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IoT Air Purifier with Humidification Function Capable of Removing PM1.0 Ultra-fine Dust

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Abstract

Recently, as the atmospheric environment is getting worse due to yellow dust and fine dust, which has a lot of influence on daily life, people's interest in air purifiers is growing. In this paper, as part of the research on air purifiers, we design an air purifying humidifier that integrates PM1.0 level ultra-fine dust removal function and natural humidification function into one. The air purifying humidifier designed in this paper uses a sensor that detects PM1.0 level ultrafine dust, and the number concentration is 95% similar to that of the reference measuring instrument. Also, by mixing the resin on the surface of the motor fan, it is possible to antibacterialize the bacteria remaining in the air even after passing through the filter. As a result of the test, more than 99% of the bacteria were removed after 6 hours of artificial incubation. In addition, it is designed to sterilize using hydroxyl generated by electrolysis of water to remove bacteria mainly generated due to the structure of the humidifier.

요 약

최근 황사와 미세먼지로 대기 환경이 갈수록 좋지 않아져 일상생활에 많은 영향을 끼치자 사람들의 공기청정기에 관한 관심이 커지고 있다. 본 논문에서는 공기청정기에 관한 연구의 일환으로 PM1.0 초미세먼지 제거와 자연 가습을 활용한 가습기를 하나로 통합한 공기 청정 가습기를 설계한다. 본 논문에서 설계한 공기 청정 가습기는 PM1.0 초미세먼지를 감지하는 센서를 사용하여 개수농도가 레퍼런스 측정기 대비 95% 유사하고, 모터 팬에 레진을 혼합하여 필터에 의해 걸러진 공기들에 남아있는 세균을 항균한다. 테스트 결과 세균을 인위적으로 배양한 후 6시간이 지나 99% 이상 제거됨을 확인하였으며 추가로 가습기의 구조상 생기는 세균들을 제거하기 위해 물을 전기분해하여 생기는 수산기로 인해 살균하도록 설계되었다.

Keywords
air purifier, humidifier, IoT, natural humidification, electrolysis, ultrafine dust

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Ⅰ. Introduction

Unlike in the past, fine dust including yellow dust from China has become more serious regardless of the season and has a great impact on daily life, and the need for air purifiers has greatly increased. Although the government is taking various steps to improve the level of fine dust that is increasing day by day, but as it is a difficult issue to solve in the short term, the market for air purifier is gaining momentum as individuals choose air purifiers as an immediate solution. In addition, since many of the lives of modern people are made indoors unlike in the past, clean air is an essential condition for improving the quality of life[1].

In this paper, we design a high-end air purifier that can remove the ultra-fine dust of PM1.0 and also have a humidification function together.

Ⅱ. Features

The function of the designed air purifier includes a function to remove PM1.0 level of ultra-fine dust, a natural humidification function, a sterilization function using hydroxyl groups, and remote control of the humidifier by communication between the app and the server. A sensor capable of detecting PM1.0 level of fine dust was used to measure the dust level, and a fine dust filter was used to remove it, and a dedicated filter for natural humidification was applied. In addition, a hydroxyl group (OH) generating module using electrolysis was designed to remove bacteria that are often generated inside the humidifier due to the structure of the humidifier[2]. As with other IoT devices, a dedicated app and server have been developed to remotely control and monitor the device, and thus, the mobile device can be used to identify and control the device status information.

Ⅲ. Circuit Board

Fig 1. shows the overall functional block diagram of the air purifier capable of humidification designed in this paper. The dust sensor, gas sensor, temperature and humidity sensor were developed as modules, respectively, and based on the information provided by these sensors, the purifier adjusts the operation of the hydroxyl generator and the rotation speed of the fan. For the temperature and humidity sensor, Sensirion's SHT31 was applied. This sensor shows a small error in the range of 10 to 60 degrees Celsius and 20 to 70% RH in the humidity range, and this range is the typical temperature and humidity range at home, which would be the main operating environment of the air purifying humidifier. This sensor does not require calibration for individual sensors because the difference in output between each sensor is small. As the dust sensor, Sensirion's SPS30, which can detect PM1.0 level dust, was used.[3]. The feature of this sensor is to measure the concentration of dust by scattering the laser into the air, and the output value can be received using UART or I2C. The WiFi module for communication with the server uses ESP8266, which is widely used in IoT devices, and MCU can send and receive from/to WiFi module through UART communication.

