Supporting information

A 3D printed gas phase photocatalysis reactor and its use for on-line monitoring of photodegradation of air pollutants

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1. List of materials:

Main components:

- 1 pc. fan – a 12 V fan 40 x 40 x 20 mm (We used a Sunon KD1204PKB2 12V fan in our original setup; other fans can also be used).
- 3 pcs. UV diodes – 5 mm in diameter with an emission wavelength of 365 nm (We used a T5F36 diodes from Seoul Semiconductors in our original setup; other diodes with similar properties may be used).
- 1 pc. Semiconductor gas sensor. Any semiconductor air sensor would do, as long as it has a 5 V heater voltage, and sensing element resistance in the range 1 kΩ – 10 kΩ. We can recommend HS-135 from Sencera Co. Ltd. In our setup we used a very similar sensor – RS286-620 (a.k.a. as NAP11AS from Nemoto & Co., Ltd.).

Passive components:

- 270 Ω resistors, 1/4W x 3
- 4.7 kΩ resistor, 1/4W x 1
- 10 kΩ resistor, 1/4W x 1
- 1 kΩ resistor, 1/4W x 1
- 7805 linear 5V regulator x 1
- 1 uF ceramic capacitor x 2
- BC537 transistor x 1
- Perfboard prototyping board (preferably not veroboard, as it limits the wiring possibilities).
- 4-pin PCB terminal block (with 5 mm step) with screws.

For the setup you will also need:

- Arduino Uno microcontroller board (other Arduino controllers may also work, as long as they can accept 5 V measurements at the ADC inputs).
- USB cable for Arduino Uno.
- 9 V adapter with 2.1 mm power plug (positive terminal in center; check Arduino’s manual for compatible adapters). For a setup with two reactors it should be able to provide at least 1000 mA current.

You will also need machining tools: screwdrivers, pliers, file, sanding paper, and drill with a set of bores. For electrical wiring we advise you to use at least four different colors to be able to differentiate between them.
2. Assembly instructions:

Begin with 3D printing all the required plastic parts. The 3D models are located in the 3D_Models.zip. In Figure S1 you will see an exploded schematic view of the device with the file-names of the separate components.

![Figure S1. Exploded view of the reactor. Annotations represent the filenames of the 3D model STL files, for printing the corresponding part.](image)

Note that the design is optimized for a 40x40x20 mm fan. There are also 40x40x10 mm fans available but the side-cover will in this case not fit. If such a fan is used you can design and 3D print a 10-mm thick mask to fix behind the fan. You can use either PLA or ABS for the printing. Note that with ABS it might be problematic, as it may contain chemicals detectable by the gas sensor and lead to increased background in the sensor measurements.

Depending on your 3D printer calibration some post-treatment might be required. The openings for the bolts may have to be widened to 4-mm with a bore. We used four M4x35 mm bolts and nuts to join the components together. The other part that might need attention is the electronics cover. If there is not enough space between the attachment joints to fit the fan and the duct they should be filed flat.

When assembling the device we recommend beginning with the UV LEDs holder. It contains the three UV LEDs and their 270 Ω current limiting resistors, as presented in the schematics shown in Figure S2:

![Figure S2. Wiring of the UV illumination source consisting of three UV diodes with current limiting resistors.](image)

To attach the LEDs to the duct Figure S3 can be used as a guide. First, attach the LEDs inside the three openings with a drop of acrylic glue and then solder the resistors and wires onto their leads according to the schematic in Figures S2 and S3.
Note, that the LEDs are polarized. If you use other LEDs the datasheet for the typical forward current and voltage must be carefully checked. In our case using a 9 V power supply, 270 Ω current limiting resistors were used, because our LEDs have 20 mA forward current and typical 3.9 V forward voltages. There is a simple online calculator for estimating what kind of resistor you will need based on data for a specific LED (http://led.linear1.org/1led.wiz).

Figure S3. Graphical representation of the wiring of the UV LEDs module. The black ring represents the diode holder. Keep in mind that the diodes are polarized, so the correct wiring is important (the pin with cathode mark must be connected to the positive terminal of the power).

Figure S4 shows the complete assembly. In Figure S3 above two examples of how to distinguish the cathode from the anode of the LEDs are shown to aid the correct mounting.

Figure S4. Installing the UV LEDs module into the reactor body.
The assembly is powered through two wires which are threaded through the openings of the main duct as shown in Figure S4. The LED ring slides inside the main duct and is positioned facing the inlet at an appropriate distance from the entrance (they should not touch the sensor, but should have enough distance from the photocatalytic filter to provide diffuse illumination - we used LEDs with wide-emission angle of 130° to provide good UV area coverage even at short distances).

The next step is the attachment of the gas sensor. Wrap some Teflon tape around the metallic ring of its base and just slide it in place (Figure S5).

