Plexiglass glove box for organic solar cells

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Abstract. The term Glove Box probably creates an image of a glass box with black gloves, but Glove Boxes are as varied as the applications in which they are used. It is a hermetically sealed, watertight box, built for the purpose of sensitive applications. In this paper we present the design, the implementation and the testing of a Glove Box using plexiglass of 6mm thickness. The entire control of the system is flashed on an ATmega328 microcontroller. The sensors inside the box include oxygen sensor, gas sensor, humidity and temperature sensor. The plexiglass used provides robustness for the system but being lightweight it can be easily moved in different places in a research laboratory, compared with the steel Glove Boxes which are difficult to handle. The Glove Box was tested, by filling it up with Argon (inert gas) and introducing bulk heterojunction organic solar cells (BHJ OSC) and leaving them inside for 12 hours. The measurement of the OSCs after 12h revealed that their efficiency decreased with only 20% compared to those left outside of the Glove Box which had an efficiency decrease of more than 70% from their initial value.

1. Introduction

A Glove Box is a sealed room that aims to allow a person to manipulate different objects in an environment with a desired atmosphere. On the sides of the Glove Box the gloves are arranged in such a way that the user can put his hands in the gloves and perform tasks inside the box, without contaminating the interior. The entire box is transparent to allow the user to see what is inside. There are two types of Glove Boxes: the first allows a person to work with hazardous substances [1-2], such as radioactive materials or infectious disease agents, and the second allows the handling of substances that must be contained in an inert atmosphere of very high purity, such as argon or nitrogen [3]. It is also possible to use the Glove Box to handle objects or substances in a vacuum chamber [4].

The applications of this product are extremely varied being used in biochemistry, metallurgy, electronics, chemistry, geology, minerals, pharmaceutical industry [5] and in other sectors. They are also used in other fields like electronic materials, magnetic materials, battery materials, organic cultivation, vacuum food packaging and many more.

In work environments where we have an inert atmosphere, the gas pumped into a Glove Box through a series of devices offer a treatment to remove solvents, water and oxygen from the inside medium. A heated metal, for example copper or another finely divided metal, is commonly used to remove oxygen. While heated it is passed through a mixture of hydrogen or nitrogen and through the column formed the oxygen normally evaporates. The formed water is removed from the box with an excess of hydrogen and nitrogen. In order to remove water, a series of molecular sieves are used that absorb it into the pores of the sieves. Such a Glove Box is often used by organometallic chemists to
transfer dry solids from one container to another [6]. Glove Box improvements are still under research [7-8].

2. Design and implementation
Having as starting point the high price of a Glove Box made-up by steal and the necessity of a Glove Box for the analysis of the organic solar cells (OSC) we wanted to design and implement one for the researchers in this field.

The first stage in the implementation of the Glove Box was the choice of a more affordable material from which the box will be assembled. One of the most suitable materials for creating this chamber are safety glass, double glazing and plexiglass. We chose to use the plexiglass because it offers a very good resistance and it is much lighter than the other options. The dimensions of the designed box are 100 x 62 x 65 cm (length x width x height) and were chosen based on other Glove Boxes that already exist on the market. The box is provided with a door on the side and two holes through which the hands will be inserted into the box using a pair of gloves.

The second stage was to choose the proper sensors and build the electronic measurement and control system knowing that we must monitor four important medium parameters inside the box: temperature, humidity, gas and oxygen level. After a large market research, the four chosen sensors were: DHT22 temperature and humidity sensor, MQ-2 gas sensor and ME2-O2-D20 oxygen sensor. Among these sensors a Reed magnetic sensor was placed to close/open the door.

In the last stage we looked for two suitable solenoid valves. Because the designed box has a small volume of 0.4m² it was not necessary to use some big ones.

The block diagram of our design is presented in figure 1.

![Figure 1. Block diagram of the system.](image)

The schematic of the entire electronic system was implemented in Eagle CAD and presented in figure 2. It consists of several blocks (B1 to B5) responsible for various actions in the circuit.

The control centre is an ATmega328 microcontroller (B2) to which all other components are connected. To power up the system a 5V stabilizer must be used (B1). In our case we used the Arduino Uno development board which incorporates the microcontroller and the voltage stabilizer.

The third block (B3) consists of: temperature and humidity sensor, oxygen sensor, Reed sensor and gas sensor. In addition to these sensors there are also the 4 LEDs with the 4 resistors related to them. Two of the LED pairs are connected to the gas sensor, and when the threshold value is exceeded, a switch will be made from the green LED to the red LED. The second pair of LEDs will make the same switch when the box door closes at the Reed magnetic sensor action.
The fourth block (B4) is an LCD screen on which it is displayed the information related to temperature, humidity, oxygen and gas level inside the box.

The last block (B5) consists in a row of four relays connected as follows: one to the electromagnetic sensor responsible for closing and opening the door actioned by a switch button; one for the solenoid responsible for inserting the gas into the box; one for the solenoid valve which has the role of extracting the oxygen from the box; one extra relay for further connections if necessary. A main switch button was placed to power up the entire system.

