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Fabrication of Optical Cell Dryer for Spectroscopic Analysis Cell

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TITLE:

Fabrication of an Optical Cell Dryer for the Spectroscopic Analysis of Cells

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KEYWORDS:

Optical cell, dryer, cuvette, drying time, quartz cell, blower, experimental instrument

SUMMARY:

A protocol for fabricating a device for simultaneously drying multiple optical cells is presented.

ABSTRACT:

Optical cells, which are experimental instruments, are small, square tubes sealed on one side. A sample is placed in this tube, and a measurement is performed with a spectroscope. The materials used for optical cells generally include quartz glass or plastic, but expensive quartz glass is reused by removing substances, other than liquids, to be analyzed that adhere to the interior of the container. In such a case, the optical cells are washed with water or ethanol and dried. Then, the next sample is added and measured. Optical cells are dried naturally or with a manual hairdryer. However, drying takes time, which makes it one of the factors that increase the experiment time. In this study, the objective is to drastically reduce the drying time with a dedicated automatic dryer that can dry multiple optical cells at once. To realize this, a circuit was designed for a microcomputer, and the hardware using it was independently designed and manufactured.

INTRODUCTION:

Optical cells are used as laboratory instruments in a wide range of fields. In life science research, biomolecules such as nucleic acids and proteins are often utilized for experiments, and spectroscopic methods are widely used for quantitative methods. Accurately quantifying the sample of the experiment is indispensable for obtaining more accurate and reproducible results. The absorption spectrum obtained by a spectrophotometer has often been used for the quantification of biomolecules such as nucleic acids and proteins¹⁻⁴. Research on oxidation-reduction characteristics caused by the change in the absorption spectrum and photoluminescence of a carbon nanotube (CNT) dispersed using DNA has also been conducted⁵⁻¹⁰. Optical cells are used for these measurements, but accurate measurements cannot be made

unless they are thoroughly washed and dried.

When measuring absorption spectra or photoluminescence, it is impossible to measure precisely in dirty optical cells¹¹⁻¹⁵. Economical disposable optical cells made of polystyrene and polymethyl-methacrylate are also used to eliminate washing and contamination. However, when precise measurements are required, quartz glasses are often used, because they have extremely excellent optical properties such as light transmittance. In this case, the optical cells are washed after the measurement of the sample and repeatedly used. Usually, after washing optical cells with water or ethanol, they are dried naturally. When rapid drying is required, they are dried one by one by using hair dryers or similar equipment. Cleaning optical cells is one of the most unpleasant and time-consuming procedures in the experiment. As the number of samples increases, the drying time increases, which, in turn, increases the time required to conduct the experiment and research. In past studies, there have been no reports on peripheral devices of optical cells. This study aims to reduce the research time by drying multiple optical cells simultaneously.

We investigated whether other similar products exist. A box-type constant temperature dryer with a temperature control function and a timer function already exists; however, no commercial products with the same configuration can be found.

An outline of the production of this device is described. First, the box-type case is made using an acrylic plate. Nylon netting is attached to the top. A plastic grid is placed on it to fix the optical cell. The control circuit is stored inside the case, and the plastic plate is attached to protect the circuit from water droplets. The control circuit consists of a CPU and is controlled by software. Blowers are attached to the back of the case, and the wind supplied by the blowers enters the optical cells set upside down. The blowers are activated by a switch on the front, and they are automatically stopped by the timer. Depending on the number of optical cells to be dried, two or four blowers can be selected for operation. Water droplets dripping from the optical cells evaporate with the wind from the blowers. The quartz cells are washed with water or ethanol, and the drying time is compared with that of natural drying.

PROTOCOL:

1 Design

1.1 See **Figure 1** for details of the development drawing.

1.2 Cut a 3-mm thick acrylic board to 210 mm in width x 60 mm in height x 104 mm in depth, bond with acrylic adhesive and assemble the case.

1.3 Install as many as 30 optical cells of 12.5 x 12.5 mm.

1.4 Attach switches and lamps for starting and stopping and a variable dial for the drying time setting on the front face of the casing.

1.5 See **Figure 2** for an external view and component configuration.

1.6 Use acrylic and nylon for the casing and net, respectively. Fix the net to the frame and attach it to the upper part of the case.

1.7 Use acrylic for the lattice of the optical-cell installation. Attach it to the top of the net.

1.8 Mount the blowers to the back of the case.

1.9 Use translucent acrylic for a waterdrop prevention partition.

2 Hardware Design Outline

2.1 See **Figure 3** for details of the circuit diagram.

2.2 Step down from 12 V to 5 V by a three-terminal regulator for operating the microcomputer.

2.3 Activate the blowers *via* an NPN transistor (25 V, 500 mA).

Note: Because the output pin of the microcomputer is 5 V.

