

P09051 Oxygen Gas Sensor

Test Plans & Test Results

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Table of contents

1. TITLE: OXYGEN MEASUREMENT TEST VIA FABRICATED OXYGEN GAS SENSOR SYSTEM.....	2
1.1. Introduction	2
1.2. Project Description.....	2
1.3. Approval.....	2
1.4. Test Strategy	2
2. MSD II WKS 2-4: - FINAL TEST PLAN	5
2.1. Data Collection Plan; Sampling Plan.....	5
2.2. Measurement Capability, Equipment.....	8
2.3. Test Conditions, Setup Instructions.....	8
2.4. Sponsor/Customer, Site Related, Requests / Considerations.....	10
2.5. Test Procedure, Work Breakdown Structure, Schedule.....	10
2.6. Assumptions	10
2.7. MSD II – WKS 3-10 design test VERIFICATION.....	11
2.8. Test Results	11
2.9. Logistics and Documentation	11
2.10. Definition of a Successful Test, Pass / Fail Criteria.....	11
2.11. Conclusion or Design Summary.....	11
2.12. Function/ Performance Reviews.....	11

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1. TITLE: OXYGEN MEASUREMENT TEST VIA FABRICATED OXYGEN GAS SENSOR SYSTEM

1.1. Introduction

1.1.1. **PURPOSE:** The purpose of this test plan document is to outline the procedure necessary to evaluate varying oxygen concentrations using the fabricated oxygen gas sensor. The goal of the project is to be able to utilize the constructed sensor in measuring oxygen content fluctuations in various biological media, including cell cultures, skin tissue, and other biomedical applications.

1.1.2. **SCOPE:** The instructions in this document will be used as a procedural reference to verify and experiment the oxygen gas sensor.

1.2. Project Description

1.2.1. This project's main objective will be to make quantified results that pertain to the concentration of oxygen present in the system. The objective of this procedure is to The object to be tested will be inserted into the chamber, then flow meters will be used to establish the gas content inside the chamber to a desired content in ratio. The LED will then be pulsed on, and measurements will be made based on the displayed data in the oscilloscope.