![Figure S5. Installing the gas sensor. Teflon tape is used for sealing the sensor base plate against the reactor body.](image)

Make sure that there is enough distance between the sensor and the UV diode holder (Figure S6):

![Figure S6. Image of the mounted sensor (right) and view from inside the air duct of the reactor (right) with the gas sensor in place. The back side of the diodes must not touch the metallic mesh of the sensor. Notice how the power supply wires protrude through the two openings in the air duct.](image)

The next step is the attachment of the fan (Figure S7):
The PCB board glued to the fan contains the fan power and RPM control electronics and the power supply for the sensor heating (Figure S7). The power and control signals for the fan RPM and the signal from the gas sensor are wired to a 4-pin terminal block for easy connection to the Arduino controller.

The RPM of the fan is controlled by a BC537 transistor. The transistor state is controlled by a PWM signal from the Arduino board with the duty cycle determining the effective voltage and rotation speed. Two resistors are required to limit the current to the transistor and hold the base in a LOW state in the case there is no signal from the Arduino (Figure S8).

Both the UV diodes and the fan are powered directly from the 9 V bus. The last part of the circuit is the detection part, which consists of the gas sensor, a 7805 linear regulator to provide 5 V to the sensor heating element, and a 1 kΩ resistor, forming a voltage divider with the sensing element in the sensor (Figure S9).
Figure S9. Schematics of the power supply for the gas sensor and wiring of the sensor. Notice that the arrangement of the 6 terminals of the sensor, represented corresponds exactly to the sensor, viewed from behind. In most cases sensors have completely symmetric pin arrangement with the heater power supplied to the middle pins (non-polarized) and the sensing element wired to both sets of outer pins (also non-polarized). Please refer to the datasheet of the sensor you are using to confirm the pin arrangement.

While the UV LEDs and their current limiting resistors are fixed inside the reactor on the 3D printed LED ring, the rest of the electronics, excluding the gas sensor itself, is soldered onto a small piece of prototyping board (as shown in Figure S7), which is fixed to the side of the reactor. A 4-pin terminal block is soldered to provide connections for the signals (Figure S10): ground (GND), +9 V, SIGNAL (from the gas-sensor) and PWM (fan RPM control) (Figure S10).

Figure S10. In our setup we used this arrangement on the 4-pin terminal block of each sensor.

In Figure S11 a schematic drawing of the wiring and electronics for the photocatalytic gas phase reactor is shown.

Figure S11. Schematic drawing showing the wiring of the gas sensor and the position of the electronics board ontop.
The fan with the control electronics board is then joined to the air duct containing the sensor and the UV diodes by M4 bolts, as shown in Figure S12):

![Figure S12](image)

Figure S12. Joining the two parts of the reactor: the fan with the control electronics and the duct with the gas sensor / UV LEDs. Take care for the correct orientation of the fan.

Then the power to the LEDs and the connections to the sensor are fixed and finally the electronics is covered by the 3D printed plastic lid (Figure S13).

![Figure S13](image)

Figure S13. The plastic cover is added to protect the electronics PCB ontop.

Reactor footrests are added and fixed in position with M4 nuts (Figure S14).
Finally, the TiO$_2$ coated filter is added at the front end of the reactor and fixed in place with the plastic cap (Figure S15).
Figure S15. Placing the TiO2-coated textile in place. We used colored tape to mark the two reactors and distinguish them – blue is for TiO2 and red – for the uncoated cotton pad.

To wire the reactor to the Arduino controller, electrical wires were fixed in place in the block terminal of each reactor. On the Arduino PCB standard 2.5 mm headers were soldered, which could slide directly into the Arduino shield header (Figure S16). The GND and Vext outputs were used to power the reactor (the Arduino is powered by a 9 V adapter, so 9 V is also available at the Vext pin). The signal from the two reactors is sent to the A0 and A1 inputs of the Arduino’s ADC and digital pins 9 and 10, which also provide PWM output used to drive the fans of each reactor.

Figure S16. Wiring the reactor to the Arduino board.
3. Firmware

The firmware is provided as a separate *.ino file in the Firmware.zip file. Please upload it to the Arduino Uno microcontroller. See the Arduino’s website (http://www.arduino.cc/) for instructions.

4. Software

The software is provided in the Software.zip file and has been tested with Windows 7. Otherwise you will be asked to download the .NET Framework. The software is only for Windows operating system.

The software is straightforward to use. Start the program and the main window appears. In the COM port list the list of available serial ports are shown. The Arduino controller driving the reactor should appear under the same port which is used to upload the software in Arduino’s IDE. Select it and click Connect. When the Record button is clicked, a plot window will appear, which is updated once a second (Figure S17). To clean the plot window, click the Delete button. To control the two fans of reactors 1 and 2, use the sliders below. Note that the fan will not switch on automatically when you connect the device.

Figure S17. Layout of the software used to control and monitor an experiment with a set of two reactors.

To copy the data use the Copy button and then paste it into e.g. an Excel spreadsheet, or any text editor for later data processing or plotting with other software.