2.4 Control the rotation speed of the blowers by the pulse width modulation (PWM) operation of the output pin.

Note: The blower is being driven, the number of revolutions is controlled, and the strength is periodically changed.

2.5 Connect the start push switch to the digital input pin.

2.6 Connect the blowers' operation time setting volume to the analog input pin to change the voltage according to the rotational position.

2.7 Connect the organic light-emitting diode (OLED) for the operation time display to the two digital output pins with an inter-integrated circuit (I2C).

2.8 Connect the LED that lights up during the operation to the digital output pin.

3 Software Design Outline

3.1 Use a microcomputer to control the blowers.

Note: The development environment was constructed using Arduino, which is one of the development environments called open-source hardware, and all circuits and software are open to the public.

3.2 Outline of the operation

3.2.1 Press the start switch.

3.2.2 Read the state of the button specified by the select button on the front and activate the blower according to that state.

3.2.3 Read the drying time set by the variable resistor on the front as a voltage signal and start counting down the timer.

3.2.4 Turn the LED lights up and display the remaining time on the OLED.

3.3 Detailed explanation

3.3.1 Read the volume position connected to the analog input pin as a voltage; then, it converts to the blower's operation time and displays on the OLED.

3.3.2 Detect the ON/OFF switch connected to J1-9, 10 pins of the circuit diagram when pressing the start switch, turn on the blowers' drive pin, activate the blowers, and turn on the LED during the operation.

3.3.3 Control the blowers by PWM. Detect the position of the 10-k Ω variable resistor connected to the circuit diagram J1-5, 6, 7, and drive the blowers with the corresponding output.

3.3.4 Detect the position of the 10-k Ω variable resistor connected to the circuit diagrams J1-1, 2, 3 pin by setting the drying time and activate the blowers for a time corresponding to that.

3.3.5 Connect the power LED to the circuit diagrams J1-15, 16 pin. Connect the start LED to the circuit diagrams J1 - 12, 13.

Note: The power LED lights up when the power turns on, and the start LED lights up while the blowers are activated.

3.3.6 Connect the OLED to PB4, PB5 of the CPU with an I2C.

Note: The operation time displayed on the OLED is counted down every second. When the operation time reaches 0, the blowers' drive pin is set to 0, the blowers are stopped, and the operating LED is turned off to make the transition to the initial standby state.

3.3.7 Use the Adafruit SSD1306 library for an OLED display of Arduino.

175
176 Note: When the power switch is turned ON, operate in the order of initialization and message
177 display. A part of the source code is shown below as an example of use of this library.

```
178  
179 #include "Wire.h";  
180 #include <Adafruit_SSD1306.h>  
181 #define OLED_RESET -1  
182 Adafruit_SSD1306 display(OLED_RESET);  
183     ↓  
184     ↓  
185 void setup() {  
186     Serial.begin(115200);  
187     while (!Serial) {  
188         ; // wait for serial port to connect. Needed for Leonardo only  
189     }  
190     Wire.begin(SDA, SCL); // (SDA, SCL)  
191     delay(1000);  
192     display.clearDisplay(); // Clear the buffer.  
193     display.setTextSize(1);  
194     display.clearDisplay();  
195     display.print(F("SD ")); // Weake Up Message Display(Version)  
196     display.println(ver);  
197     display.display();  
198     ↓  
199     ↓  
200 }
```

201 202 **4 Method of Operation**

203
204 4.1 See **Figure 2** for details of the External View.

205
206 4.2 Turn the main power switch of number 10 ON. The operation lamp of number 11 lights up.

207
208 4.3 Place the optical cells on the mesh number 2 from the lattice part of the plastic of number 1.

209
210 Note: The number of optical cells that can be mounted is as many as the number of lattices.

211
212 4.4 Select a two-blower operation or four-blower operation. Depending on the driving situation,
213 the operation lamp of number 5 and number 6 lights up.

214
215 Note: Number 3 is a switch for operating the blowers on the right side, and number 4 is a switch
216 for operating the blowers on the left side.

217
218 4.5 Set the operation time with the timer with number 9.

4.6 Turn number 7 on.

Note: The fan with number 12 starts, and, at the same time, the operation lamp of number 8 lights up.

5 Method to Measure the Drying Time

5.1 In the case of natural drying

5.1.1 Wash the optical cells thoroughly with water or ethanol. Use thick absorbent paper to absorb the moisture of the optical cells, then move the cells to another place on the thick absorbent paper and wait until they dry.

5.2 In the case of the optical-cell dryer

5.2.1 Wash the optical cells thoroughly with water or ethanol.

Note: Use thick absorbent paper to temporarily absorb the moisture.

