Nitrous Oxide Detection in Dental Operatories

Stephen Schneider, Nazia Hasan, Gaurang Dimri, Robert E. Baier (PhD, PE)

Abstract

According to a report published by the National Institute for Occupational Safety and Health, unwanted nitrous oxide (N_2O) exposure levels in dental operation rooms, which should be around 50 parts per million (ppm), were shown to be as high as 1000 ppm. When N_2O is inhaled, it is rapidly absorbed through the lungs to the alveoli, blood, and tissues. Overexposure can result in adverse health effects such as neurological, renal, and liver disease. Current N_2O detection methods, which use IR spectroscopy, are very costly. A cheaper, alternative method must be implemented to alert dental health professionals of N_2O overexposure.

Background

- In order to regulate the N_2O overexposure limit of 50 ppm (set by NIOSH) in dental operatories, we would like to design a detector. This detector will act like a smoke detector; alerting dentists when the N_2O levels are reaching maximum overexposure levels.
- Two devices were used to calibrate the detector.
- The first device we used was an infrared gas analyzer, or *MIRAN*, device. The MIRAN device allows us to release gases of different volumes into the device and determine the spectrum of any gas with asymmetric covalent bonds. This analytical ability, specifically for N_2O, can assist us in finding the infrared peak for nitrous oxide.
- The second device is the *contact potential device*. The contact potential device measures the voltage potential difference between two surfaces. The two surfaces are the reference electrode which is part of the device, and a metal, semiconducting plate that is inserted in the device. This entire system is exposed to N_2O and the voltage differences are then read within the contact potential device.

Desired Outcomes

- Determine the optimal plate-monolayer setup to detect N_2O in the contact potential device.
- Graph contact potential voltage and % transmittance to determine a correlation curve, with IR confirmation.
- Use correlation curve to design readout device to convert contact potential voltage to ppm.
- This will be used to as a "safe-limit" device to regulate the NIOSH overexposure limit of N_2O at 50 ppm.

Methods and Materials

Device 1: MIRAN

- The initial steps of the project involved understanding and determining the optimal setup for the MIRAN device. The infrared spectra of gases such as methane, diesel fumes, and biodiesel fumes were used to determine this.
- The optimal setup for the MIRAN was determined to be a path length of 6 cm, a low gain, and with a main peak value of 7.75 µm.
- N_2O was injected into the MIRAN device to determine the peaks. Once the main peak was found, the inserted volume was incrementally varied to determine a relation between volume and % Transmittance.

Device 2: Contact Potential Device

- All combinations of Germanium, Titanium, and Steel plates with monolayer coatings of both Stearic Acid and Octadecylamine were used to determine the optimal setup for N_2O attraction and contact potential measurement.
- ΔV readings were recorded

Figure 1 – Device 1

Infrared gas analyzer (MIRAN)

