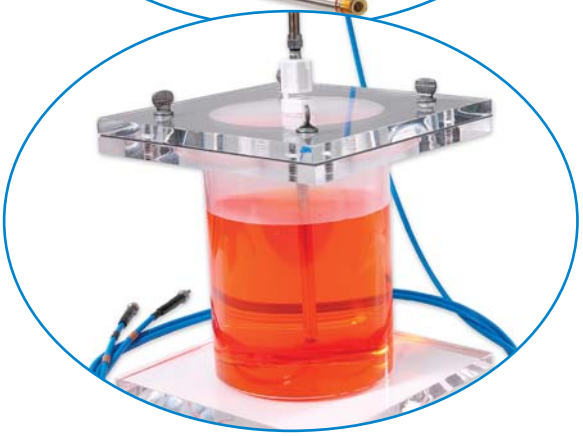
Optical Sensors



Overview: Optical Sensors

Sensors for Real-Time, In Situ Analyte Monitoring

Ocean Optics has combined its expertise in miniature fiber optic spectroscopy with advances in materials science to develop an innovative line of modular fiber optic chemical-sensing systems.

Sensors are constructed by placing a transducer material at the tip of an optical fiber. These materials change optical properties in response to specific analytes in their immediate environment.

Our transducer materials include both fluorescence-based and absorbance-based indicators. These indicators are immobilized or trapped in a variety of proprietary materials, including sol-gels, hydrophobic and hydrophilic polymers, and cellulose acetate. Materials can be coated on flat substrates such as optical fibers, optical flats, cuvettes and other containers.

Optical sensors can be used for a variety of applications. Here, our "R" Optic Oxygen Sensor monitors oxygen in a liquid.

We produce components that can be used to monitor oxygen or pH in biological samples, headspace gases, slurries, cosmetics, foods, gases and liquids in natural environments.

Optical O_2 Sensors vs. Electrodes

Commercial Electrodes		Fiber Optic Oxygen Sensors
Most electrodes are designed for use in gas or liquids, but not both media	✔	Sensors measure both oxygen gas and dissolved oxygen in gases and liquids
Polarographic electrodes can be affected by changes in pH, salinity and ionic strength of the environment	✔	Sensors are immune to environmental changes in pH, salinity and ionic strength
Electrochemical electrodes are subject to interference from a number of substances and sampling conditions	✔	Sensors are immune to interference from moisture, carbon dioxide, methane and other substances
Electrodes can have a response time of 1.5 minutes, depending on temperature	✔	Sensors response time is <1 second for dissolved O_2 and O_2 gas
Electrodes have a typical lifetime of 3 months	✔	Sensors have a long life – more than 1 year
Electrodes can consume oxygen of ~0.1 micrograms/hour	✔	Sensors do not consume oxygen, allowing for continuous contact with sample
Calibration may be needed hourly	✔	Frequent calibration is unnecessary
The temperature range for some electrodes is 0-45 °C	✔	Sensor probe temperature range is -60 °C to +80 °C
Electrodes often introduce electrical currents into a sampling setup	✔	Sensors allows remote sampling without introducing electrical fields to sample

Ocean Optics Offers Optical Sensor Coating Services

Our optical-sensor coating services provide OEMs and product developers with multiple solutions in creating proprietary products for chemical sensing applications. You can take advantage of these services to develop and manufacture a variety of custom optical oxygen and pH sensor accessories including fiber optic probes, cuvettes, Petri dishes, microscope slides and more. The added services include the licensing of Ocean Optics proprietary oxygen and pH coating technologies, custom sensor coating development, and contract manufacturing services.

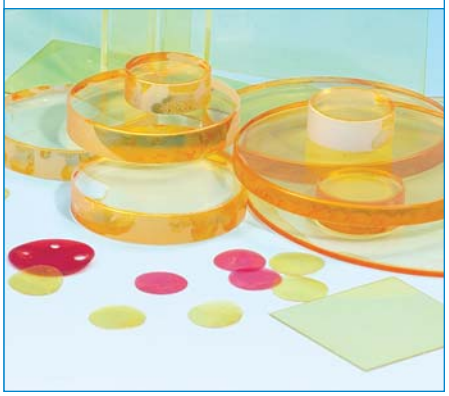
We can supply our proprietary optical sensor coating technologies to you through a license agreement. We manufacture the coatings and apply them to any media specified.

You can supply a proprietary indicator to be included in an Ocean Optics coating. We then produce the coating and apply it to the media specified.

You can supply a proprietary coating and indicator to us and we will apply the coating to the media specified. This option requires a contract agreement.

We can research and develop a proprietary coating for you. This option is available through NRE and/or research fees.

Services may also include costs associated with the type of sensor material; the surface area; and the time required to apply the sensor material to a substrate.

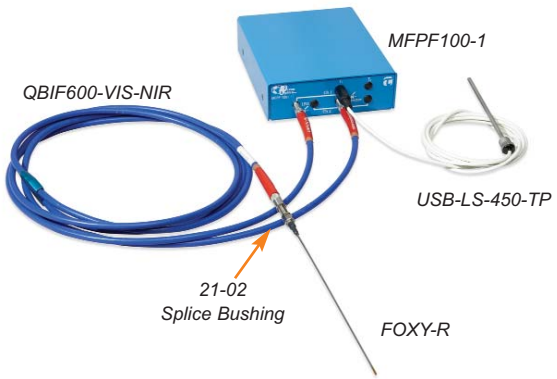


Oxygen Sensor Operation

Our Fiber Optic Oxygen Sensors are coated probes that use fluorescence quenching to measure the partial pressure of dissolved or gaseous oxygen. You specify a sensor probe with one of our three sensing formulations -- along with a sensing detector, excitation source and software -- to build a complete system that typically works like this:

1. An LED sends excitation light to one leg of a bifurcated optical fiber assembly.
2. The fiber carries the light to the oxygen probe, which is polished to a 45° angle. The distal end of the probe tip consists of sensor formulation trapped in a sol-gel matrix, immobilized and protected from the sample. FOXY and HIOXY sensors use a ruthenium formulation, while FOSPOR sensors use a Pt-porphyrin formulation.
3. The light from the LED excites the ruthenium or porphyrin sensor formulation at the probe tip. The excited complexes fluoresce, emitting energy at ~600 nm and 650 nm, respectively.
4. If the excited complex at the probe tip encounters an oxygen molecule, the excess energy is transferred to the oxygen molecule in a non-radiative transfer, decreasing or quenching the fluorescence signal. The degree of quenching correlates to the partial pressure of oxygen in the sol-gel, which is in dynamic equilibrium with oxygen in the sample.
5. The fluorescence is collected by the probe and carried to the USB4000-FL Spectrometer or MFPF Fluorometer via the second leg of the bifurcated optical fiber assembly. The fluorescence intensity (for USB4000-FL Spectrometer) or phase (for MFPF Fluorometer) is measured and related to the partial pressure of oxygen through the Stern-Volmer equation.

Oxygen Sensor with MFPF100-1 MultiFrequency Phase Fluorometer



Overview

Oxygen is sensed by measuring the phase shift of fluorescence of a fluorophore bound to the tip of an optical fiber. The sensor responds to the partial pressure of oxygen. Below is a list of components typically specified in an oxygen sensing application with a MultiFrequency Phase Fluorometer (MFPF) as the sensor detector.