5.2.2 Place the optical cells in the optical-cell dryer, then wait until they are dry.

5.2.3 Measure the drying time 3x for each cell.

5.3 Comparison of the average values

5.3.1 Measure the drying times 3x at 30 places to obtain the distribution.

Note: This is to detect the time difference according to the position of the cells in the optical-cell dryer.

5.3.2 Use average values of all 30 places for a comparison with water.

Note: In the case of washing with water, determine the positions of the optical cells randomly, then measure the drying time at 10 points.

REPRESENTATIVE RESULTS:

As shown in **Table 1**, in the case of ethanol washing, the average drying time in natural drying was 426.4 s, and the average drying time in the optical-cell dryer was 106 s. In the case of water washing, the average drying time in natural drying was 1481.4 s, and the average drying time in the optical-cell dryer was 371.6 s. In both cases, the drying time was reduced to approximately one-fourth. The drying time distribution of the optical-cell dryer is shown in **Figure 4**. The average drying time at 30 locations was 106 s. The number in the upper row represents the position of the cell. The number in the lower row represents the average value of the drying time.

The air volume of the blower was 31 m³/h per one unit, and the total of the four units was 124 m³/h. The air temperature was room temperature, and the temperature control was not performed.

FIGURE AND TABLE LEGENDS:

Figure 1: Development drawing. Attach the net on the top of the acrylic case and mount a plastic grid for fixing the optical cells that are attached on top of it. The size of the case is 210 mm in width x 60 mm in height x 104 mm in depth, and 30 optical cells of 12.5 x 12.5 mm can be mounted at the same time.

Figure 2: External view. The material of the casing is acrylic, which is easy to process. The material of the net is nylon. It is fixed to the frame and attached to the upper part of the case. The material of the lattice for the optical cell installation is acrylic, and it is attached to the top of the net. Number description: 1 = the plastic lattice, 2 = the net, 3 = the blower selection button (right side), 4 = the blower selection button (left side), 5 = the blower-operating lamp (right side), 6 = the blower-operating lamp (left side), 7 = the blower start button, 8 = the blower-operating lamp, 9 = the timer, 10 = the power supply switch, 11 = the power supply lamp, 12 = the OLED display, and 13 = the blowers.

Figure 3: Circuit diagram. The power supply is 12 V. The operating voltage of the blowers is 12 V. Control the rotation speed of the blower by pulse width modulation (PWM) operation of the output pin. Connect the blower operation time setting volume to the analog input pin to change the voltage according to the rotational position. Connect the organic light-emitting diode (OLED) for the operation time display to the two digital output pins with an I2C.

Figure 4: Drying time distribution using ethanol. The drying time at 30 locations was measured three times using ethanol to obtain the distribution. The average drying time at 30 locations was 106 s. The number in the upper row represents the position of the cell. The number in the lower row represents the average value of the drying time.

Table 1: Comparison of the drying time for optical cells. The average drying time of natural drying after washing with ethanol was 426.4 s, and the average drying time using the optical-cell dryer was 106 s. The average drying time of natural drying after washing with water was 1481.4 s, and the average drying time using the optical-cell dryer was 371.6 s.

DISCUSSION:

The optical cells can be dried simultaneously with the blowers, and the drying time can be considerably reduced. Even if the stop operation is not executed, it can be safely stopped by using the automatic stop function of the timer. From the measurement results of the drying time distribution, there was no significant difference in drying time because of the difference in the installation position of the optical cells.

A critical step of the protocol is the design of the casing. The challenge is how to make the casing compact. It is also important to figure out how to prevent the excess ethanol or water from dropping into the blower.

To reduce the drying time, the wind volume of the blowers can be increased, but there is a risk that the optical cells might jump out. To raise the blowers' capacity and reduce the drying time, it is necessary to devise measures that prevent this, such as attaching a fixture for fixing the optical cells or attaching a lid to the dryer to put it in a box. There is also a method of increasing the inlet air temperature of the blowers to reduce the drying time. To this end, it is necessary to add a temperature control function so as not to damage the optical cell. However, this is a future task because more complicated devices and control circuits are required.

Another way to reduce the drying time is to vibrate the water droplets to make them drop, but that is also a future research topic.

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DISCLOSURES:

The authors have nothing to disclose.