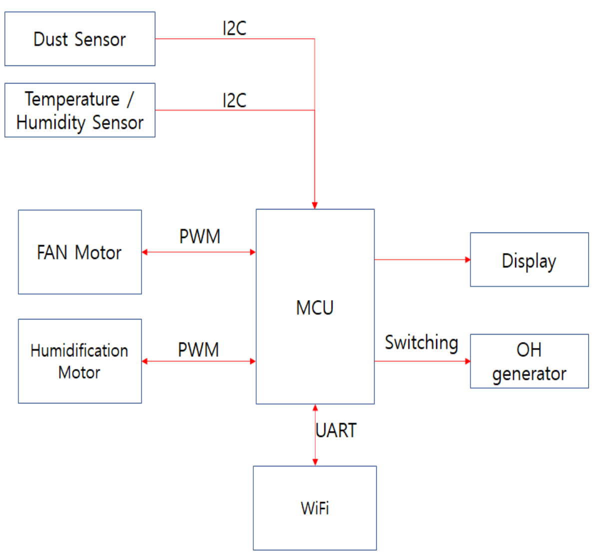


Fig. 1. Circuit board functional block diagram

Ⅳ. Natural Humidification

Natural humidification is a method of increasing humidity by using vaporization of water and generally consists of the configuration shown in Fig. 2. As a filter partially submerged in water, water permeates into the filter due to capillary action, and the water vaporizes in the filter in contact with air, resulting in humidification. And by attaching a fan to the filter to allow air to pass through, more vaporization is possible. In this paper, a natural humidifier as shown in Fig. 3 was designed to operate similarly to the principle of the water wheel, and the filter cover was perforated to maximize contact with air.

Since bacteria are easily generated inside the humidifier, in the past, humidifier disinfectants that are harmful to the human body were used. Because of the humidifier disinfectant, the health of many people actually worsened before. In this humidifier, a module that electrolyzes water to generate hydroxyl groups was used to help sterilize bacteria that may occur in water. When a voltage of 24V was applied to the hydroxyl module, water was electrolyzed and hydroxyl groups were generated. When water is electrolyzed, the water is changed to a low pH and the sterilizing effect is exerted by oxidation-reduction[4]-[6].

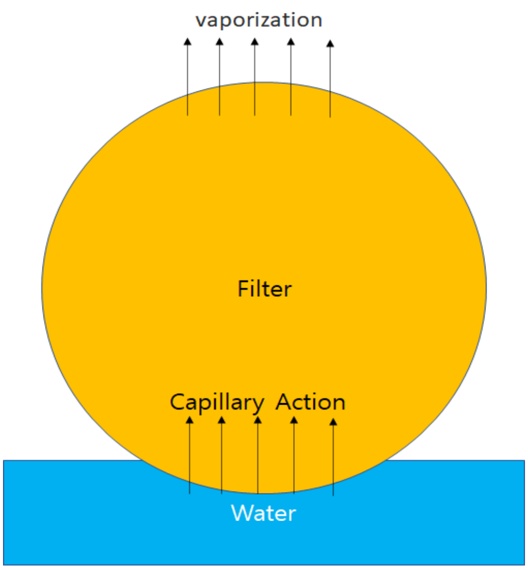


Fig. 2. Natural humidification concept

Fig. 4 shows the hydroxyl generator designed in this paper, and Fig. 5 illustrates the concept of hydroxyl generation by electrolysis of water.