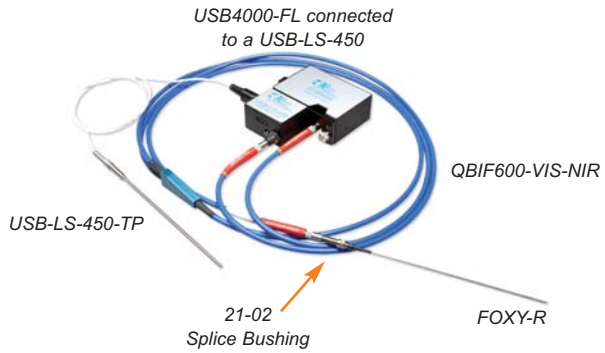
MultiFrequency Phase Fluorometer

The MultiFrequency Phase Fluorometer (MFPF) is a flexible platform for measurement of luminescence lifetime, phase and intensity. The MFPF is especially useful for oxygen sensing applications where sensitivity to drift is important and where sample set-ups must be undisturbed for long periods of time. Because it utilizes phase-shift technology, it is invariant to fiber bending and stray light and has a wide dynamic range of optical intensity as well as low optical and electronic crosstalk, and low drift and phase noise.

Sampling Optics

This compact, self-contained frequency-domain luminescence monitor uses included red and blue LED excitation light that transmits to one leg of a QBIF600-VIS-NIR Bifurcated Optical Fiber Assembly, which is connected to one of our oxygen sensor probes, such as the FOXY-R, via a 21-02 Splice Bushing.

Oxygen Sensor with USB4000-FL Spectrofluorometer



Overview

Oxygen is sensed by measuring the decrease in fluorescence intensity of a fluorophore bound to the tip of an optical fiber. The sensor responds to the partial pressure of oxygen. It works equally well in gases, solutions and even viscous samples. Below is a list of components typically specified in an oxygen sensing application.

Spectrometer

We recommend the USB4000-FL Fluorescence Spectrometer for general purpose oxygen measurements. The USB4000-FL is preconfigured with a 200 μm Slit, Grating #3 and a 360-1000 nm wavelength range. Grating #3 is blazed at 500 nm to optimize the fluorescence signal at 600 nm. Also included in the optical bench is an L4 Detector Collection Lens to increase light-collection efficiency.

Sampling Optics

The USB-LS-450 Pulsed Blue LED Excitation Source transmits light (at ~475 nm) to one leg of a QBIF600-VIS-NIR Bifurcated Optical Fiber Assembly, which is connected to one of our oxygen sensor probes, such as the FOXY-R, via a 21-02 Splice Bushing.

Oxygen Sensor Spectrometers

Preconfigured Spectrometers for Use with Sensors

Our high-sensitivity, preconfigured fluorescence spectrometers -- the USB4000-FL, USB4000-FL-450 and USB4000-FL-395 -- were conceived for use with fluorescence-based sensors. Each fluorescence unit is set to 360-1000 nm and comes with a 200-µm entrance aperture and an L4 Detector Collection Lens for increased light throughput.

USB4000-FL: Excitation Source not Included

The USB4000-FL does not come with an excitation source, which you will need to excite the sample. We have a series of compact, low-cost excitation sources that work with our fluorescence-based sensors such as the LS-450 (at right) or the USB-LS-450 (see pages 130-131). The excitation sources produce pulsed or continuous output and easily couple to our line of spectrometers, optical fibers and other accessories.

USB4000-FL-450 & USB4000-FL-395: Excitation Source Included

The USB4000-FL-450 and USB4000-FL-395 Spectrofluorometers are spectrometers configured the same way as the USB4000-FL, but each comes with a direct-attach excitation source. The USB4000-FL-450 comes with a 470 nm LED Excitation source and the USB4000-FL-395 comes with a 395 nm LED Excitation source. The 470 nm LED is great for exciting the FOXY and HIOXY formulations, while the 395 nm LED is used for exciting the FOSPOR formulation. In addition, these Excitation sources connect to temperature sensors and contain onboard memory that can be programmed to store temperature and oxygen calibration coefficients.

USB4000-FL: $2,499
USB4000-FL-450: $3,049
USB4000-FL-395: $3,049

Specifications

	USB4000-FL	USB4000-FL-450	USB4000-FL-395
PHYSICAL			
Dimensions:	89.1 mm x 63.3 mm x 34.4 mm	89.1 mm x 120.3 mm x 34.4 mm	89.1 mm x 120.3 mm x 34.4 mm
Weight:	190 grams	310 grams	310 grams
DETECTOR			
Detector:	Toshiba TCD1304AP linear CCD array (see page 17 for detector specifications)	Toshiba TCD1304AP linear CCD array (see page 17 for detector specifications)	Toshiba TCD1304AP linear CCD array (see page 17 for detector specifications)
OPTICAL BENCH			
Design:	f/4, Asymmetrical crossed Czerny-Turner	f/4, Asymmetrical crossed Czerny-Turner	f/4, Asymmetrical crossed Czerny-Turner
Focal length:	42 mm input; 68 mm output	42 mm input; 68 mm output	42 mm input; 68 mm output
Entrance aperture:	200 µm wide slit	200 µm wide slit	200 µm wide slit
Grating:	Grating #3, groove density of 600 lines set to 360-1000 nm, blazed at 500 nm	Grating #3, groove density of 600 lines set to 360-1000 nm, blazed at 500 nm	Grating #3, groove density of 600 lines set to 360-1000 nm, blazed at 500 nm
Fiber optic connector:	SMA 905 to 0.22 numerical aperture fiber	SMA 905 to 0.22 numerical aperture fiber	SMA 905 to 0.22 numerical aperture fiber
SPECTROSCOPIC			
Wavelength range:	360-1100 nm	360-1100 nm	360-1100 nm
Optical resolution:	~10.0 nm FWHM	~10.0 nm FWHM	~10.0 nm FWHM
Signal-to-noise ratio:	300:1 (at full signal)	300:1 (at full signal)	300:1 (at full signal)
A/D resolution:	16 bit	16 bit	16 bit
Dark noise:	50 RMS counts	50 RMS counts	50 RMS counts
Stray light:	<0.05% at 600 nm; <0.10% at 435 nm	<0.05% at 600 nm; <0.10% at 435 nm	<0.05% at 600 nm; <0.10% at 435 nm
Corrected linearity:	>99.8%	>99.8%	>99.8%
ELECTRONICS			
Power consumption:	250 mA @ 5 VDC	250 mA @ 5 VDC and 60 mA @ 5 VDC	250 mA @ 5 VDC and 60 mA @ 5 VDC
Data transfer speed:	Full spectrum to memory every 4 ms with USB 2.0 port, 18 ms with USB 1.1 port	Full spectrum to memory every 4 ms with USB 2.0 port, 18 ms with USB 1.1 port	Full spectrum to memory every 4 ms with USB 2.0 port, 18 ms with USB 1.1 port
Inputs/Outputs:	Yes, 8 digital user-programmable GPIOs	Yes, 8 digital user-programmable GPIOs	Yes, 8 digital user-programmable GPIOs
COMPUTER			
Operating systems:	Windows 98/Me/2000/XP, Mac OS X and Linux with USB port; Any 32-bit Windows OS with serial port	Windows 98/Me/2000/XP, Mac OS X and Linux with USB port; Any 32-bit Windows OS with serial port	Windows 98/Me/2000/XP, Mac OS X and Linux with USB port; Any 32-bit Windows OS with serial port
Computer interfaces:	USB 2.0 @ 480 Mbps; RS-232 (2-wire) @ 115.2 K baud	USB 2.0 @ 480 Mbps; RS-232 (2-wire) @ 115.2 K baud	USB 2.0 @ 480 Mbps; RS-232 (2-wire) @ 115.2 K baud
Peripheral interfaces:	I^2C inter-integrated circuit; SPI (3-wire)	I^2C inter-integrated circuit; SPI (3-wire)	I^2C inter-integrated circuit; SPI (3-wire)
LIGHT SOURCE			
Stability:	n/a	±1.0% drift after 2-minute warm-up period	±1.0% drift after 2-minute warm-up period
Wavelength range:	n/a	460-490 nm	380-410 nm
Power consumption:	n/a	60 mA @ 5 VDC	60 mA @ 5 VDC
Power output:	n/a	60 µW (minimum) into a 600 µm fiber	60 µW (minimum) into a 600 µm fiber