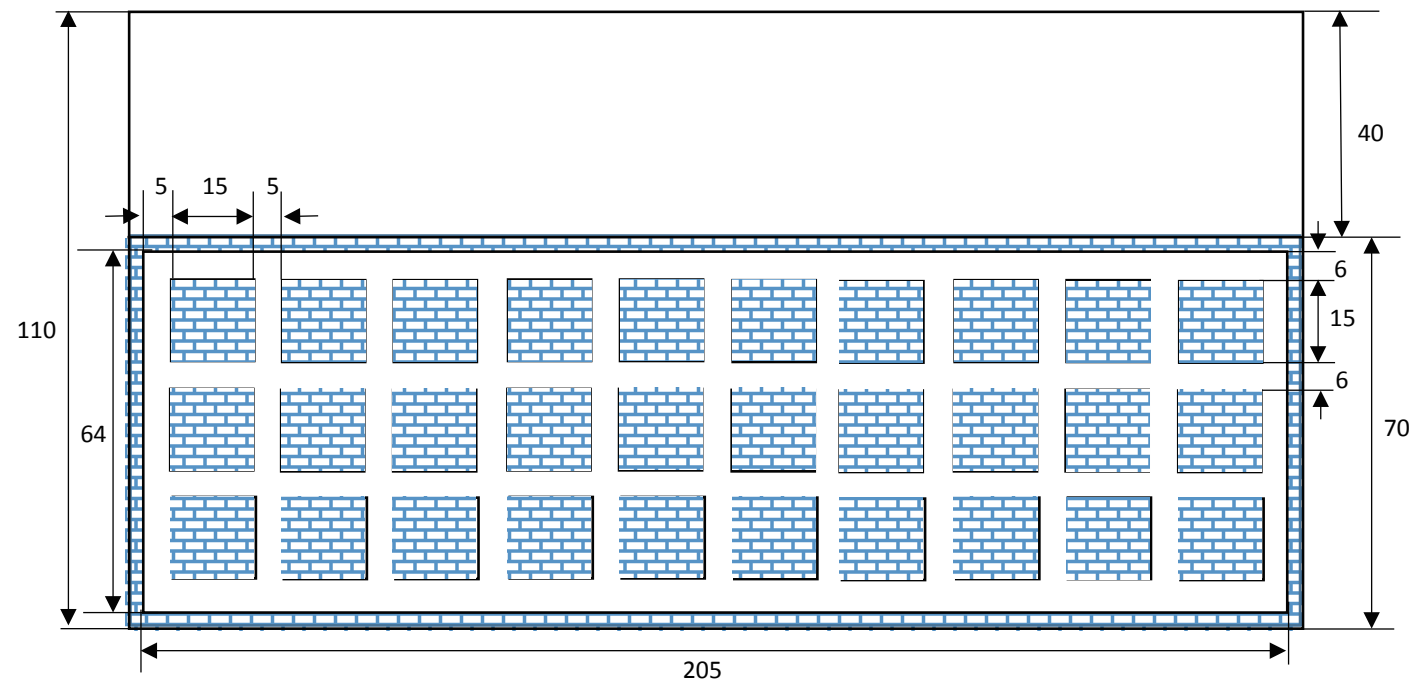
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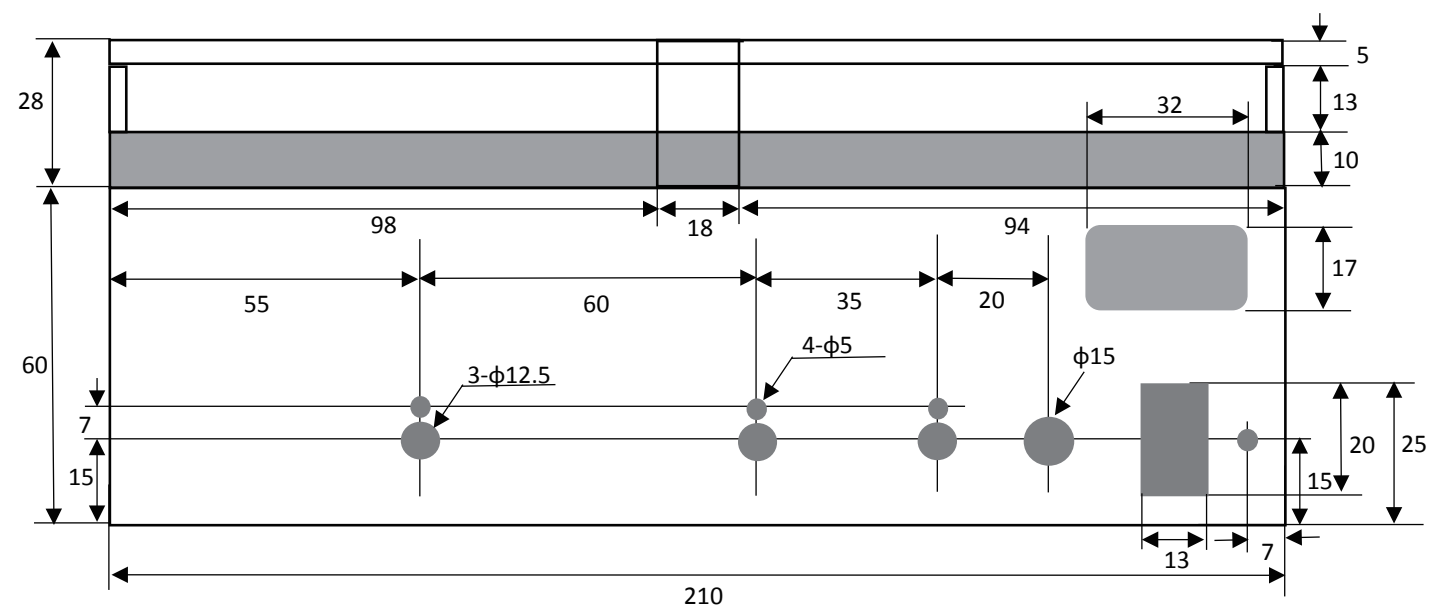
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Figure1

