1. INTRODUCTION

In the automotive, lots of fatal pollutants are produced such as sulfur oxides and NOx gas. Particulate matter is one of the harmful components discharged from the vehicle. Particulate matter refers to microscopic particles that consist of elemental carbon and combustion by-product. Since the size of each fine particle is smaller than 1um, it may adversely affect to penetrate deeply into alveoli of human [1, 2].

Diesel particulate filter (DPF) is installed downstream of the engine in order to reduce the amount of PM emitted from the diesel vehicles [2]. Most particulate matter is filtered by normal DPF installation. But if it breaks down due to causes such as aging, particulate matter will not be filtered. So, on-board diagnostics regulation is made to detect whether the normal operation of the exhaust emission control system. In Europe, Euro6 regulations, it must be able to measure 9-12 mg/km particulate matter for diesel vehicles which will be sold after 2014. Conventionally, it has been determined whether the failure of the DPF from the pressure difference information obtained by mounting the pressure sensor on the DPF front and rear ends. But, in this method, it is impossible to measure the amount of particulate matter of lower than 13-22 mg/km. Therefore, a new PM sensor can diagnose whether failure of the DPF to accommodate Euro6 OBD regulation is necessary.

Various methods are proposed a method for measuring suspended particulate matter in the air. One of the method to measure the microscopic particles in air uses its optical properties. When the light passes the exhaust gas, the optical absorption phenomenon depending on the amount of particulate matter included, such as scattering occurs and the intensity of light changes. Optical method is mostly used to measure the particulate matter, but it is not suitable to attach to the vehicle [3].

Differential mobility analyzer (DMA) is another way to measure the amount of particulate matter. After charging particulate matter by corona discharge, electric field is applied to it. Moving distance of particulate matter by the electric field is measured to determine size and count of particulate matter.
field is changed depending on the weight. This method has an advantage of being able to know with the mass and the number of particulate matter, while it requires very high voltage [4].

B. Park developed a method of using paddle-type piezoelectric resonator which detects the weight of the particles. Because resonator frequency characteristics is determined by the spring constant and the mass, precipitated particles on resonator mass changes the resonating frequency. It is possible to measure the weight of the particles directly; it is characterized with high sensitivity. This method requires means of particulate matter removal and the structural stability in the exhaust gas flow [5].

Bosch company developed a particulate matter sensor of electrical resistivity method. If particulate matter is accumulated between two electrodes, it is detected by measuring their resistance. This method is simple and inexpensive, easy to install, but it can be affected by temperature and humidity [6].

Honeywell developed particulate matter sensor of charge induction method with Minnesota University. This method measures the amount of charge induced in the sensor electrode by charged particulate matter which moves through the peripheral of the sensor. To install each particulate matter sensor in the front and rear ends of DPF, it is determined whether the damage of the DPF from the difference of the signals of the both sensors. While it has an advantage of real-time measurement, two same sensors are required [7].

We developed a silicon particulate matter sensor using the MEMS process. In order to detect the particulate matter, charge induction method is used. To increase sensitivity of the sensor, sensor surface is increased by formation of groove. Then, to prepare a heater on the backside in order to remove the particulate matter accumulated on the sensor surface. In this paper, we describe fabrication process and the property proposed particulate matter sensor.

2. DESIGN AND FABRICATION

2.1 Sensor

The principle of the sensor that was proposed in this paper is the charge induction by charged particles. When the charged particles pass through the sensor surface, the amount of charge induced in the electrode with grooves are more than planar electrode. Increase induced charge increases sensitivity of the sensor. To increase sensitivity we formed groove pattern with width 10 um and depth 40 um by deep reactive ion etching process. Silicon oxide 100 nm is deposited to prevent the particulate matter from impinging directly on the electrode and additional silicon nitride 100 nm to prevent oxidation caused by high-temperature exhaust gas. On the back side of silicon wafer, platinum heater is patterned to remove the particulate matter accumulated on the surface of the sensor. Fig. 1 is a photograph of the rear and front of the sensor element and packaged sensor with a bolt and ceramic past. In order to measure the particulate matter sensor, it is necessary to fix the sensor element to the pipe.

![Fig. 1. Photograph of (a) front, (b) backside of sensor element, and (c) packaged sensor.](image)

2.2 Heater

Particulate matter is accumulated on the surface of the sensor which is exposed to exhaust gas for a long time. Since particulate matter is a fine particle of which diameter is smaller than 1μm, it can fill the groove of the silicon. So, accumulated particulate matter should be removed periodically. Main component of the particulate matter is elemental carbon which can be oxidized at high temperature of 650°C. By using heater for raising the temperature locally in the sensor unit, accumulated particulate matter is removed. We placed the platinum heater in the form of a zig-zag on the backside of the sensor unit. Fig. 2. shows simulation (COMSOL) of the temperature distribution when 20 W power is applied to platinum heater. We confirmed the sensory temperature of the surface beyond 650°C by the heat generated from the