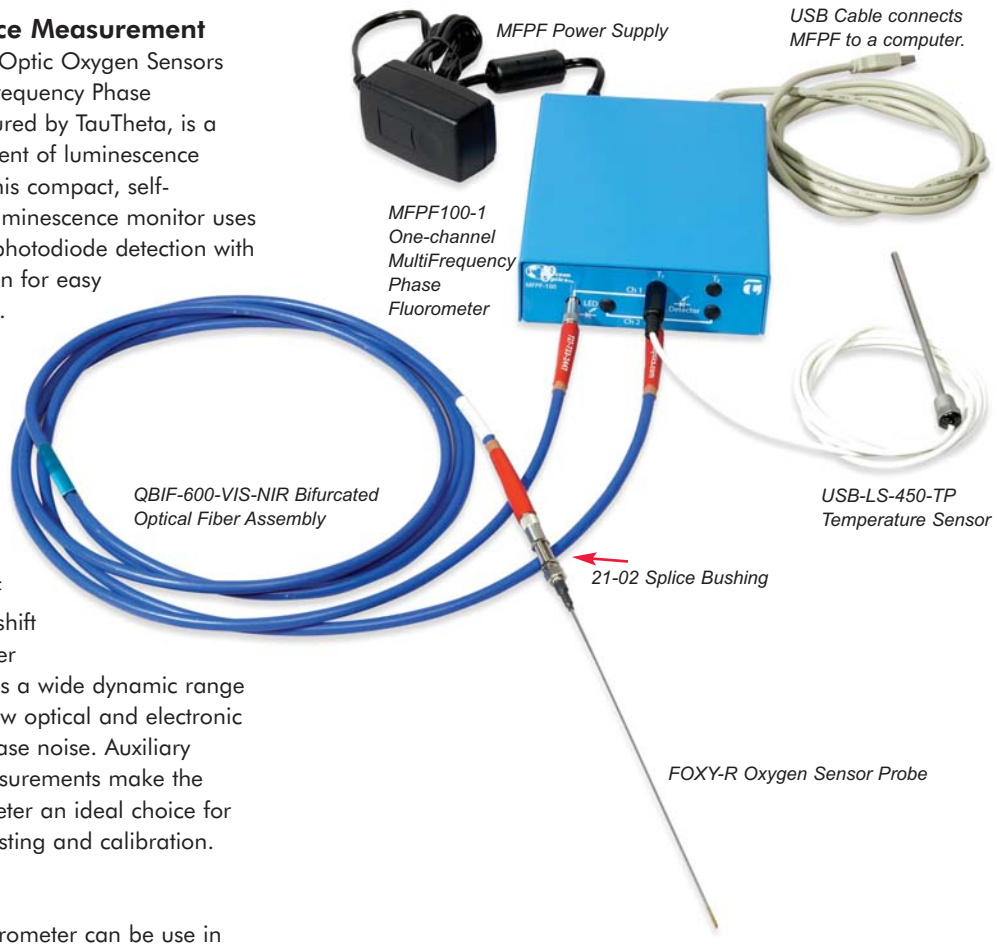
Oxygen Sensor Phase Fluorometer

Flexibility in Luminescence Measurement

Used with Ocean Optics Fiber Optic Oxygen Sensors and custom probes, the MultiFrequency Phase Fluorometer (MFPF), manufactured by TauTheta, is a flexible platform for measurement of luminescence lifetime, phase and intensity. This compact, self-contained frequency-domain luminescence monitor uses LED excitation and avalanche photodiode detection with filter-based wavelength selection for easy experimental setup and control.

Perfect System for O_2 Sensing

The MFPF is especially useful for oxygen sensing applications where sensitivity to drift is important and where sample setups must be undisturbed for long periods of time. Because it utilizes phase-shift technology, it is invariant to fiber bending and stray light and has a wide dynamic range of optical intensity as well as low optical and electronic crosstalk, and low drift and phase noise. Auxiliary pressure and temperature measurements make the MultiFrequency Phase Fluorometer an ideal choice for luminescence sensor design, testing and calibration.



Application Flexibility

The MultiFrequency Phase Fluorometer can be use in applications such as:

- Luminescent materials characterization
- Phase/Lifetime sensor development
- Calibration of phase/lifetime sensors
- Stability and photodegradation studies
- Characterization of phase shift over frequency
- Oxygen consumption measurement on cell and islet cultures

Configuration Options

The MFPF can be configured with two-channel LED excitation and detection and modulation frequencies to 500 kHz. This configuration will give you lifetime measurements from 200 µsec down to 0.3 µsec. The onboard pressure transducer measures atmospheric pressure or external pressure with a 1/4" hose fitting. The single-channel MFPF100-1 comes with one thermistor, and the two-channel MFPF100-2 includes two thermistors. The thermistor option allows temperature logging, calibration and temperature correction.

USB Connection for Easy Startup

The MultiFrequency Phase Fluorometer can connect to your PC via an RS-232 or USB connection and saves your data in an easy-to-use Excel format.

MFPF100-1 (one channel): $5,000
MFPF100-2 (two channels): $7,500

Specifications	
LED modulation range:	2 kHz to 100 kHz (200 µsec to 0.3 µsec)
Parameters measured:	Luminescence phase shift, AC luminescence intensity, temperature (optional through external thermistors), pressure (via onboard pressure transducer)
Control software:	Windows 2000/XP control software with data logging capability; controls include: modulation frequency, data rate, LED duty cycle, signal averaging, APD gain, analog gain, LED intensity
Measurement modes:	Intermittent LED (to minimize photodegradation); Continuous LED (for rapid measuring and accelerating photo-bleaching); Frequency sweep for luminescence characterization
Thermistor probes:	Closed end stainless steel tube with thermistor sensor mounted in tip; liquid immersible rugged design; 1/8" NPT fitting; temperature range 0 to 75 °C, absolute maximum 100 °C +/- 0.2 °C; Interchangeable thermistors
Pressure measurement:	Onboard pressure transducer monitors atmospheric pressure, optional configuration allows external connection for 0 to 15 psiA
Power input:	6v - 12v, 1.5 Amps
Communications:	USB or RS-232

Oxygen Sensor Formulations

By combing miniature fiber optic spectrometers, excitation sources and optical probes coated with chemically sensitive transducers, Ocean Optics has created an extensive line of fiber optic oxygen sensors. Sensors are constructed by placing a transducer material -- typically, a dye embedded in a sol gel -- at the tip of an optical fiber. These materials change optical properties in response to specific analytes in their immediate environment. The sensor uses fluorescence quenching of the indicator dye to measure the partial pressure of dissolved or gaseous oxygen.

FOXY Sensor Formulation

General-purpose Oxygen Sensors

Our Oxygen Sensing Probes with the FOXY Formulation are designed for monitoring partial pressure of oxygen in benign gases, liquids and gels. Standard FOXY probe tips are covered with a layer of hydrophobic sol-gel material with a ruthenium compound trapped in the sol-gel matrix. When excited by an LED, the ruthenium complex fluoresces. If the excited ruthenium complex then encounters an oxygen molecule, the excess energy quenches the fluorescent signal. The fluorescence intensity or phase shift is measured by an Ocean Optics spectrometer or MFPF system, and is related to the partial pressure of oxygen.