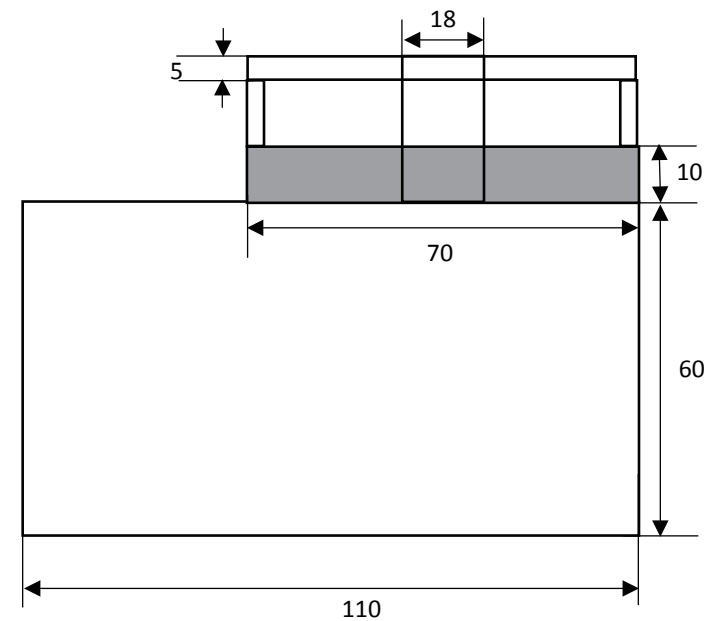
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Top View