1.3. Approval

Approved by:
Team Members – Jeremy Goodman (uE).
Guide – Professor George Slack

1.4. Test Strategy

1.4.1. Figure 1 below shows the high-level block diagram of the operation behind the oxygen gas sensor.

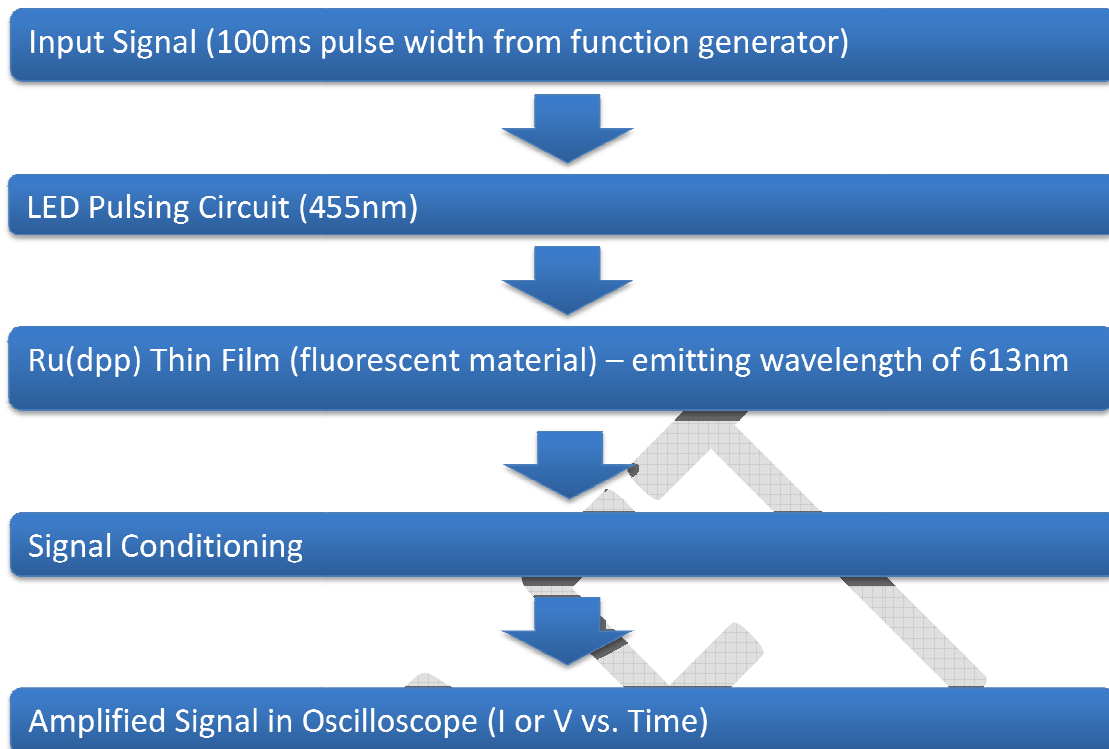


Figure 1- Operational block diagram of the Oxygen Gas Sensor

1.4.2. TEST EQUIPMENT

- 1.4.2.1. Oxygen Gas Sensor System (Fabricated)
- 1.4.2.2. Function generator capable of delivering a positive width signal of >100ms & rise time <5ns.
- 1.4.2.3. Power Supply capable of delivering +/- 5V
- 1.4.2.4. Oscilloscope with visual output.

1.4.3. TEST PHASES

- 1.4.3.1. Phase 1: Functional Compliance of required components in the oxygen gas sensor.
 - 1.4.3.1.1. Electrical Components
 - 1.4.3.1.1.1 LED verification: Shine known pulse of light to diode and verify it exhibits light
 - 1.4.3.1.1.2 MOSFET verification: Measurement of the current output at the LED.
 - 1.4.3.1.1.3 Photodiode verification: Measurement will be done for a given amount of light via the LED or known source; output current will be measured accordingly.
 - 1.4.3.1.1.4 Schott Glass Filter verification: The filtered light will be visually and quantitatively verified (if sufficient testing equipment available)
 - 1.4.3.1.1.5 Tris-Ruthenium Polymer Complex- After the polymer has been fabricated, a known wavelength of light will be fed through and

its intensity will be visually and quantitatively verified (if sufficient testing equipment is available).

1.4.3.2. Phase 2: Functional Compliance of Subsystems

- 1.4.3.2.1. LED Pulsing Circuit – A known amplitude and pulse width of signal will be fed through the MOSFET into the LED- the time interval and output amplitude will be checked via visual and quantitative recording through the oscilloscope.
- 1.4.3.2.2. Oxygen Detecting Complex – A known wavelength and intensity of light will shine to the detecting complex after being filtered to have its intensity measured via visual and quantitative recording (through power measurement in light, if available).
- 1.4.3.2.3. Photodiode/ Transimpedance Amplifier- The final amplified voltage reading will be checked vs. theoretically derived values to confirm functionality.
- 1.4.3.2.4. Test Chamber and Gas chamber assembly – Complete system will be verified to see if sufficient ratio of nitrogen and oxygen gas can be established inside chamber for a certain period of time.

1.4.3.3. Phase 3: Integration

- 1.4.3.3.1. Assembly of gas chamber / electrical components/ chemical components

- 1.4.3.3.1.1 Ensure that consistent reliable measurements can be made at extreme conditions (E.g. 0% Oxygen, 100% Oxygen)

1.4.3.4. Phase 4: Gathering empirical data

- 1.4.3.4.1. Will first test at wide intervals, and verify its functionality by constructing the stern-volmer plot accordingly.

- 1.4.3.4.1.1 Gradually shorten measurement intervals to increase sensitivity of device.

- 1.4.3.4.2. 20% increments -> 10%

- 1.4.3.4.3. Target incremental sensitivity = 10%

2. MSD II WKS 2-4: - FINAL TEST PLAN

Introduction:

Individual components will require testing to verify proper operation before the system is assembled. This includes, but not limited to: support electronics, LED, fluorescent film, optical filter, and photodiode. After verification of operation, sub-systems will be created to observe interaction between various components, eg. LED→optical filter→photodiode, and LED→fluorescent film. Finally, the complete system will be assembled and initially tested in open atmosphere to observe a working sensor output followed by testing in a controlled gas-flow chamber, flowing known quantities of oxygen through the system and measuring the sensor output.