The system was tested initially on a breadboard prototype and after that transferred into a PCB level (figure 3 – top side) implementation which contains two PCBs: one for the sensors unit which must be placed inside the box to monitor the inside medium and one to command and control the unit mounted outside the box. The PCBs were encapsulated in custom designed and 3D printed boxes (figure 3 – bottom side). For the design we used the Autodesk platform: Eagle and Fusion360.

The electro-valve for the insertion of the inert gas into the box was mounted on the right-bottom side of the box and the electro-valve for the extraction of the oxygen from the box in the left-top side of the box as presented in figure 4. Near the oxygen extraction valve the sensor unit was mounted. We used this setting knowing that argon has a higher density than oxygen, so the argon will fill the bottom of the box and push the oxygen to the top. In this way we will have an accurate measurement for the oxygen level inside the box.
Among the holes for the glove mounting an extra sealed hole was placed to connect the sensor unit to the control unit. This hole permits the insertion of a power cord inside the box for powering up different equipment intended to be used under inert gas.

![Image of PCB level implementation](image1)

**Figure 3.** PCB level implementation: detailed (top), mounted in enclosures (bottom), sensor unit (left), command and control unit (right).

![Image of final assembly](image2)

**Figure 4.** Final assembly of the Glove Box.

The microcontroller receives all the information from the sensors and redirects it to the display. Also, it controls the relays which in turn control the valves and the electromagnetic lock. The whole operation algorithm is presented in figure 5 and explained beneath.

It all starts with the system initialization then it continues with the activation of the interruption and initialization of the LCD. Both solenoids and the door lock are closed. The LEDs related to the Reed sensor and the gas sensor are ON depending on which condition is accomplished. The sensors start the monitorization and the data is read and transferred to the microcontroller and then displayed on the LCD. If the oxygen value is higher than 50.000 PPM, then the valves will open and start the process of
argon insertion and oxygen extraction. To speed up the extraction process a vacuum pump can be mounted. When the condition is accomplished the valves will close automatically and inside the chamber, we will have a hermetic environment ready for the experiments.

3. Experimental results
The values read by the sensor at the beginning of the first test were: O2: 209808.69PPM; Gas: 30.54PPM; Temperature: 35.2°C; Humidity: 44.9%.

The entire evolution of oxygen level during this first test is presented in figure 6 (top graph). We started the insertion of argon with a pressure of 1.25Bar for a time period of seven minutes and after that we doubled the insertion for two minutes. We could see that the decrease of the oxygen level is much faster in the case of the 2.5Bar than in the one with 1.25Bar insertion pressure. The 2.5Bar pressure is the maximum pressure allowed in the laboratory where we took the testing. Keeping the valves sealed for 5 minutes the oxygen level remained constant around 100.000PPM. After this, we inserted more argon at 2.5Bar and we reached in sixteen minutes the minimum oxygen level of
20.000PPM that could read by the sensor. At this point we closed the valves for eight minutes and observed that the oxygen level remained unchanged at 20.000PPM. At the end of this test the other sensors read: Gas: 3.66PPM; Temperature: 36.2°C; Humidity: 22.4%.

For the second test (figure 6 - bottom), we start the whole process from the ambient medium oxygen level, around 210.000PPM. After closing the door, we inserted argon at 2.5Bar for almost 30min. when the read oxygen level dropped to 20.000PPM. At this point we closed the valves and monitored the oxygen level for 12 hours. Analysing the data saved for this time period we found that the oxygen level was kept at 20.000PPM for five hours and after that we had small changes every hour. After 12 hours the oxygen level was around 24.000PPM.

The last test was taken with eight organic solar cells and after their initial measurement, four of them were introduced in the Glove Box and kept at 20.000PPM oxygen level medium and four of them outside the Glove Box for 12 hours. After this storage time the OSCs were measured again and the results revealed a decrease of the efficiency (PCE) with 20% for the cells kept in the inert medium and with more than 70% for the cells kept in the high oxygen level medium. The measurement results are presented in table 1.

Table 1. BHJ OSC testing results with and without Glove Box.

| Cell Name | Initial PCE [%] | PCE [%] after 12h | PCE decrease percent [%] | Storage condition |
|-----------|-----------------|------------------|--------------------------|-------------------|
| P1_E1     | 2.33            | 1.86             | 20                       | Inside Glove Box  |
| P1_E2     | 2.01            | 1.67             | 17                       | Inside Glove Box  |
| P2_E1     | 2.76            | 2.29             | 17                       | Inside Glove Box  |
| P2_E2     | 2.62            | 2.14             | 18                       | Inside Glove Box  |
| P3_E1     | 2.08            | 0.56             | 73                       | Outside Glove Box|
| P3_E2     | 2.14            | 0.51             | 76                       | Outside Glove Box|
| P4_E1     | 2.57            | 0.57             | 78                       | Outside Glove Box|
| P4_E2     | 2.31            | 0.67             | 71                       | Outside Glove Box|

4. Conclusions

The Glove Box design and the implementation of it proved to work properly for a time period of at least 12 hours where the oxygen level remains almost constant at 20.000PPM. The test made on the organic solar cells shows that the Glove Box offers a good environment for them. From the price point of view the Glove Box materials (plexiglass and electronics) are less than 1000EUR, which is a big plus compared to the more expensive Glove Boxes available on the market. Future work can be considered by replacing the oxygen sensor with one with a higher sensibility.

References

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