Front View



Rear View

Figure2

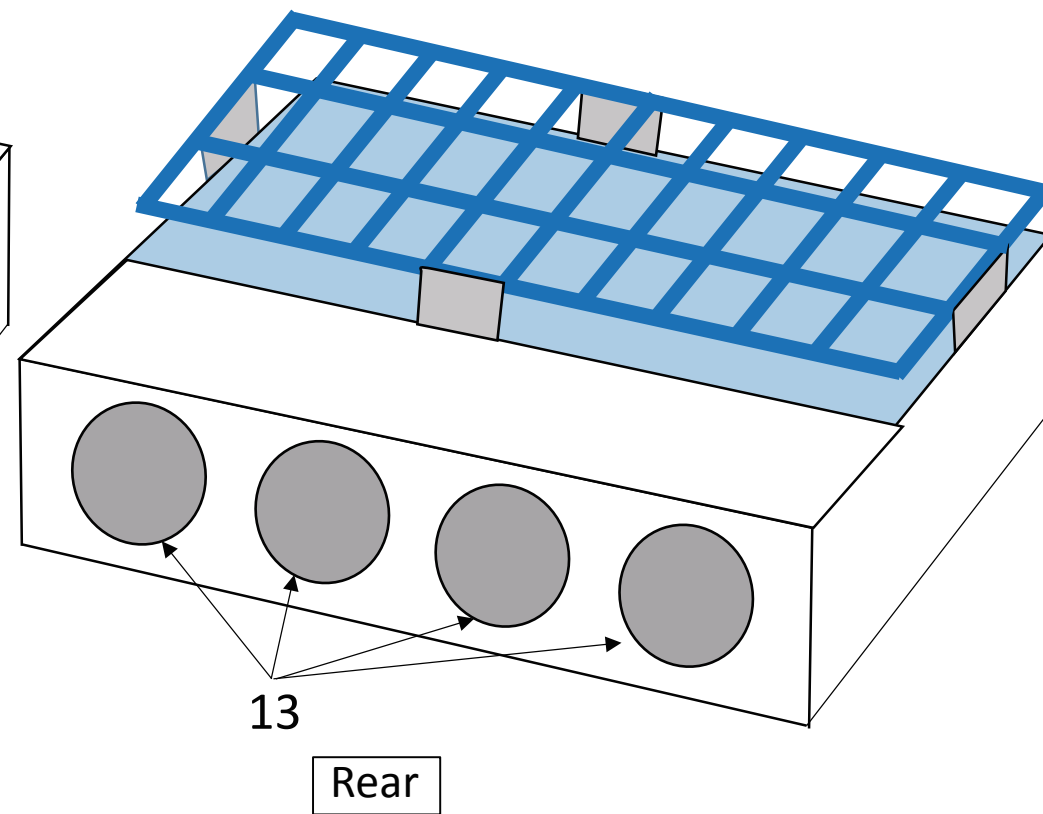
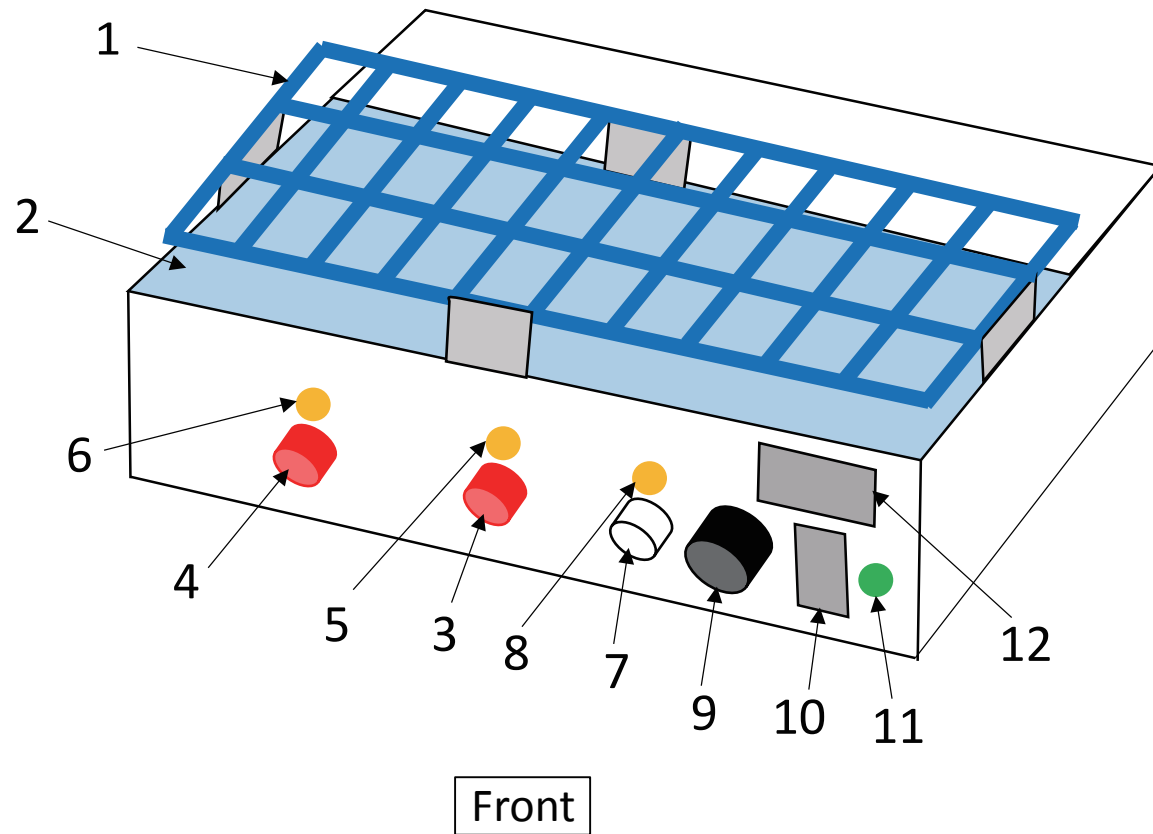