2.1. Data Collection Plan; Sampling Plan

2.1.1. Test Templates/ Tables/ File Locations

	Test #	System Component(s)	Brief Description
Individual Components	1a	LED	Test for brightness, off/on time, operation
	1b	Fluorescent Film	Visual Operation Test
	1c	Optical Filter	
	1d	Photodiode	Working operation using room light
	1e	Support Electronics	Pulses LED / Records/Amplifies photodiode signal
Group Components	2a	LED + Photodiode	Photodiode receives signal from LED
	2b	LED + Filter + PhotoD	Photodiode <i>does not</i> receive signal from LED
	2c	LED + Fluorescent Film	Fluorescence is excited by LED (<i>visual</i>)
Complete System	3a	System – Open Atm.	System operates with little signal variation/noise
	3b	System – Test Chamber	System output responds to changes in oxygen %

Notes: Detailed listing of test date, test phases, spec, pass/fail requirements, and comments on individual test #s on next page.

Test #	Test Date	Specifications	Pass/Fail Requirements	Comments
1a	wk5			
1b	wk5		- Fluoresces in room lighting - Visual quenching phenomenon (film turns darker) when sprayed with nitrogen	Is there any visual cues from the film that its quenching O ₂ ?
1c	wk5		- Visually blocks blue light - Held up to film, can see orange fluorescence	
1d	wk5		- Using room lighting, achieves stable/quantifiable output	Already tested, would like to test again w/ new board
1e	wk5		- Signal input to LED pulses device to reach maximum photonic emission/known time - Signal output of photodiode filtered/amplified to measureable level	
2a	wk6		- Photodiode receives large output signal from LED - Output signal is large enough (amplified/filtered) to be measured	Checking if photodiode operates properly
2b	wk6	- 95% less incident power	- Output Photodiode signal after filter is approximately 95% less than non-filter	Is the long-pass filter effective at blocking LED?
2c	wk6		- Fluorescent film emits fluorescence with incident 455nm LED light (visual test)	Will the film emit fluorescence from incident LED power? How bright does it get?
3a	wk7		- System assembled completely - System receives fluorescent signal from excited fluorescent film - System outputs very little noise from LED/environment	This procedure is used to determine if the system actually operates.
3b	wk8			

2.1.2. Phases of Testing

2.1.2.1. Subsystem

2.1.2.1.1. LED emitter/ Receiver Specification verification test list

- 2.1.2.1.1.1 Royal Blue LED Emission- Visual Verification of Royal Blue Color on the LED.
- 2.1.2.1.1.2 Polymer excitation and emission wavelength- Will be verified visually through the optical filter.
- 2.1.2.1.1.3 Absorbed Photodiode Power- Use a power light meter at differing distances in the basement optical labs.
- 2.1.2.1.1.4 Lowest Current from Diode- Will Measure the change in voltage in test light shining through the photodiode.
- 2.1.2.1.1.5 Length of desired input signal pulse- Will be measured through an oscilloscope.
- 2.1.2.1.1.6 Desired Response Frequency- Picked Components that can handle these response frequencies; will verify via direct assembly and testing's.
- 2.1.2.1.1.7 Rise time of LED- the LED time is set by the function generator, and will be verified in the oscilloscope.

2.1.2.2. Integration

2.1.2.2.1. Will be assembled together first with a commercial photodiode, and it will be verified with the actual fabricated photodiode.

- 2.1.2.2.1.1 It would be first simulated in pspice, then built and verified through hardware, and integrated into protoboard.
- 2.1.2.2.1.2 The circuitry will be first tested for operation by toggling between no light (by manual shielding) and ambient, classroom light.
- 2.1.2.2.1.3 Receiver circuit will then be tested based on input from LED; first by a steady source of light, then in pulses. Output will be measured and evaluated in the oscilloscope.
- 2.1.2.2.1.4 Same process of toggling light will be used for the fabricated photodiode as well.
- 2.1.2.2.1.5 This portion will then be integrated to the box for chamber testing in varying gas levels. All results will be viewed and recorded in oscilloscope.

