots were identified on four different particles. Codes were also readable under a microscope
1	109.700	110.500	110.500	No	Microdots could not be seen under microscope
<1	156.200	158.200	158.300	No	
Sample sprayed with 3 000 microdots					
3.35	101.100	101.700	99.700	Yes	Three microdots were seen on three different particles. The codes were readable under the microscope
2	201.700	201.300	203.900	Yes	Two microdots were seen on two different particles. Codes were also readable.
1	96.600	96.900	96.100	No	Due to the tiny nature of particles, it was difficult to see microdots on any of the particles. No microdot was visible under the microscope.
555<1	132.900	133.300	133.600	No	

(Cudjoe, 2020)

Table X

SWOT diagram of microdot technology in comparison to past and present tracking technologies (Cudjoe, 2020)

Strengths	**Weaknesses**
• Data integrity is retained after exposure to undergoing conditions such as water immersion, heating to 100°C, and crushing. • Microdots stick to the surface of the core or broken rock. • The health and safety impacts of using the microdot aerosol system can be minimized by the effective use of personal protective equipment (PPE). • Microdots' unique codes can be linked to ore attributes in a single database to enable the management of ore flow properties.	• The microdot aerosol system propellant is flammable. • The visibility of code is affected by dust. • Microdots do not transmit signals to a reader and hence detection is done manually and not digitally.
Opportunities	**Threats**
Further opportunities to improve the technology include: • How to enable real-time digital tracking of microdots and their respective codes • How to combine the technology in the ore flow process stream, which is usually a complex one • How to use the technology to ensure easy identification of mixed ore sources and their locations • How to use the technology to prevent misrouting challenges • How to use the technology to minimize risks and identify potential hazards in real time.	• Due to the flammable nature of the propellant in the aerosol system, it cannot be used in the coal industry or in other mines where there are methane concentrations. • Due to the presence of dust in mines, it would be difficult to identify the codes of microdots.

Occupational Health and Safety and the South African Hazardous Chemical Substance Regulations, 1995. Although these regulations impose similar conditions, the former has more requirements, namely ecological, disposal, transportation, regulatory, and other requirements.

Basic measurements (mass, diameter, and length) were conducted on core samples of anorthosite rock samples from the Bushveld Complex. The structure of the microdots was determined as well.

Further laboratory tests were carried out to determine the visibility of microdots on samples using 10 000, 5 000, and 3 000 microdot aerosol systems. Microdots were generally visible irrespective of the aerosol system that was used. Immersion of samples in water for 24 hours had no influence on the visibility of microdots. Samples were heated to a maximum of 100°C and allowed to cool to room temperature. Heat had no effect on the data integrity of the microdots. The final stage of test work involved the crushing of samples into coarse (2–3 cm) and fine (1.0–3.35 cm) sizes. The microdots were visible, and the codes were readable under the microscope.

A SWOT study was undertaken to evaluate microdots as a viable tracking solution against the RF tags currently used in the mining industry. A positive strength identified in the microdots technology is its ability to retain data integrity after subjection to heat, water, and crushing. However, the aerosol system renders it inappropriate for use in the coal industry because of spontaneous combustion risks. Due to ventilation issues, the technology may also not be suitable for underground mines. However, microdot technology could still have some potential for real-time material tracking if the microdots can be digitally tracked along with parts of the ore flow.

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