FOSPOR Sensor Formulation

High-sensitivity Coating

Our FOSPOR sensor coating for Oxygen Sensor Probes is a highly sensitive sol-gel thin film immobilized with Pt-porphyrin, a fluorescent dye with high quantum efficiency and low non-specific adsorption on different surfaces. FOSPOR-coated sensors are capable of monitoring low levels of oxygen in gas (to ppm) and dissolved oxygen in liquids (to ppb), making them especially useful for measuring trace amounts of oxygen in vacuum systems and in food and pharmaceutical packaging.

HIOXY Sensor Formulation

Hydrocarbon Environments

We've developed a high-performance oxygen sensor compatible with hydrocarbon environments. Our new HIOXY formulation is a hydrophobic and oleophobic coating material encapsulated with oxygen-sensitive luminescence molecules. The HIOXY sensor is designed for monitoring oxygen in non-aqueous vapors and solutions. The sensor coating chemistry is ideal for use with oils, alcohols and hydrocarbon-based vapors and liquids. HIOXY has been tested successfully in commercial and military aviation fuels, gasoline, diesel, some alcohols, glycol, military hydraulic fluids and various wines.

Specifications

Specification	FOXY Probes	FOSPOR Probes	HIOXY Probes
Principle:	Photoluminescence-quenching using Ru compound. Measures O_2 partial pressure.	Photoluminescence-quenching using Pt compound. Measures O_2 partial pressure.	Photoluminescence-quenching using Ru compound. Measures O_2 partial pressure.
Sensor mechanism:	Phase shift due to change in partial pressure of O_2	Phase shift due to change in partial pressure of O_2	Phase shift due to change in partial pressure of O_2
Applications:	Benign environment, aqueous liquids and vapors	Low O_2 (0-5%), vacuum systems packaging, benign environment	Hydrocarbon-based liquids and vapors, fuels, alcoholic beverages, vegetable oil
Time-constant (µsec) dynamic range:	Air: 2.50, N2: 5.00; Low 1.00, High 7.00	Air: 10.00; N2: 50.00; Low: 3.00, High: 70.00	Air: 0.50, N2: 2.50; Low: 0.30, High: 6.00
Accuracy: (0-20% O_2, 0-50 ºC):	5% of reading (using polynomial fit to multipoint calibration)	5% of reading (using polynomial fit to multipoint calibration)	5% of reading (using polynomial fit to multipoint calibration)
Response time of probe with no overcoat:	~1 second, in liquid and gas	~1 second, in liquid and gas	~1 second, in liquid and gas
Response time of dissolved oxygen in liquid (with overcoat):	30-45 seconds	30-45 seconds	Overcoat not required
Response time of probe with overcoat of Oxygen Gas (at 1 atmosphere):	15-20 seconds	15-20 seconds	Overcoat not required
Dynamic range of dissolved oxygen in liquid:	0-40.7 ppm; 0-760 mm Hg partial pressure	0-40.7 ppm; 0-760 mm Hg partial pressure	0-40.7 ppm; 0-760 mm Hg partial pressure
Dynamic range of oxygen gas (at 1 atmosphere):	0-100% (mole percent); 0-760 mm Hg partial pressure	0-100% (mole percent); 0-760 mm Hg partial pressure	0-100% (mole percent); 0-760 mm Hg partial pressure
Stability dissolved oxygen in liquid:	Drift <0.01 ppm per hour	Drift <0.00008 ppm O_2 per hour at low dissolved oxygen; Drift ~ 0.006 ppm O_2 per hour in air-saturated water	Drift <0.002 ppm per hour
Stability oxygen gas (at 1 atmosphere):	Drift ~0.03% O_2 per hour	Drift ~0.0002% O_2 drift per hour at low O_2; Drift ~0.015% O_2 per hour air	Drift ~0.01% O_2 per hour
Resolution of dissolved oxygen in liquid:	0.02 ppm at room temperature	0.002 ppm at room temperature	0.02 ppm at room temperature
Resolution of oxygen gas (at 1 atmosphere):	0.05% (0.4 mm Hg) at room temperature	0.005% at room temperature	0.05% (0.4 mm Hg) at room temperature
Lowest detectable limit of dissolved oxygen in liquid:	0.02 ppm	0.002 ppm at room temperature	0.02 ppm
Lowest detectable limit of oxygen gas (at 1 atmosphere):	0.05% (0.4 mm Hg)	0.005% (0.04 mm Hg)	0.05% (0.4 mm Hg)
Overcoat available:	Yes, FOXY-AF and FOXY-AF-MG	Yes, FOSPOR-AF and FOSPOR-AF-MG	No overcoat available
Temperature range:	-50 ºC to +80 ºC	0 ºC to +60 ºC	-50 ºC to +80 ºC
Probe lifetime:	Recondition once per year	Recondition once per year	Recondition once per year
Recommended excitation source:	USB-LS-450 470-nm LED	USB-LS-395 395-nm LED	USB-LS-450 470-nm LED
Recommended detector:	MFPF-100-1, MFPF-100-2, USB4000-FL, USB4000-FL-450	USB4000-FL, USB4000-FL-395	MFPF-100-1, MFPF-100-2, USB4000-FL, USB4000-FL-450

Oxygen Sensor Care & Compatibility

Care of Oxygen Sensor Formulation & Probe

Your Oxygen Sensor probe is very easy to maintain. It can be left in air indefinitely, but don't leave it exposed to your excitation light source when it is not in use. Dropping the probe could cause the optical fiber to break. Be sure not to over-tighten the SMA 905 Connectors. Clean your probes with 10% hypochlorite detergent and sterilize them with gamma radiation or sodium hypochlorite (bleach). See below for further details on cleaning and sterilization methods available for your Sensor Probes.

Method	FOXY	FOSPOR	HIOXY
Sodium hypochlorite (bleach)	Safe	Safe	Safe
Gamma radiation	Safe	Safe	Safe
Hydrogen peroxide plasma gas, low temperature, Plazlyte	Degrades probe signal by about 15% with each cycle	Degrades probe signal by about 15% with each cycle	Degrades probe signal by about 15% with each cycle
Autoclaving (steam sterilization) >30 minutes at 121 °C	Each cycle decreases signal by 50%; probe lifetime is 6-8 cycles	Each cycle decreases signal by 50%; probe lifetime is 6-8 cycles	Each cycle decreases signal by 50%; probe lifetime is 6-8 cycles
Methanol and ethanol wash	Unsafe	Unsafe	Safe with brief exposure to ethanol
Hydrogen peroxide	Unsafe	Unsafe	Unknown
Ozone	Unsafe	Unsafe	Unsafe

Compatibility with Fiber Optic Oxygen Probes: Observational Results

Though our oxygen sensing probes work well in most environments, some chemicals interfere with performance by deteriorating the fluorescence irreversibly or by chemically attacking the coating. In some cases, overcoats may reduce such interference.

This table lists known observational effects of chemicals and gases on sensor probes. If a chemical or gas passes the "observational" test (inserting the probe into the environment for 24 hours and observing no change in sensor performance), it warrants further comprehensive determinate testing. Please note that the table lists compatibility on an observational level only. (Comprehensive determinate testing results are available upon request.)

For chemical compatibility testing of samples, we suggest our SGS products (page 72), coated substrates such as microscope glass cover slips that are ideal for evaluating coating formulations exposed to your sample environment.

For the most up-to-date compatibility list, visit www.oceanoptics.com/products/sensorcarecompatibility.asp.

