TELEDYNE
ANALYTICAL INSTRUMENTS

Replenishible BDS
Bi-potentiostat Driven Sensor

PPB Oxygen Detection

BDS-3000 • BDS-306

As the density of wafers produced within a semiconductor facility increases, so does the stringent requirement to accurately monitor for oxygen contamination at or below parts-per-billion (ppb) levels.

Oxygen contamination is routinely monitored in the ultra-high purity (UHP) bulk gases such as nitrogen, argon, helium and hydrogen, which are used as blanket or carrier gases during the vapor deposition, sputtering and annealing processes. The ingress of oxygen at any point during the wafer fabrication process will have a detrimental effect on product yields. Therefore, it is imperative for semiconductor manufacturers to prevent oxygen contamination problems caused by corroded valves, cylinder leaks or improperly mated fittings (at the process or tool level) as well as potential atmospheric oxygen leakage in load-locks or various other processing chambers.

In response, TAI offers a high sensitivity Bi-potentiostat Driven Sensor (BDS). The replenishable BDS is a culmination of an extensive R&D effort within Teledyne in conjunction with several beta tests conducted with key Teledyne users in the semiconductor industry. The BDS achieves greater sensitivity (LDL of 500 ppt), faster response / recovery, and ease-of-use over any previous wet-cell oxygen sensor offering from Teledyne.

THEORY OF OPERATION

The BDS is constructed as a four electrode, non-depleting electrochemical cell driven by a bi-potentiostat circuit. The four electrodes, all located within the natural ABS sensor body and see-through acrylic cap, are referred to as:

- Sensing or "working" electrode
- Protective electrode
- Reference electrode
- Counter electrode

A potentiostat is an electronic circuit designed to control the potential of a "working" electrode. A Bi-potentiostat is an electrochemical system in which two working electrodes are under potential control. In the BDS design, the reference electrode provides a precise potential reference for both the sensing and protective electrodes. There is no pure electrochemical reaction at the reference electrode since the electronic circuit prevents current flowing through this electrode.

The sensing electrode (gas diffusion type) detects the oxygen found in the sample gas. The electrochemical reaction on the sensing electrode is the reduction of oxygen from the sample gas to form hydroxyl anions in the electrolyte. The counter electrode, where the hydroxyl anions from the electrolyte are oxidized back to oxygen, provides the current path for the sensing electrode.

In order to achieve a fast recovery from air to ppb oxygen levels, and to allow the sensor to operate in an open-to-air fashion, a second working electrode (i.e. the protective electrode) is incorporated into the sensor design. The protective electrode, made from Reticulated Vitreous Carbon (RCV), effectively removes any dissolved oxygen from the electrolyte in the vicinity of the sensing electrode while allowing hydroxyl anions to move through freely.

Since the only electrochemical reactions inside the BDS are the oxygen reduction to hydroxyl anion (at the sensing and blocking electrodes), and the conversion back to oxygen at the counter electrode, it is a non-depleting system.

Sensing Electrode Reaction: $O_2 + 2H_2O + 4e^- \ddagger 4\ OH^-$

Counter Electrode Reaction: $4OH^- \ddagger 4e^- + 2H_2O + O_2$

Also, because a potential gradient is established between the lower part of the sensor (sensing and blocking electrodes) and the top part of the sensor (counter electrode), the BDS can also be used in applications where limited amounts of acid gases (i.e. CO_2) may be present.

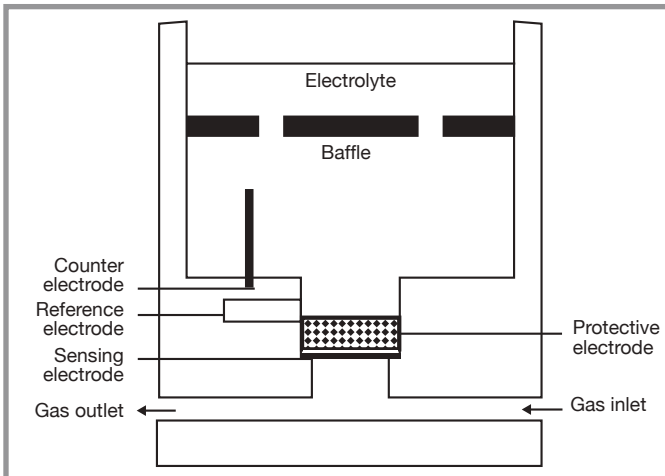

Figure 1. Potentiostat driven oxygen sensor

The detailed construction and sample gas flow through the sensor is shown in Figure 1.

The BDS design is superior to existing wet-cell oxygen sensors as the bi-potentiostat clearly controls the electrode potential much more precisely than conventional means. This enhanced design also provides the user with a sensor that is faster to respond to oxygen concentration changes and one that is unaffected if left exposed to zero gas for extended periods of time (i.e. no "sleep effects").

The BDS sensor has a two-year warranty with an expected life of three to five years when used properly. There are no pro-rated warranty issues to be concerned with and the sensor replacement cost, when and if it must occur, is a fraction of other ppb wet cell sensing technologies currently available on the market.

SENSOR BAFFLE MECHANISM

Teledyne's unique, patent-applied-for mechanism within the BDS sensor minimizes sensor downtime when water is added.

Wet cells (replenishable sensors) generally suffer from oxygen reading upset when water is added to replace the amount lost to evaporation. Adding water to this class of sensor upsets the delicate electrochemical balance in the cell necessary to accurately analyze parts-per-billion of oxygen.