2.1.3. Sampling Techniques

The sensor will be initially tested in open atmosphere followed by testing in a flow chamber. Flow chamber testing will serve to pass different quantities of oxygen through the sensor while the output is being monitored. Given the amount of bottled gas available, two or three samples of each %O₂ increment will be taken to quantify sensor variation as well as performance.

2.1.4. Sample Size

One oxygen sensor will be created from available resources (sensor can be re-used). Two films slides have been created; however, film thickness/sensing element concentration varies between the two.

2.1.5. Reporting Problems; Corrective Action

All problems should be reported to the team members. If a device does not work properly, the quality or ability to execute the project will be in jeopardy. All problems will be analyzed to determine a correct course of action.

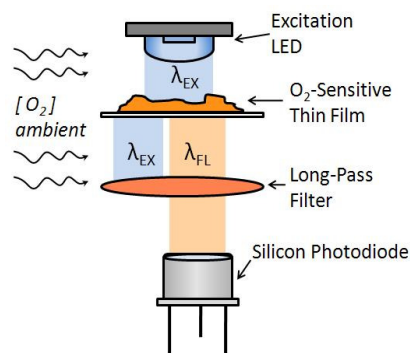
2.2. Measurement Capability, Equipment

2.2.1. Gas Flow Chamber

A gas flow chamber will need to be constructed in order to test the sensor at varying %O₂ concentrations. Most materials will be donated by the RIT SMFL, and all other individual components purchased by the Microelectronic Department. A calibrated oxygen sensor will be needed to precisely calibrate the flow meters in the system – RIT Engineering Department will be polled in order to find a calibrated oxygen sensor.

2.3. Test Conditions, Setup Instructions

2.3.1. Sensor Setup

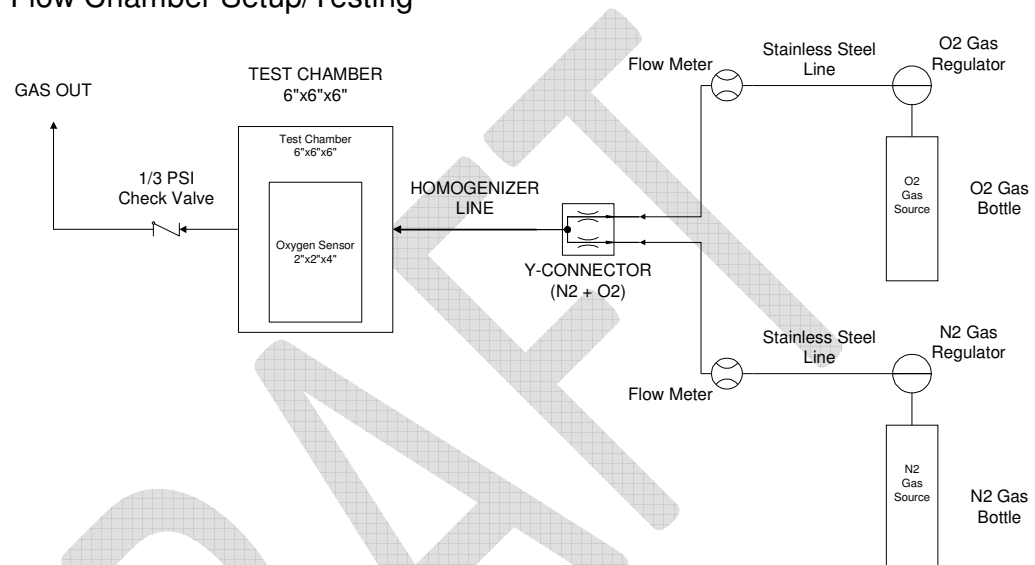


LED will be placed at the top of the sensor with the fluorescent film in close proximity to absorb a maximum amount of optical power. The long-pass filter will be placed below the fluorescent film with the photodiode situated below to record the fluorescent signal. Support electronics will be connected to both LED and photodiode to drive the measurement procedure.