Chemical	FOXY	FOSPOR	HIOXY
Acetone	No	No	No
Acetonitrile	No	No	Unknown
Acids	Yes	Yes	Unknown
Acrylonitrile	No	No	Unknown
Alcohols >50% concentration	No	No	Yes
Alcohols <50% concentration	Yes, overcoat required	Yes, overcoat required	Yes
Ammonia	Yes	Yes	Unknown
Benzene (long-term)	No	No	Yes
Benzene (short-term)	Yes	Yes	Yes
Diesel Fuel	No	No	Yes
Ethanol	No	No	Yes
Gasoline	No	No	Yes
Heptane	No	No	Unknown
Hexane	No	No	Unknown
Hydrofluoric Acid (HF)	No	No	No
Isopropyl Acetate >60% concen.	No	No	Unknown
Isopropyl Alcohol <60% concen.	Yes, overcoat required	Yes, overcoat required	Yes
Hydrogen Peroxide	No	No	Unknown
Ketones (such as acetone)	No	No	No
Methanol <50% concentration	Yes, overcoat required	Yes, overcoat required	Yes
Methyl Methacrylate	No	No	Unknown
Nitrogen Trifluoride (NF3)	Yes	Yes	Yes
Non-polar solvents	No	No	Unknown
N-Vinyl-2-Pyrrolidinone	No	No	Unknown
Organic solvents	No	No	Unknown
Perfluorodecalin & Perfluorohexane	Yes	Yes	Yes
Skydrol (Aviation Hydraulic Fluid)	No	No	Yes
Sodium Hypochlorite and Sulfide	Yes	Yes	Yes
Sodium Hydroxide (1 Molar) NaOH	Yes	Yes	Yes
Solutions with pH >10	No	No	No
Styrene	No	No	Unknown
Sulfur Dioxide (SO2)	No	No	Unknown
Sulfur Hexafluoride (SF6)	Yes	Yes	Yes
Tetrahydrofuran	No	No	Unknown
Toluene and Toluene/Ethyl Acetate	No	No	No
Trichloroethyelene	No	No	Unknown
Xylene	No	No	No

Oxygen Sensor Probes

Once you select the Sensor Formulation best suited for your application, you need to select the Sensor Probe onto which the formulation or coating is applied. Ocean Optics offers several off-the-shelf Sensor Probes and has the ability to create the custom probe assembly that best fits your needs. After selecting your Sensor Formulation and Sensor Probe, you need to purchase a 21-02 Splice Bushing and Bifurcated Optical Fiber Assembly (page 72) to attach the Sensor Probe to your Oxygen Sensing System.

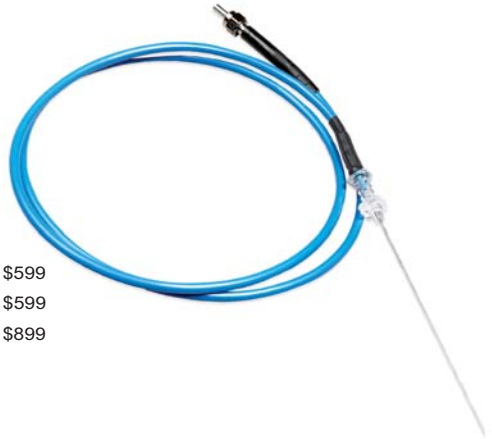
18G Sensor Probe

Typical Usage:	Penetration of vial septa and rigid packaging
Probe Assembly:	300 µm optical fiber, 18-gauge needle tip
Dimensions:	1.27 mm diameter, 90 mm length tip
Pressure:	300 psi

Ordering Information

FOXY-18G	18G Sensor Probe with FOXY Formulation	$599
FOSPOR-18G	18G Sensor Probe with FOSPOR Formulation	$599
HIOXY-18G	18G Sensor Probe with HIOXY Formulation	$899

21G Sensor Probe

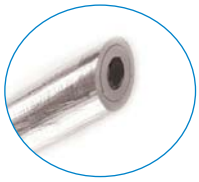


Typical Usage:	Penetration of vial septa and rigid packaging
Probe Assembly:	300 µm optical fiber, 21-gauge needle tip
Dimensions:	1.27 mm diameter, 90 mm length tip
Pressure:	300 psi

Ordering Information

FOXY-21G	21G Sensor Probe with FOXY Formulation	$599
FOSPOR-21G	21G Sensor Probe with FOSPOR Formulation	$599
HIOXY-21G	21G Sensor Probe with HIOXY Formulation	$899

OR125 Sensor Probe



Typical Usage:	Direct replacement for 1/8" OD O_2 electrodes
Probe Assembly:	1000 µm optical fiber, stainless steel ferrule
Dimensions:	3.175 mm OD, 63.5 mm length
Pressure:	300 psi

Ordering Information

FOXY-OR125	OR125 Sensor Probe with FOXY Formulation	$599
FOSPOR-OR125	OR125 Sensor Probe with FOSPOR Formulation	$599
HIOXY-OR125	OR125 Sensor Probe with HIOXY Formulation	$899

OR125-G & OR125-GT Sensor Probes

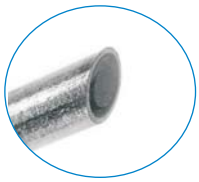
Typical Usage:	Direct replacement for O-ring grooved electrodes
Probe Assembly:	1000 µm optical fiber, stainless steel ferrule or titanium ferrule
Dimensions:	3.175 mm OD, 63.5 mm length
Pressure:	300 psi

Ordering Information

FOXY-OR125-G	OR125-G Sensor Probe with FOXY Formulation, SS ferrule	$599
FOSPOR-OR125-G	OR125-G Sensor Probe with FOSPOR Formulation, SS ferrule	$599
HIOXY-OR125-G	OR125-G Sensor Probe with HIOXY Formulation, SS ferrule	$899
FOXY-OR125-GT	OR125-GT Sensor Probe with FOXY Formulation, titanium ferrule	$649
FOSPOR-OR125-GT	OR125-GT Sensor Probe with FOSPOR Formulation, titanium ferrule	$649
HIOXY-OR125-GT	OR125-GT Sensor Probe with HIOXY Formulation, titanium ferrule	$979

Oxygen Sensor Probes

R Sensor Probe

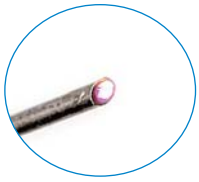


Typical Usage:	General Purpose
Probe Assembly:	1000 µm fiber in a stainless steel 1/16" OD ferrule
Dimensions:	1.587 mm OD, 152.4 mm length
Pressure:	300 psi

Ordering Information

FOXY-R	R Sensor Probe with FOXY Formulation	$499
FOSPOR-R	R Sensor Probe with FOSPOR Formulation	$499
HIOXY-R	R Sensor Probe with HIOXY Formulation	$749

AL-300 Sensor Probe

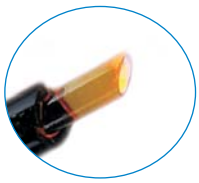


Typical Usage:	Fine spatial resolution applications
Probe Assembly:	300 µm aluminum-jacketed fiber assembly
Dimensions:	500 µm OD, 1 m length
Pressure:	300 psi

Ordering Information

FOXY-AL300	AL300 Sensor Probe with FOXY Formulation	$499
FOSPOR-AL300	AL300 Sensor Probe with FOSPOR Formulation	$499
HIOXY-AL300	AL300 Sensor Probe with HIOXY Formulation	$749

PI600 Sensor Probe



Typical Usage:	Environments where non-metallic probe is indicated
Probe Assembly:	600 µm optical fiber with silicone jacketing
Dimensions:	710 µm OD, 2 m length
Pressure:	300 psi