Only Teledyne has solved this problem with a unique enhancement that radically slows the mixing of new water with the KOH solution already in the sensor. The concept is simple. A circular disk is inserted in the top of the cell. The disk has holes that allow for the passage of water, but at a greatly reduced rate to lessen the upset of existing water and KOH. This is comparable to adding cream to coffee. When added quickly, clouds of cream billow up inside the coffee cup. With a baffle system, adding cream would not create clouds but rather trap the cream on top where it would then slowly mix with the coffee.

ANALYZER INTERFACE

The Teledyne Bi-potentiostat Driven Oxygen Sensor is available in two configurations:

BDS-3000 | BDS-306

The BDS-3000 provides the user with a compact, cost-effective means of reliably detecting ppb levels of oxygen for either on-line or mobile-cart type applications for point-to-point gas-line tubing certification. By incorporating the BDS into the field proven Series 3000 platform, we have been able to provide the operator with a wide variety of features and benefits:

- Built-in isolation valves to lock off the sensor from atmospheric oxygen (when moving the unit from point-to-point)
- Automatic sensor shutdown mode to protect the BDS in the event the sensor is inadvertently exposed to oxygen concentrations of 30 ppm or higher. The analyzer will restart in 60 seconds from initial high oxygen detection and retry three times before user intervention is required.
- Three user-programmable ranges which can be tailored to the application needs in either a fixed or auto-ranging analysis mode
- Auto-calibration software
- RS-232C bi-directional serial interface as well as 4-20 mA and 0-1 VDC concentration output signals
- Self-diagnostics and system failure alarm along with 2x fully adjustable concentration alarm set points
- For low inlet sample pressure furnace-type applications, the BDS-3000 can also be fitted with an integral sample pump to draw the sample gas to the BDS for continuous analysis

Teledyne can also provide the BDS 3000 in a single 19" rack mount design or mount two BDS-3000s side-by-side in a single 19" rack panel, space-saving configuration.

The BDS-306 was specifically designed to allow for current Model 306WAM / Model 366 Open Cathode PPB / PPM Analyzer users to conveniently replace their existing units with a higher sensitivity drop-in replacement. The BDS sensor is mated with the Series 3000 electronics / software in the familiar 306 panel-mount enclosure to facilitate the upgrade to the next generation design without having to redesign the user's existing panel.

LEAK-FREE INTEGRITY

The ultra-clean sample systems found in each design have been constructed using techniques and components that meet the quality requirements for high purity gas monitoring in the semiconductor industry. Electropolished 316L stainless steel tubing, VCR fittings, leak-proof, bead-and-crevice-free orbital welds with a minimal design of dead space volume and air-actuated metal bellows valves which eliminate the possibility of gas absorption. The BDS-3000, BDS-3960, and BDS-306 sample systems are all helium leak checked to 10-9 atm cc / sec to insure against atmospheric leaks prior to qualification.

SPECIFICATIONS

Ranges:	Three user programmable ranges
Default ranges:	0-50 ppb, 0-1000 ppb, 0-10 ppm plus Over-range of 0-100 ppm
	Over-range is not user programmable
Accuracy:	±2% of full scale at constant temperature ±5% of full scale over entire operating temperature range
Detection method:	Bi-potentiostat Driven Sensor (BDS) Technology (replenishable, non-depleting type)
Operating temp range:	5 to 40° C
Lower detection limit:	500 ppt
Response time:	90% in less than 60 seconds
Resolution:	0.1 ppb
Outputs:	4-20 mADC isolated percent of range output
	0-1 VDC percent of range output and range ID output
Contacts:	2 x fully programmable concentration alarms, 1C contacts, 250 VAC, 3A resistive
	System failure alarm, power failure or calibration failure, 1C contacts, 250 VAC, 3A calibration contact, 1A, 250 VAC, 3A resistive
	Four Range ID contacts, 1A, 250 VAC 3A resistive
Serial interface:	Bi-directional RS-232 for output, concentration, ranges and alarm information (fed every two seconds). Accepts zero and span commands through RS-232
Power requirements:	100 VAC to 240 VAC, 50 / 60 Hz
Sensor warranty:	Two years (expected life of 5 years +)
Auto-calibration software:	Standard; the frequency of the auto-calibration cycles is user programmable.
Dimensions:	BDS-3000: 7" H x 8.75" W x 12.25" D
	BDS-306: 17.0" H x 15.0" W x 10.0" D

SENSOR FEATURES

- Bi-potentiostat driven, 4-electrode non-depleting sensor
- Precise control of potential voltages delivered to the sensor electrodes ensuring high accuracy
- Simple-to-use, long-life, low-cost sensor design
- No sensor temperature control requirements
- Quick response to changes in O2, even after extensive exposure to oxygen-free sample or zero gas streams (i.e. no sensor "sleep" effects)
- Baffle mechanism in sensor lessens downtime

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TELEDYNE
ANALYTICAL INSTRUMENTS
A Teledyne Technologies Company
16830 Chestnut Street
City of Industry, California 91748, USA

TEL: 626-934-1500 or 888-789-8168
FAX: 626-934-1651 EMAIL: ask_tai@teledyne.com
www.teledyne-ai.com

Warranty

Instrument is warranted for 1 year against defects in material or workmanship

NOTE: Specifications and features will vary with application. The above are established and validated during design, but are not to be construed as test criteria for every product. All specifications and features are subject to change without notice.

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