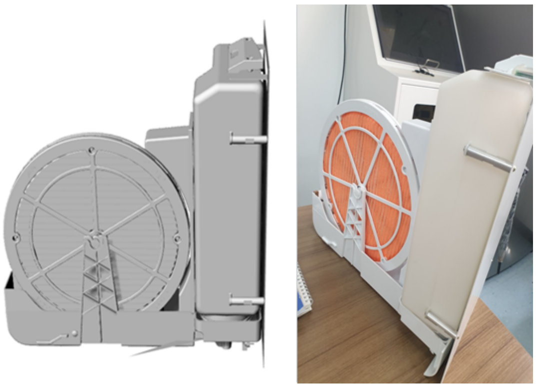


Fig. 3. Natural humidifier

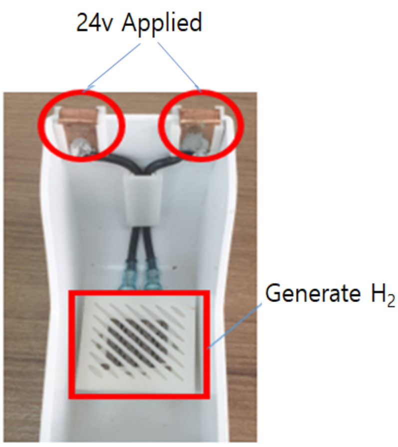


Fig. 4. Hydroxyl generator

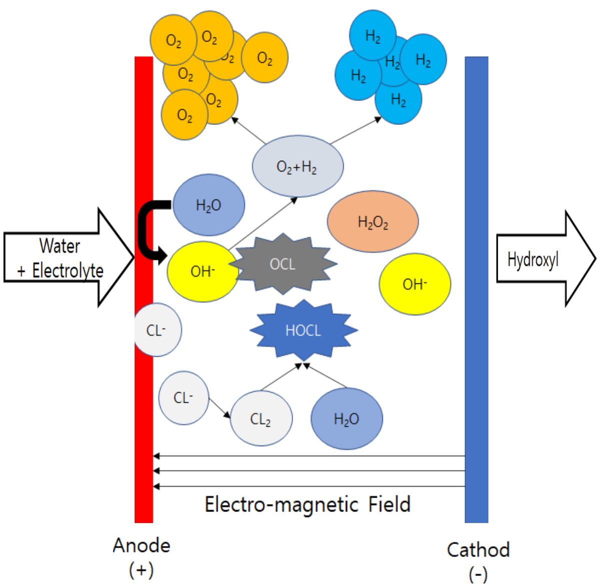


Fig. 5. Water electrolysis concept diagram

V. App and Server

In this paper, App and Server were built to remotely control and monitor the state of the air purifier humidifier. Most recently released air purifiers have remote control and monitoring configurations with App and Server configurations. Fig. 6 shows the configuration of the App and Server built in this paper, and the App and Server were implemented using the Public API.

Public API is used to help the efficient use of air-purifying humidifiers, such as allowing users to decide whether to ventilate or not, by collecting and providing air pollution information measured at each local observation station across the country. The App and Server are designed to send and receive data in JSON format using Web API, and the port is designed to use SSL for security.

VI. Performance Evaluation

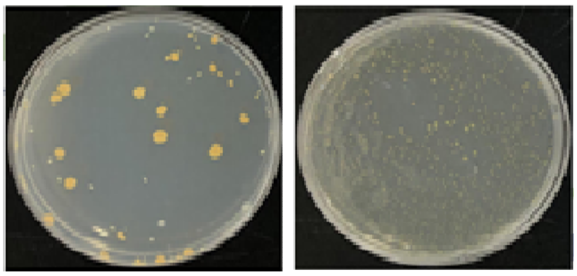
For the functional verification and performance evaluation of the designed air purifying humidifier, a prototype was built and the tests are carried out for 5 evaluation items as shown in Table 1. For each item, the evaluation method followed the specified standard method, and if there was no specified evaluation method, it was measured using its own measurement target.

Table 1. Air purifing humidifier evaluation list and result

Evaluation Spec	Unit	Result
Antibacterial ability	%	99% removal of bacterias
Efficiency of removing harmful substances	%	More than 90% removal efficiency
Number density	$\mu g/m^3$	95% similar to reference measure instrument
Temperature detection range	℃	Normal operation within the room temperature and humidity range
Humidity detection ragne	%	

6.1 Antibacterial Ability Evaluation

In compliance with the KS M ISO 22196 test method, 0.4 mL of pre-culture was administered to the antibacterially treated prototype which is mixed with resin. As a result of comparing the number of cultures after 6 hours, it was confirmed that the number of cultures was reduced by more than 99% compared to the initial number. The result is shown in Fig. 7.