Ordering Information

FOXY-PI600	PI600 Sensor Probe with FOXY Formulation	$499
FOSPOR-PI600	PI600 Sensor Probe with FOSPOR Formulation	$499

T1000 Sensor Probe

Typical Usage:	Process environments, high-pressure applications
Probe Assembly:	1000 µm optical fiber, stainless steel ferrule
Dimensions:	6.35 mm OD, 177.8 mm length
Pressure:	3000 psi

Ordering Information

FOXY-T1000	T1000 Sensor Probe with FOXY Formulation	$999
FOSPOR-T1000	T1000 Sensor Probe with FOSPOR Formulation	$999
HIOXY-T1000	T1000 Sensor Probe with HIOXY Formulation	$1,499

T1000-RTD Sensor Probe

Typical Usage:	Process environments, has embedded RTD
Probe Assembly:	1000 µm optical fiber, stainless steel ferrule
Dimensions:	6.35 mm OD, 177.8 mm length
Pressure:	300 psi

Ordering Information

FOXY-T1000-RTD	T1000 Sensor Probe with FOXY Formulation	$1,499
FOSPOR-T1000-RTD	T1000 Sensor Probe with FOSPOR Formulation	$1,499
HIOXY-T1000-RTD	T1000 Sensor Probe with HIOXY Formulation	$1,499

Oxygen Sensor Accessories

Bifurcated Optical Fiber Assemblies and Splice Bushing

Our Y-shaped Bifurcated Optical Fiber Assemblies contain two fibers side-by-side in the common end of the assembly, which connects to the Sensor Probe. From the breakout of the assembly, the two fibers diverge into two legs, one connects to a spectrometer, the other to the excitation source. A 21-02 Splice Bushing is an adapter that connects an SMA 905-terminated Sensor Probe to a SMA-terminated Bifurcated Optical Fiber Assembly.

BIF-600-VIS-NIR Bifurcated Optical Fiber Assembly

QBIF-600-VIS-NIR Bifurcated Optical Fiber Assembly

Item	Description	Price
21-02	Splice Bushing to connect Sensor Probe to Bifurcated Optical Fiber Assembly	$13
BIF-600-VIS-NIR	Laboratory-grade Bifurcated Optical Fiber Assembly	$329
QBIF-600-VIS-NIR	Premium-grade Bifurcated Optical Fiber Assembly	$369
QBIF-600-VIS-BX	Premium-grade Bifurcated Optical Fiber Assembly with BX cable jacketing (not shown)	$369

Sensor Probe *21-02 Splice Bushing* *Bifurcated Optical Fiber Assembly*

Respiration Monitor "RESP" Sensor Probe

The FOXY-RESP is a fiber optic oxygen sensor for in situ respiration monitoring of oxygen tension in respiratory gases. The probe can be combined with a spectrometer and accessories to measure inspired and expired oxygen in real time -- valuable data that complements existing respiratory parameters and airway mechanic values. For remote monitoring, use the sensor with optical fiber of variable lengths. You can also configure the stable probe with a monochromator for wavelength-specific analysis. The sensor can be used in magnetic resonance imaging environments. The probe assembly contains 200 μm optical fiber in a plastic ferrule and is 6.35 mm OD and 107.9 mm in length. See the Planar Oxygen Sensors table below on purchasing -RESP-FILM, the membranes needed for the FOXY-RESP Probe.

FOXY-RESP: $549

Planar Oxygen Sensors

Though our fiber optic sensor probes work well in most solutions, some environments interfere with sensor performance by deteriorating the fluorescence irreversibly or by chemically attacking the coating. We offer a variety of coated substrates for testing or for applications where a probe is undesirable.

-GF

-SGS-M

Item	Description	Typical Usage	Price
-SGS	Custom coating service for coating various substrates (supplied by user or Ocean Optics) with different transducer materials, specify Sensor Formulation	qualitative, quantitative feasibility testing	Custom Pricing
-SGS-M	One 1" x 3" sol-gel spin-coated microscope slide, specify Sensor Formulation	qualitative, quantitative testing	$300
-GF	Pack of 5 sol-gel coated fiberglass filters, specify Sensor Formulation	qualitative, quantitative testing	$50
-RESP-FILM	Pack of 25 sol-gel coated glass fiber membranes for Respiration Monitor (above)	qualitative, quantitative testing	$50

Silicone Overcoats

We can apply silicone overcoats over FOXY and FOSPOR Oxygen Sensor Probes to improve chemical resistance, exclude ambient light and eliminate refractive index effects of the sample. We recommend an overcoat if you are using solutions or if you are switching between gases and solutions. Overcoats are free. (The HIOXY Sensor Formulation does not benefit from overcoats.)

Item	Description	Response in Gases	Response in Solutions
-AF	RTV silicone adhesive overcoat (overcoat increases response time), specify FOXY or FOSPOR Sensor Formulation	10-30 seconds	15-45 seconds
-AF-MG	High-strength RTV silicone adhesive overcoat is a medical implant-grade silicone -- a thicker and more robust coating than the -AF (overcoat increases response time); specify FOXY or FOSPOR Sensor Formulation	15-45 seconds	45-60 seconds (depending on viscosity)

Oxygen Sensor Accessories

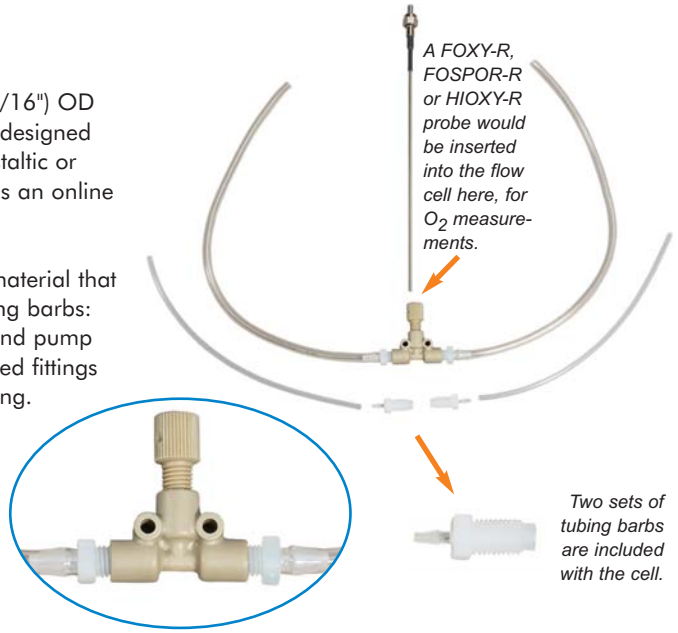
In-line Flow Cell

The FOXY-FLOW-CELL is an in-line flow cell for 1.587 mm (1/16") OD probes, such as the FOXY-R, FOSPOR-R and HIOXY-R. It was designed for use in a low-pressure flowing stream of liquid with a peristaltic or positive displacement pump. The flow cell also can be used as an online sampling accessory for 1/16" OD reflectance probes.

The flow cell is made of PEEK polymer, a radiation-resistant material that has excellent chemical resistance. Also included are four tubing barbs: two for 1/16" ID tubing and two for 1/8" ID tubing. (Tubing and pump are not included.) You can replace these fittings with other-sized fittings from Upchurch Scientific as long as they have 1/4-28 threading.