2.3.2. Open Atmosphere Testing

Expose assembled sensor to open oxygen. Enclose the sensor in a light-shielding enclosure to ensure all measured light comes from ONLY the sensor. At 5 minute intervals, pulse the LED and record the fluorescent emission from the fluorescent film using the photodiode/support electronics. Repeat this process 3 times to ensure data is accurate/non-varying. A successful test will result in 3 closely-matching plots of photodiode output voltage versus time. The purpose of this test is to verify proper construction of the sensor, as well as operation – this will allow enough time to work out problems before the sensor is tested in the flow chamber

2.3.3. Flow Chamber Setup/Testing



Chamber Materials:

- Oxygen/Nitrogen Gas Bottles w/ 30PSI pressure regulator
- Stainless steel/Teflon Tubing
- 2x Floating Ball Flow Meters
- Stainless Steel Y-Connector
- Swagelok tube fittings
- Stainless Steel Test Chamber w/ Lid
- Scrap blocks of stainless steel (to decrease volume inside chamber)
- 1/3 PSI check valve
- Calibrated Oxygen Sensor (from RIT departments)

After chamber construction, the sensor (after testing in open atmosphere) will be loaded into the center of the test chamber. The chamber will be sealed to prevent all outside atmosphere from entering the system. The system will be purged with Nitrogen for 2 minutes to ensure all oxygen is expelled from the system and a measurement will be taken with the sensor (baseline 0% oxygen). Using the calibrated oxygen sensor to guide the gas mixture, the oxygen flow meter flow will be increased to allow for 10% oxygen concentration increments. Each increment will have one measurement taken with the sensor; however, the gases will require time to be stabilized. Therefore, approximately 1 minute will be

elapsed before a single measurement is taken at each increment. Once at 100% oxygen, the system will remain at 100% oxygen for a separate measurement. The oxygen flow meter flow will then be decreased at 10% increments and the sensor will be used to take a single measurement at each increment. Like before, the gas concentrations will be allowed time to stabilize; therefore, each increment will wait roughly 1 minute before a measurement is taken.

A second cycle of measurements can be executed if enough gas remains. Each cycle of measurements will generate a Stern-Volmer plot, as well as a plot of normalized intensity (I/I₀) over elapsed experiment time. There will be one plot for the increase increment test and one plot for the decreasing increment test, respectively.

2.4. Sponsor/Customer, Site Related, Requests / Considerations

2.5. Test Procedure, Work Breakdown Structure, Schedule

2.5.1. Work Breakdown – Member Assignments

	Test #	System Component(s)	Member Assigned	Scheduling
Individual Components	1a	LED	Sam	Week 5/6
	1b	Fluorescent Film	Jeremy	
	1c	Optical Filter	Jeremy	
	1d	Photodiode	Sam	
	1e	Support Electronics	Sam	
Group Components	2a	LED + Photodiode	Sam	Week 5/6
	2b	LED + Filter + PhotoD	Sam/Jeremy	
	2c	LED + Fluorescent Film	Sam/Jeremy	
Complete System	3a	System – Open Atm.	Sam/Jeremy	Week 7
	3b	System – Test Chamber	Sam/Jeremy	Week 8

2.6. Assumptions

2.7. MSD II – WKS 3-10 design test VERIFICATION

2.8. Test Results

2.8.1. Component

- i. Each component will be tested separately for functionality
 - a. Could be quantitative or visual .

2.8.2. Subsystem / Integration

- i. Entire subsystem will be assembled, and fixed amounts of respective gas hooked on.
- ii. Main purpose is to see a change in varying concentrations of gas.

2.9. Logistics and Documentation

Circuitry testing done at Senior Design Lab; Complete system testing with chamber and gas purging will be done in the fabrication building.

2.10. Definition of a Successful Test, Pass / Fail Criteria

Successful test will depend on change that will occur with varying oxygen levels inside the chamber. Main pass will be defined by whether a visible, changing output can be viewed in the oscilloscope based on varying oxygen levels.

2.11. Conclusion or Design Summary

The complete circuit works as planned in testing scenarios. The lack of an actual chamber made the response from the varying concentrations of gases difficult to view. All testing documentation will be available in EDGE.

2.12. Function/ Performance Reviews

2.12.1. Debriefing your Guide and Faculty Consultants

Test Results will be evaluated via demonstrations, as mentioned in the next section, and through documentation and technical papers.

2.12.2. Lab Demo with your Guide and Faculty Consultants

Perform each of the specifications and features, with the faculty guide and TA, if applicable.