(a) Before (b) After

Fig. 7. Evaluation result of antibacterial ability

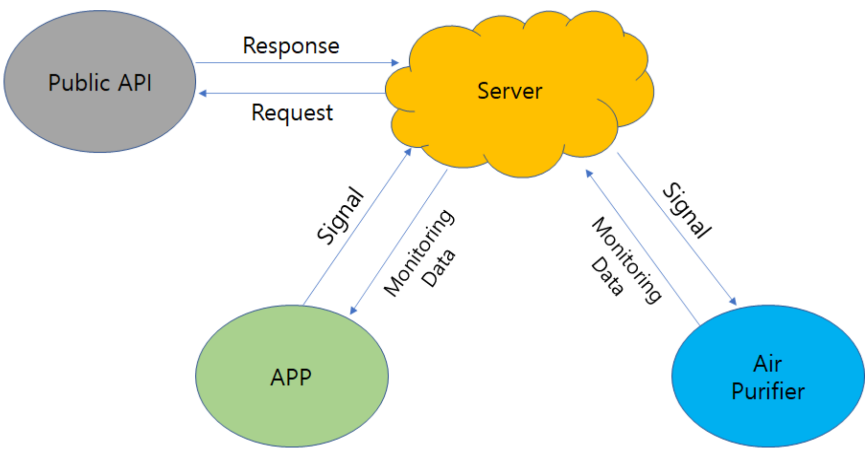


Fig. 6. App and server configuration

6.2 Efficiency of Removing Harmful Substances

After ammonia is injected in the chamber according to the SPS-KACA002-132:2018 test method, the prototype is operated at a set air volume for 30 minutes. Afterwards, the harmful gas removal efficiency was measured to be more than 90%.

6.3 Number Density

Number concentration is a measure of the density of a particle in physical space[7]. A standard instrument and prototype were placed together in the chamber, and then, aerosol was sprayed into the chamber as shown in Fig. 8.

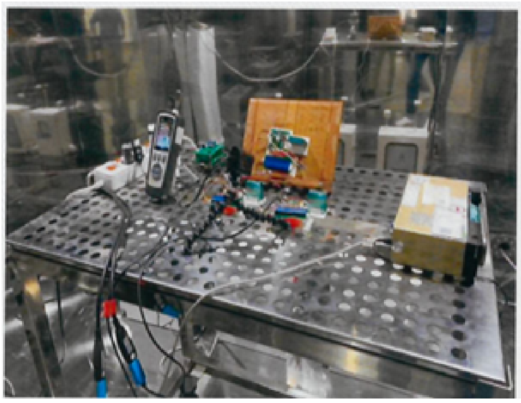


Fig. 8. Number density evaluation environment

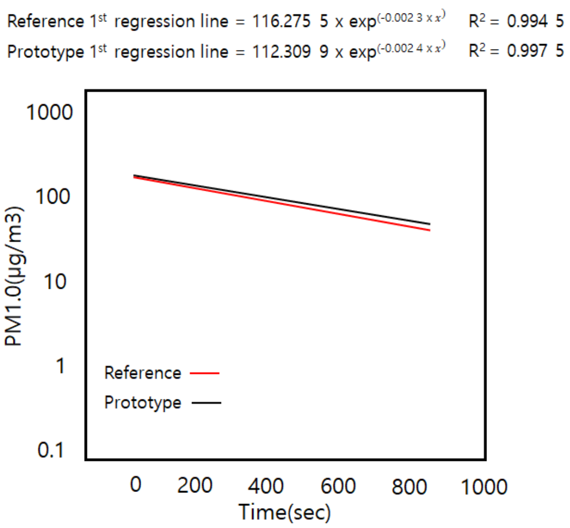


Fig. 9. Number density result graph

The similarity between the graphs in the case of the reference instrument and of the prototype was examined[8]. The test result showed a 95% similarity to the reference instrument as illustrated in Fig. 9.

6.4 Temperature / Humidity Detection Range

The temperature range was -20 to 80 degrees Celsius, and the humidity range was set within an error of 10% at a relative humidity of 20% or less[9]. When the temperature and humidity were changed in units of 1 minute and compared with the measured values of the chamber[10], the measurement was performed without any problem.

Ⅶ. Conclusion

As the air environment is getting worse, the demand for air purifiers, which is a device for removing fine dust, is explosively increasing along with an increase in awareness of the seriousness of environmental pollution caused by fine dust. Due to the social problem of fine dust and ultra-fine dust, the demand for high-performance air purifiers with a function to remove at least PM2.5 level of ultra-fine dust is increasing. By adding the humidification function to a single purifier appliance, home appliance that can be used all year round was presented.

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