Demonstration of a highly sensitive fine particle matter sensor

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In this paper, a fine particle matter (PM) sensor has been designed, built up, and measured. It consists of a LED, a photodiode, a glass air channel and collimated structure, as show in Fig.1. Compared with the conventional fine PM sensors [1-2], this sensor has higher sensitivity and better reliability via immunity to particle contamination.

A simulation model of the particle matter sensor is built based on the right angle Mie-scattering theory [3]. The simulation results are shown in Fig 2. In the simulation, the wavelength of LED is 650 nm, and particles diameter is 1 μm. The particles are guided into a "U" shape glass channel with a good light transparence at visible light region. And the light is collimated by an embedded lens in LED packaging, and injected into the glass channel with the minimum scattering from the glass channel. The particles are isolated by the glass channel so that they cannot contaminate the LED and the photodiode, which is a common failure mode in conventional PM sensors. Based on the simulation and fitting process, the detection limitation is down to around 0.2 $\mu g/m^3$ when the power of the light source is 0.4mW and specific detectivity of the photodiode is 0.017uW.

The sensor used in characterization is assembled as shown in Fig. 3. A TSI 9306 six-jet atomizer is used to generate fine particles (diameter ~ 1 μm) carried by dry-air gas flow. A reference PM detector (model: TSI 8520 DustTrak Aerosol Monitor) is connected at the outlet of the sensor to monitor the particle mass concentration in real-time. The glass channel with gold coating is used to guide the particle air. The experimental results are shown in Fig. 4. The blue dots and red line are the testing and fitting results, respectively. Through analysis, the relationship between particle mass concentration and PD voltage can match to linear trend. The output signal is up to approximate 1.5 μV when the PM concentration changes 1$\mu g/m^3$, and the detection limitation is around 3.3ug/m^3, which is much better than the value of 10$\mu g/m^3$ of the conventional PM sensors.

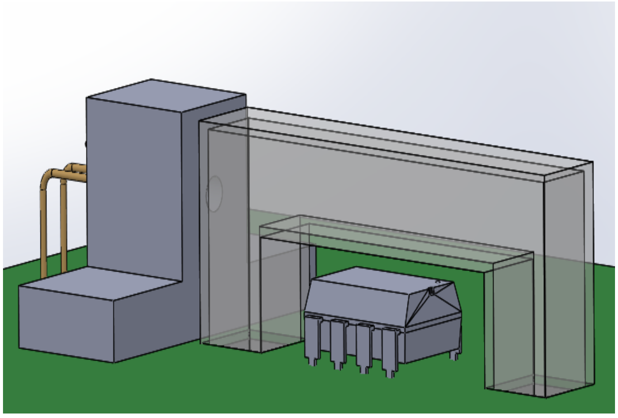

Fig. 1 The photograph of particle matter detection system includes a LED with 650nm wavelength, a photodiode, a U-tube for particle flowing and simple collimated structure.

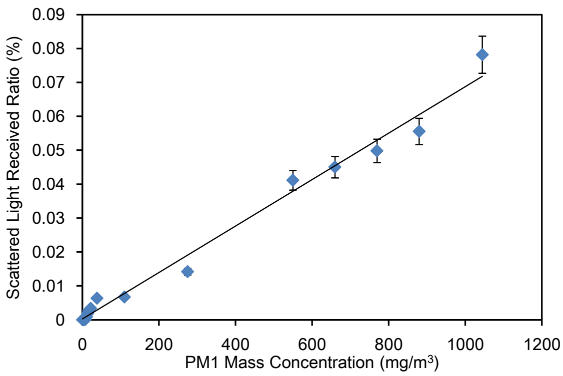

Fig. 2 The simulation and fitting results about the relationship between PM1 mass concentration and the scattered light received ratio.

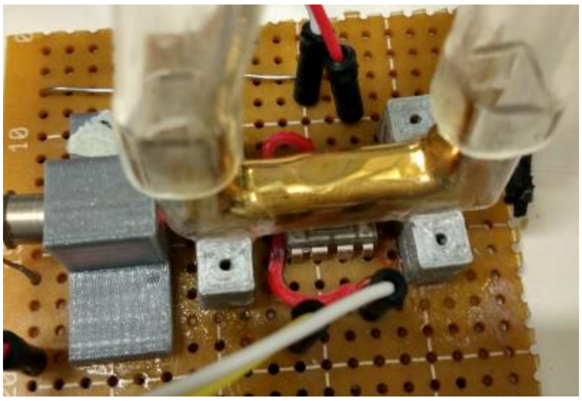

Fig.3 The total assembled system in lab testing.

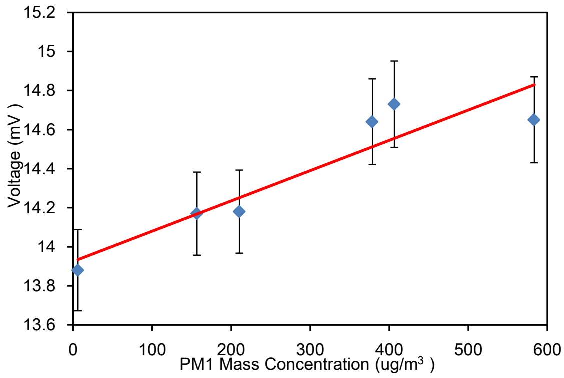

Fig.4 Lab testing and fitting results, these blue dots represent the detected data, and red line is the fitting trend.

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