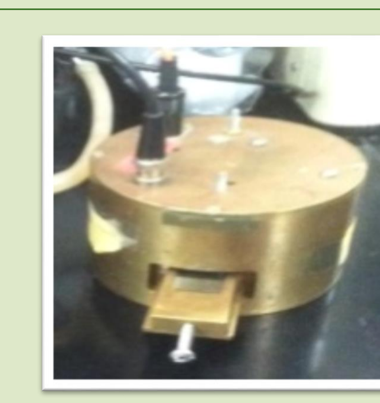

Figure 2 – Device 2

Contact potential device

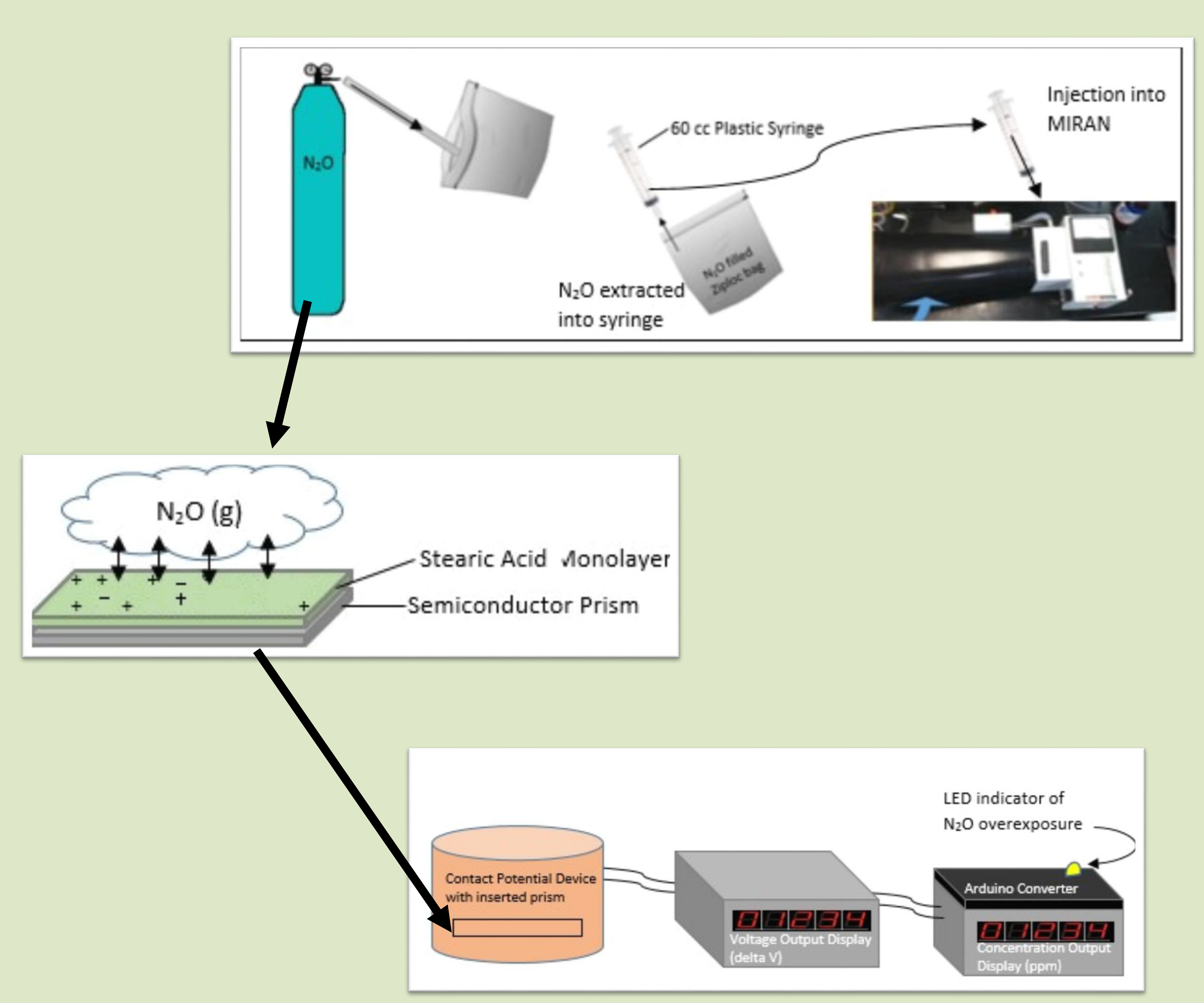

Figure 3: Methods and Desired Outcome

Results

Germanium Plate: Both types of coatings were observed to create a drop of approximately 0.04 ΔV after N_2O exposure. The difference between the two different types of monolayers was almost negligible on Germanium.

Steel Plate: The drop of ΔV was shown to be much more significant, averaging about .0754 ΔV with the Stearic Acid monolayer and .0887 ΔV when using the Octadecylamine monolayer. Varying monolayer coatings did not change the output by more than .02 ΔV on Steel.

Titanium Plate: There was an increase of about .04 ΔV upon exposure of N2O to an Octadecylamine coated plate. When using the Stearic Acid monolayer on Titanium, the output dropped by about .1546 ΔV, a decrease much greater than when using other metals with the same monolayer

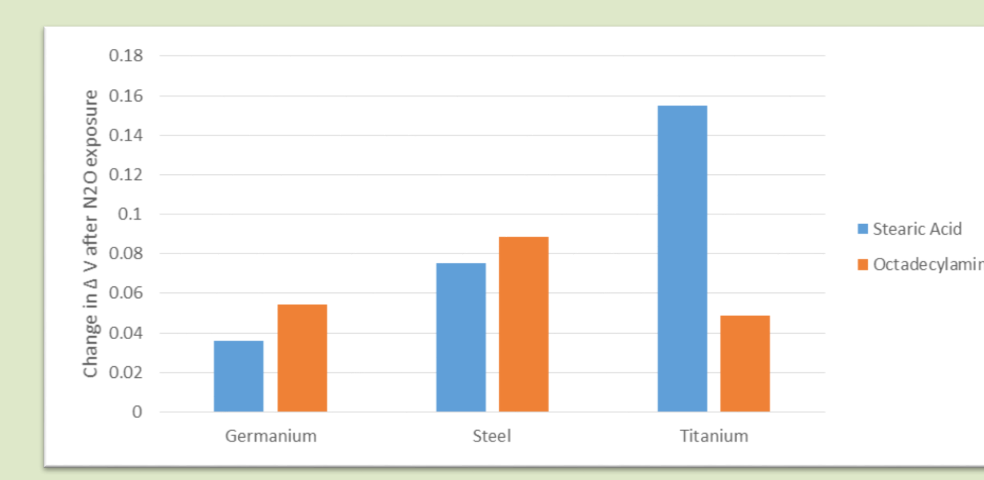

Figure 4: Change in ΔV before and after N_2O exposure to a Germanium, Steel and Titanium plate.

Conclusions

- A Titanium plate coated with Stearic Acid provides the most sensitivity to N_2O when using a contact potential device.
- The relationship between volume and IR % Transmission is an exponential decay with the equation $y = e^{-0.106x}$
- A correlation between the MIRAN's percentage transmittance output and the contact potential ΔV output during N_2O administration can be used to program an Arduino that will alert dental staff of unsafe levels of N_2O.

References

1. "Controlling Exposures to Nitrous Oxide during Anesthetic Administration." Centers for Disease Control and Prevention. Centers for Disease Control and Prevention, 06 June 2014. Web. 02 Oct. 2014.
2. Cohen; Brodsky, "Adverse Effects of Nitrous Oxide" Medical Toxicology 5 (1986) 362-374. PubMed with full text. Web. 15 Nov. 2015.
3. Calibration of Contact Potentials for Detection of Biofilm Base-Layer Orientations. A University at Buffalo 2012 Biomedical Engineering Senior Design Project. Peter Oldani and Robert Baier.