Application Note

Comparison of gas detection limits of NDIR Thermopile, Pyroelectric and PbSe detectors

Nondispersive infrared (NDIR) spectroscopy technique allows the reliable measurement of various gases including volatile organic compounds (VOC) over a broad concentration range. As compared to electrochemical alternatives, gas monitoring systems based on NDIR are in high demand due to their robustness. This makes them suitable for gas analysis in medical and automotive industry, environmental pollution monitoring, emission monitoring and gas leak detection in the oil, gas and chemical industries.

For any gas concentration measurement system, the detection limit is the figure of merit. It characterizes the minimum detectable change in concentration that can be measured. The detection limit for a given NDIR gas monitoring system depends strongly on the measurement setup itself, the gas and its concentration to be measured. The theoretical background and the mathematical calculations for the detection limit are explained in the white paper "Carbon dioxide (CO2) measurement using Non-Dispersive Infrared (NDIR) Spectroscopy with lead selenide (PbSe) photodetectors".

In designing a gas measurement system, the system designer must consider key parameters such as reliability, measurement frequency, power consumption, mechanical dimensions and desired detection limit. This application note compares the achievable gas detection limits of different state-of-the-art photodetector technologies for several different gases. For a fair comparison, a hypothetical NDIR gas concentration measurement setup, as depicted in Figure 1 is simulated. Table 1 lists the considered system parameters for this setup, while Table 2 presents the calculated detection limits for given concentrations.

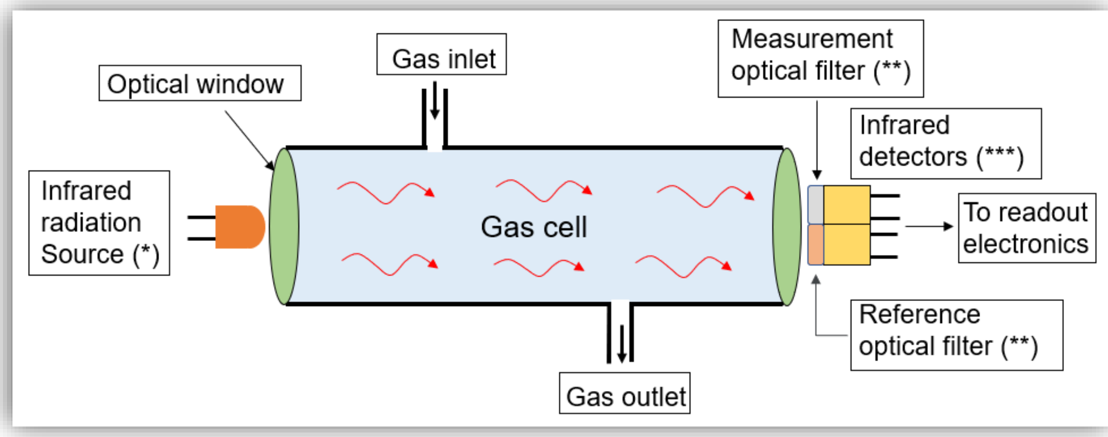

Figure 1 Hypothetical NDIR gas concentration measurement setup.

Infrared Source (*)			
Optical power output		7	mW
Opening angle		15	°
Modulation frequency		10	Hz
Optical filters (**)			
Measurement optical filter			
Center wavelength		Gas specific (see **Table 1**)	
Full-width half maximum		60 to 180	nm
Reference optical filter			
Center wavelength		3.91	µm
Full-width half maximum		80	nm
Infrared Photodetectors (***)			
Active area		1	mm^2
Detectivity	Thermopile	1.5×10^8	cm √Hz / W
	Pyroelectric	2.5×10^8	cm √Hz / W
	PbSe	2.3×10^9	cm √Hz / W
Optical path length		20	mm

Table 1 System parameters for the hypothetical setup in Figure 1 used in the calculation of the detection limit for a particular gas.

As explained in the above referenced white paper, the detection limit depends, amongst other factors, on the concentration range being measured. The concentrations in Table 2 are selected for each gas based on their exposure hazard limits given by NIOSH and OSHA.

			Detection Limits [ppm]		
Gas	Wavelength [µm]	Concentration [ppm]	Thermopile	Pyroelectric	PbSe
Carbon Monoxide CO	4.6	1000	76	45	5
Water H_2O	2.65	10000	181	109	12
Carbon Dioxide CO_2	4.26	10000	9	5	0.6
Nitrous Oxide N_2O	4.52	1000	9.7	5.8	0.6
Phosphine PH_3	4.15	100	76	46	5
Sulphur Dioxide SO_2	4.0	1000	960	574	63
Formaldehyde CH_2O	3.6	10000	42	25	3
Methane (+ HCs) CH_4	3.4	10000	87	52	6
Ethylene C_2H_4	3.2	10000	141	85	9
Acetylene C_2H_2	3.05	10000	83	50	5.5
Hydrogen Cyanide HCN	2.98	500	100	60	6.5

Table 2 List of gases and respective detection limits (a lower detection limit corresponds a higher resolution) measured using NDIR technique with state-of-the-art Thermopile, Pyroelectric and Lead Selenide (PbSe) detectors. Note: These values detail a theoretical comparison in between the detection limits for different detector technologies. The actual detection limit is highly system dependent.

Table 2 clearly shows that trinamiX PbSe photodetectors offer a significantly better detection limit due to their higher detectivity in the wavelength range 1-5 µm as compared to pyroelectric and thermopile technologies. A system designer can utilize this advantage to either have a gas sensor with a better resolution or to build a more compact and lower power gas detection system by reducing the system parameters, such as size of photodetector and optical path length or using a lower power infrared source.

Conclusion

trinamiX PbSe detectors, due to their high detectivity, faster response and high selectivity enable NDIR gas monitoring with an improved accuracy and fast measurement rate. The detectors are available in traditional TO packages and additionally as bare-chips with patented thin film encapsulation. These bare chip sensors can provide a significant reduction in the footprint and BoM (bill of materials) cost of the gas detection system. Multi-pixel sensors can also be supplied to enable simultaneous detection of specific gases in multi-gas detection systems. The availability of a wide range of components as well as the large-scale manufacturing facilities, technology and interface electronics development expertise and application specific knowledge make trinamiX the perfect partner to assist in overcoming gas detection challenges.

About trinamiX:
trinamiX www.trinamixsensing.com is a wholly-owned subsidiary of BASF SE, the world's largest chemical company. Founded in 2015, trinamiX has developed a wide-ranging portfolio of technologies and products around both infrared detection as well as 3D imaging and distance measurement. The company employs a team of more than 100 experts across a wide range of scientific disciplines.

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