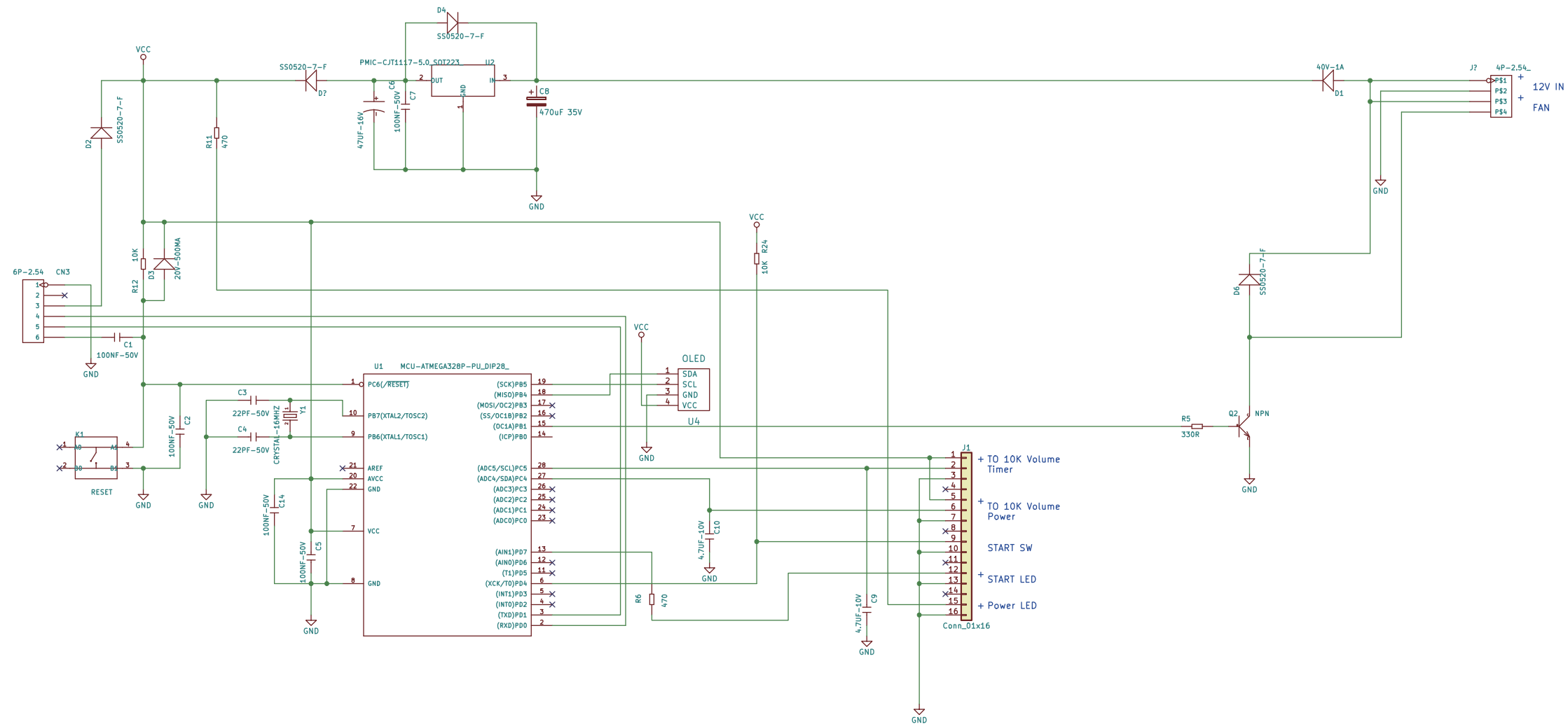
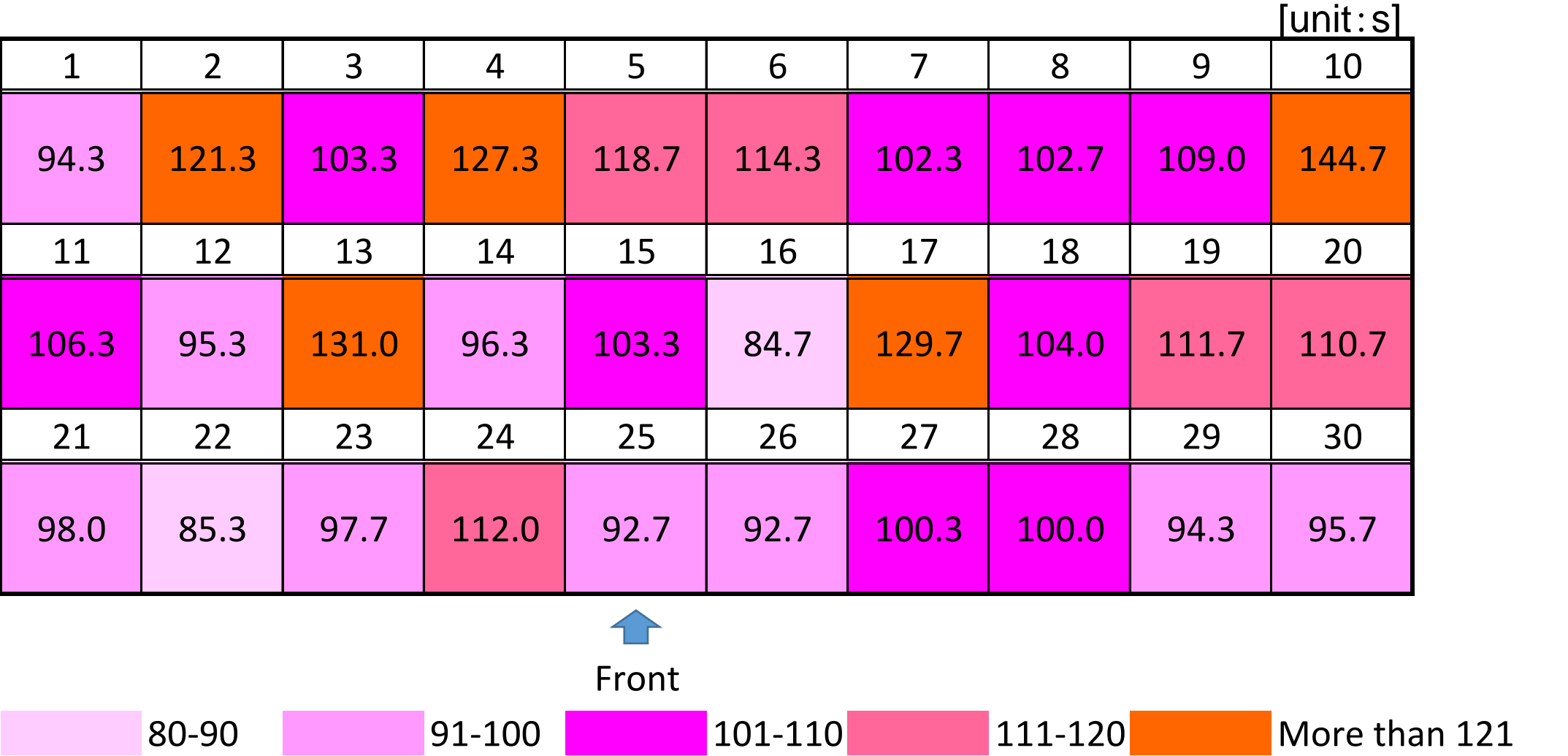