FOXY-FLOW-CELL: $100

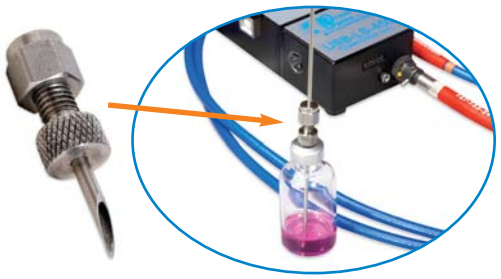
Specifications	
Tee:	Upchurch Scientific PEEK tee
Tubing barbs:	(2) 1/8" Tefzel tubing barbs, (2) 1/16" Tefzel tubings barbs
Ferrule:	1/16" PTFE ferrule
Nut:	1/16" PEEK nut
Threading size:	1/4-28
Pressure limits:	1000 PSI



Puncturing Needle

The Puncturing Needle is an Oxygen Sensor Probe accessory that allows 1.587 mm (1/16") outer diameter sensors -- such as the FOXY-R, FOSPOR-R and HIOXY-R (page 71) -- to puncture a septum and seal without damaging the sensor coating. The Puncturing Needle includes a 1/16" needle and a 1/16" Swagelok adapter to seal the sensor in place.

FOXY-R-PNA: $150



O_2 Acrylic Sampling Chambers, Respirometers

Our Acrylic Sampling Chambers are used by biologists and zoologists in dissolved oxygen sensing applications such as respiration rate and metabolic rate monitoring of fish and crustaceans. You can combine a sample chamber, probe, spectrometer and light source to configure a complete respirometer. The sampling chambers provide users with a fixed-volume environment. Each chamber cover is equipped with high-pressure (220 psi) polypropylene collars and a Swagelok fitting for an Oxygen Sensor Probe. The acrylic chambers have a temperature range of -30 °C to 82 °C and are FDA-approved for food applications. The polypropylene fittings are temperature rated from 0 °C to 100 °C. Each chamber has a watertight seal seated between the body and its cover.

Item	Acrylic Chamber Type	Dimensions (in mm)	Fittings	Price
RESP-CL2IN	Clear Round	44.4 ID x 139.7 length	1 bored 1/4" OD tubing fitting	$160
RESP-BL2IN	Black/Opaque Rectangle	139.7 x 50.8 x 50.8	1 bored 1/4" OD tubing fitting	$180
RESP-CL4IN	Clear Acrylic Round	95.2 ID x 139.7 length	2 bored 1/4" OD tubing fittings	$175
RESP-BL4IN	Black/Opaque Rectangle	140 x 101.6 x 101.6	2 bored 1/4" OD tubing fittings	$195
RESP-CL6IN	Clear Round	146 ID x 139.7 length	3 bored 1/4" OD tubing fittings	$190
RESP-BL6IN	Black/Opaque Rectangle	139.7 x 127 x 127	3 bored 1/4" OD tubing fittings	$210

Sensor Reconditioning/Recoating Service

Each Oxygen Sensor Probe contains a Sensor Formulation at its tip. Cleaning and protection from harsh environments will extend the life of the sensor. Severe biofouling, physical abrasion, and chemical etching of the glass may erode the sensing surface, requiring our probe recovery service. For -18G and -21G Needle Probes, we re-polish the probe and add a new needle tip for $125. For all other probes, we re-polish and re-coat the probe for $100. Specify FOXY, FOSPOR or HIOXY Sensor Formulation.

-RECOV: $100
-RECOV-N: $125

Oxygen Sensor Temperature Compensation

Our Fiber Optic Sensors are affected by temperature. Temperature affects the fluorescence decay time, fluorescence intensity, collisional frequency of the oxygen molecules with the fluorophore, and the diffusion coefficient of oxygen. The net effect: a change in the calibration slope. Because of this, the sample must be maintained at a constant temperature (±3.0 °C) for best results. If this is impractical, the sensor can be calibrated by measuring temperature and oxygen concurrently using one of our temperature-compensation accessories and in-house calibration services.

The USB-LS-450-TP Platinum RTD -- for use with the USB-LS-450 -- helps adjust for temperature changes.

In-house Temperature Calibration Services

If your sample cannot be maintained at a constant temperature (±3.0 °C), you can perform a temperature calibration in OOISensors Software or we can perform the calibration for you. The -CAL is an in-house factory-calibration service for environments from 0-80 °C. The -CAL-EXT is a factory-calibration service for extended temperature ranges below 0 °C or above 80 °C. You'll need to determine the temperature and O_2 concentration range of your sample environment before ordering an in-house calibration service. Be sure to specify the Oxygen Sensor Formulation (FOXY, FOSPOR or HIOXY) being used in the calibration.

-CAL: $199
-CAL-EXT: $299

Thermistor & Thermocouples for Ocean Optics Spectrometers

Item	Description	Price
FOXY-TS1	Thermistor is 1/8" outer diameter stainless steel tubular electrode probe that monitors temperatures from 0 °C to 100 °C; it most often is used for liquid immersion	$105
FOXY-T-MOD-1	An RS-232 module interfaces up to four of the FOXY-TS1 Thermistors to your PC	$500
FOXY-TK1	Thermocouple is a 1/8" outer diameter K-type electrode that monitors temperatures from -150 °C to 220 °C	$105
FOXY-TK1-W	Wire-type thermocouple that monitors temperatures from -150 °C to 220 °C	$105
FOXY-T-MOD-K	An RS-232 module interfaces up to four of the FOXY-TK1 Thermocouples to your PC	$500

RTDs for Sensing Temperature Changes

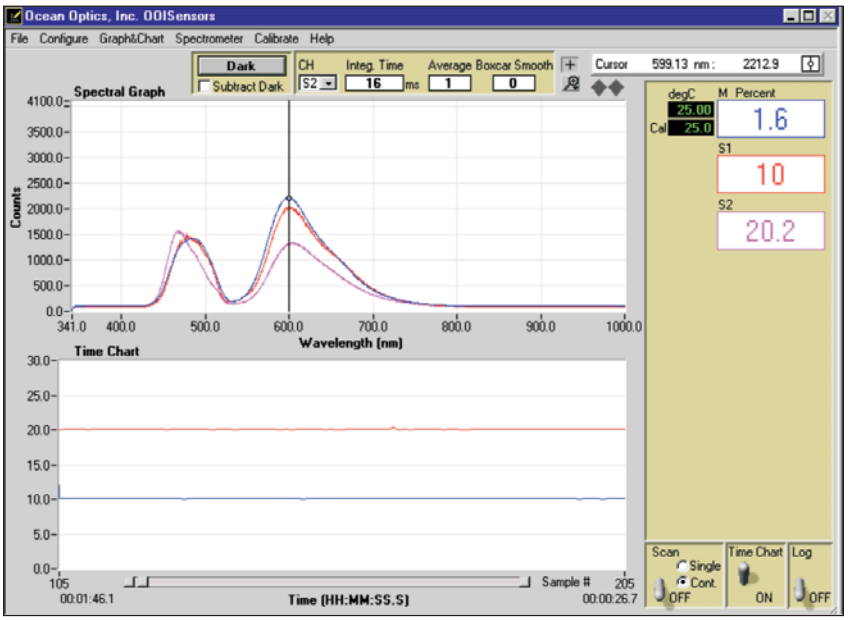
We offer three RTDs to adjust for temperature changes. The USB-LS-450-TP is a 1/8" outer diameter, 100 ohm platinum RTD that connects to the USB-LS-450 Excitation Source (see page 131). The USB-LS-450's onboard memory can be programmed to store temperature and oxygen calibration coefficients. The USB-LS-450-TP16 is a 16-gauge needle RTD, also for use with the USB-LS-450.

The -T1000-RTD (at right) is a -T1000 probe, but with an embedded RTD in the 1/4" outer diameter casing. When ordering the -T1000-RTD, be sure to specify the FOXY, FOSPOR or HIOXY Sensor Formulation being applied to the -T1000 Probe tip.

