Development of an Integrated Antenna Sensor for the Detection of Cyanide

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Introduction & Objectives

Cyanide is a poisonous agent potentially causing death within minutes. Detecting the presence of cyanide is necessary to identify potential chemical weapons threats. This device would be an added layer of anti-terrorism security. The goal of this project was to print an integrated antenna sensor for the detection of cyanide. The antenna sensor will emit two different signals depending on the state of the material i.e. compromised or uncompromised. The following four goals outline the stages required to develop the device.

1) Establish a relationship between the sensing material properties(Au or Ag) and the presence of aqueous cyanide.

2) Test the electrical behavior of the sensing material before and after cyanide exposure.

3) Design and fabricate the antenna circuit to produce a different signal when the integrity of the sensor component is compromised.

4) Integrate the sensing material in the antenna and test the antenna behavior in the presence of cyanide.

Procedures

Suspended Gold Wire

- Slides were fabricated with electrical leads to test the change in conductivity when gold wire was exposed to cyanide solution as shown in Figure 1a.
- Initial resistance readings were recorded and samples were monitored at intervals until recorded resistance readings increased to kilo or mega ohms, which indicated the exposed material had been dissolved by the cyanide solution.
- Verification was accomplished under magnification, as the gold wire had dissolved or was broken (Figure 1b).
- 70 and 12.7 µm diameter gold wires were evaluated.
- Minimum dissolution times for each diameter of gold wire are shown in Table 1.

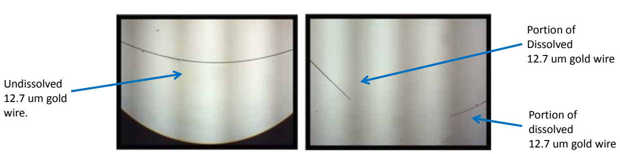

Figure 1a. 12.7 µm gold wire before cyanide exposure (intact)

Figure 1b. 12.7 µm gold wire after cyanide exposure (dissolved)

Table 1. Gold wire resistance readings

Sample	Initial resistance	Final resistance	Time to dissolution
Gold wire 70 µm diameter			
#3	41 Ω	500 k Ω	90 minutes
#4	26 Ω	2.1 M Ω	75 minutes
#5	58 Ω	1.1 M Ω	80 minutes
#6	46 Ω	1.2 M Ω	80 minutes
Gold wire 12.7 µm diameter			
#9	35 Ω	64 k Ω	40 minutes
#10	46 Ω	128 k Ω	*10 minutes
#11	41 Ω	98 k Ω	*20, 40 minutes
#12	28 Ω	178 k Ω	40 minutes

* The sample did not evenly dissolve across the slide but indicated a break.

Submerged Silver Trace Deposit

- Silver traces were deposited as shown in Figure 2.
- Using the same testing method as the *Suspended Gold Wire*, electrical leads were affixed to the electrode pads to continually monitor the resistance readings.
- The resistance readings are summarized for the silver trace deposits in Table 2.

Table 2. Silver deposit resistance readings

Silver Trace Deposits			
Sample	Initial resistance	Final resistance	Time to dissolution
#1	52 Ω	133 kΩ	7 minutes
#2	64 Ω	67 kΩ	4 minutes

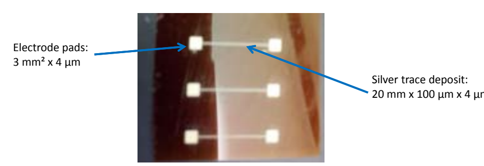

Figure 2. Silver deposits with silver deposit electrode pads

Antenna Integrated with Sensing Material

- An all silver dipole antenna was printed with an Optomec M_3D aerosol jet printer as shown in Figure 3a.
- The sensing material was placed on one arm of the antenna 1.25 mm in length.
- A portion of the antenna was coated with a 1 micron thick layer of poly(methyl methacrylate) to protect it from the cyanide solution.
- The antenna was submerged in cyanide solution to expose the sensor as shown in Figure 3b.

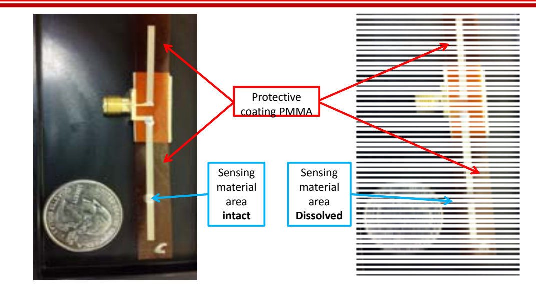

Figure 3a. Dipole antenna with silver sensing material before cyanide solution exposure

Figure 3b. Dipole antenna with silver sensing material dissolved after exposure to cyanide solution

Results & Conclusions

Post exposure evaluation of the dipole antenna concluded that the antenna emitted a shifted signal indicating the device had been exposed to cyanide. The antenna sensor has been validated to produce two different signals depending upon the integrity of the sensor. The unexposed signal was 2.82 GHz and the exposed signal being emitted had two peak signals resonating at 2.63 and 3.1Ghz. The signal shifts are displayed in figure 4 below.

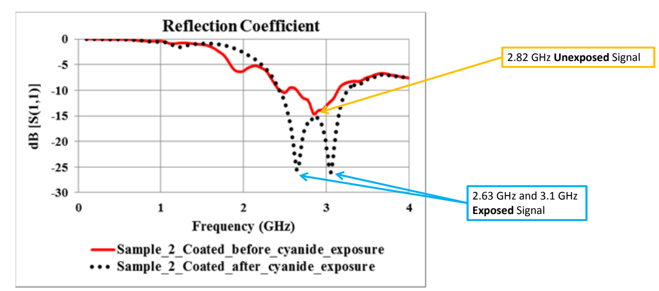

Figure 4. Before and after cyanide exposure signal emissions from antenna sensor

Future Work

Further experimentation of the antenna design will refine the signal shift emitted from the antenna post exposure. The ideal sensing material must still be determined. Current ink formulations using silver are capable of printing the device and sensing cyanide as in Figure 2. The development of a high yield gold ink formulation is still in need to properly determine the best material to be integrated into this device for optimum sensor performance. Once an ideal sensing material has been isolated, additional testing to identify the minimal concentrations of cyanide that can be detected is needed.