Figure3





Type	Cleaning Solution	Times	Drying Time (s)		Cleaning Solution	Times	Drying Time (s)	
			Natural	Dryer			Natural	Dryer
Quarts cells	Ethanol	1	327	106 (see Figure4)	Water	1	1209	257
		2	491			2	1330	364
		3	558			3	1162	231
		4	391			4	1231	535
		5	379			5	1761	394
		6	514			6	1952	463
		7	323			7	1342	417
		8	379			8	1949	483
		9	495			9	1663	276
		10	407			10	1215	296

Name of Material/ Equipment	Company	Catalog Number	Comments/Description
blower	ebm-papst	422JN	Mulfingen, Germany
Microcomputer	Atmel Corporation	ATmega 328 P	CA, USA
Blower selection button	Sengoku Densyo Co., Ltd.	MS-358 (red)	Tokyo, Japan
Blower operationg lamp	Akizuki Denshi Tsusho Co., Ltd.	DB-15-T-OR	Tokyo, Japan
Blower start button	Sengoku Densyo Co., Ltd.	MS-350M (white)	Tokyo, Japan
Timer	Akizuki Denshi Tsusho Co., Ltd.	SH16K4A105L20KC	Tokyo, Japan
Power supply switch	Marutsuelec Co., Ltd.	3010-P3C1T1G2C01B02BKBK-EI	Tokyo, Japan
Power supply lamp	Akizuki Denshi Tsusho Co., Ltd.	DB-15-T-G	Tokyo, Japan
OLED module	Akihabara Co., Ltd.	M096P4W	Tokyo, Japan



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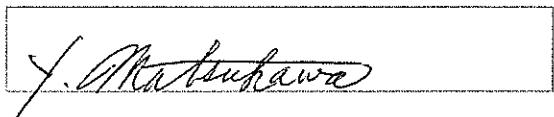
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Response to Reviewers comments (R3)

We are greatly appreciated for your thoughtful and supportive comments. We have revised our manuscript in response to your suggestions and hope that this improved manuscript is acceptable for publication.

[Editorial Comments]

We have updated using 58518_R2.docx.

1. We calibrated the manuscript thoroughly again.
2. We added an Acknowledge section after Discussion.
3. Step 1.2: We added more details.
4. We removed “Kintowel” from the manuscript.
5. We revised the sentence.
6. We revised the sentence.
7. We deleted 3.3.8 because we have not used this library.
We also deleted 3.3.7 because this library is included in 3.3.9.
Step 3.3.9: We added more detail sentence and added a use example of source code of the library in Note.
8. We changed the sentence.
9. Since Figure 4 and Table 1 were missing in R2, we added them.