USB-LS-450-TP: $99
USB-LS-450-TP16: $249
FOXY-T1000-RTD: $1,499
FOSPOR-T1000-RTD: $1,499
HIOXY-T1000-RTD: $1,499

Sensor Software

OOISensors Software is a 32-bit, advanced acquisition and display program that provides a real-time interface to display and processing functions for use with our O_2 and pH sensors as well as with Ocean Optics spectrometers and the MultiFrequency Phase Fluorometer. OOISensors can acquire data, convert the data into concentration values, and save the data in spectral files and logs. The software has the ability to perform timed experiments and to display and correct for temperature fluctuations and for atmospheric pressure changes in the sample. It can also display pH values when used with our pH probe.



OOISensors Software gives you the opportunity to view spectral data from multiple spectrometer channels (top part of the graph) as well as collect and view oxygen, sensor or pH data over time (bottom part of the graph).

OOISensors features include:

- Obtains oxygen partial pressure, pH or concentration values from sensors
- Contains easy-to-use functions for all system parameters
- Performs time acquisition experiments
- Collects data from up to eight spectrometers simultaneously and displays the results in a single window
- Allows each spectrometer channel to have its own data acquisition parameters
- Monitors temperature (when using one of the temperature sensors on page 74), displays temperature data and corrects the data for any fluctuations in temperature and pressure
- Supports oxygen calibration procedures with first-order linear Stern-Volmer algorithm and with second-order polynomial algorithm to provide more accurate data
- Displays a time chart with the data from all active channels at a specific wavelength over time
- Allows user to enable Data Logging function and add experiment notes to a log file
- Works with all Windows 95/98/XP/2000/NT Operating Systems

OOISensors: $199

Pocket Carbon Monoxide Meter

Size as shown.
The tiny Pocket CO runs on a watch battery.

Carbon monoxide (CO) is a colorless, odorless, poisonous gas. Appliances fueled with natural gas, liquefied petroleum, oil, kerosene, coal, or wood may produce CO. Burning charcoal and running cars produce CO. Every year, hundreds of people in the United States die from CO produced by fuel-burning appliances and cars left running in attached garages.

The Pocket CO Carbon Monoxide Meter from Transducer Technology, Inc., is a technically advanced, long-life electrochemical sensor (patents pending) combined with a microprocessor for convenient and reliable monitoring of CO. The sensor's features allow CO monitoring, spot check measurements and CO dosimetry.

The Pocket CO is warrantied for one year. After one year, we recommend a recalibration of the sensor and battery change for best performance.

CHEMSEN-CO: $149

Specifications	
Size:	2.4" x 1.4" x 0.6"
Weight:	Less than 1 ounce, 20 grams
Material:	Impact resistant plastic case
Range:	0-600 ppm CO
Accuracy:	+/- 10% of reading at standard conditions
Response time:	Less than 30 seconds to 90%
Warm-up time	2 seconds (CO is measured every 2 seconds)
Operating life	1 year minimum
Operating temperature:	32 °F to 105 °F, or 0 °C to 40 °C
Temperature limits:	10-120 °F; 3-50 °C
Pressure effect:	Reading decreases with decreasing pressure, to 70% at 10,000 ft.
Humidity limits:	0-100% RH, non-condensing
Alarms, visual, audio:	CO level greater than 25 ppm CO level greater than 125 ppm Temperature greater than 105 °F or 40 °C Temperature less than 32 °F or 0 °C
Interferences:	None significant, except hydrogen

Fiber Optic pH Sensors

Sensor Holds Indicator Dyes

The Fiber Optic pH Sensor system consists of a fiber optic probe designed to hold immobilized colorimetric indicator dye materials, plus a light source, spectrometer and OOISensors Software. You can supply your own indicator material, or select from our line of transparent or reflective films. Calibration involves recording spectra in high and low pH samples, and in at least one pH standard such as a NIST-traceable buffer.

Transmissive & Reflective pH Films

Transmissive films are for clean, transparent samples. These films consist of a cellulose mechanical matrix surrounded by a hydrophilic polymer that entraps the indicator dye. Reflective films are used for turbid or absorbing media. When immersed in water, the film dyes may leach very slowly over time and will have to be replaced. The film response rate is slow (on the order of minutes), being limited by diffusion of ions into the material. Increasing stirring speed, ionic strength and temperature all tend to increase the response rate and do not affect the pH measurement. Nearly any aqueous sample environment is suitable, as are some solvents.

TP300 Probe

The TP300-UV-VIS Probe (at right) is a chemically inert PEEK transmission probe that can be equipped with a tip (RT-PH) for mounting transmissive films in the optical path. Light is directed via one fiber through the mounted film to a mirror. Then light is redirected back through the film to a receive fiber that returns the light to the spectrometer. The sample is free to flow over the sides of the film. By using an RTP-2-10 (adjustable from 2-10 mm) or RTP-10-20 (adjustable from 10-20 mm) transmission tip, the TP300-UV-VIS can be used for routine transmission measurements. See page 151 for details.

TP300-UV-VIS: $750
RT-PH Tip: $240

RFP200 Probe

The RFP200-UV-VIS Reflective Film Probe consists of a 6-around-1 fiber bundle in a chemically inert 6.35-mm outer diameter Torlon body. The open tip of the probe screws onto the body to hold 3.17-mm to 4.76-mm discs of reflective indicator material. The 6-fiber leg attaches to the light source; the central fiber leg connects to the spectrometer. The sample has access to the sensing material from one side only.

RFP200-UV-VIS: $499

Use transmissive films with the TP300-UV-VIS Probe for transparent samples. Use reflective films with the RFP-200-UV-VIS Probe for turbid, dense samples.

Transmissive Indicator Dye Films for pH Sensing

Item	Film Type	pH Range	Color Change	Price
F-PR	Phenol Red	6.5-8.5	yellow-purple	$50
F-CR	Cresol Red	8.0-10.0	orange-purple	$50
F-MCP	m-Cresol Purple	8.5-10.5	yellow-purple	$50
F-TB	Thymol Blue	9.0-12.0	yellow-purple	$50
F-BY	Brilliant Yellow	7.0-9.0	yellow/red-purple	$50
F-xxx	Transparent Film	reference	not applicable	$50
FILM300	Sample pack of transmissive films			$50

All pH films come in packages of 5 films.

Reflective Indicator Dye Films for pH Sensing

Item	Film Type	pH Range	Color Change	Price
FR-PR	Phenol Red	6.5-8.5	yellow-purple	$50
FNY-PR	Phenol Red Nylon	6.5-8.5	yellow-purple	$50
FR-CR	Cresol Red	8.0-10.0	orange-purple	$50
FR-MCP	m-Cresol Purple	8.5-10.5	yellow-purple	$50
FR-TB	Thymol Blue	9.0-12.0	yellow-purple	$50
FR-BY	Brilliant Yellow	7.0-9.0	yellow/red-purple	$50
FILM	Sample pack of reflective films			$50

All pH films come in packages of 5 films.

Phenol Red pH Test Kit

The CHEMTEST-PH is a Phenol Red pH Test Kit that includes 100 tests in cuvettes with covers. The CHEMTEST-PH can be used to determine the pH level in solution. Simply add 3 mL solution to a cuvette, cap it, shake the cuvette to disperse the dye, and then measure the absorbance value of the reactive color to determine the pH level. CHEMTEST-PH works with any Ocean Optics system that is configured for absorbance, including the CHEM4-series Spectrophotometers on pages 36-37. Software included.

CHEMTEST-PH: $99