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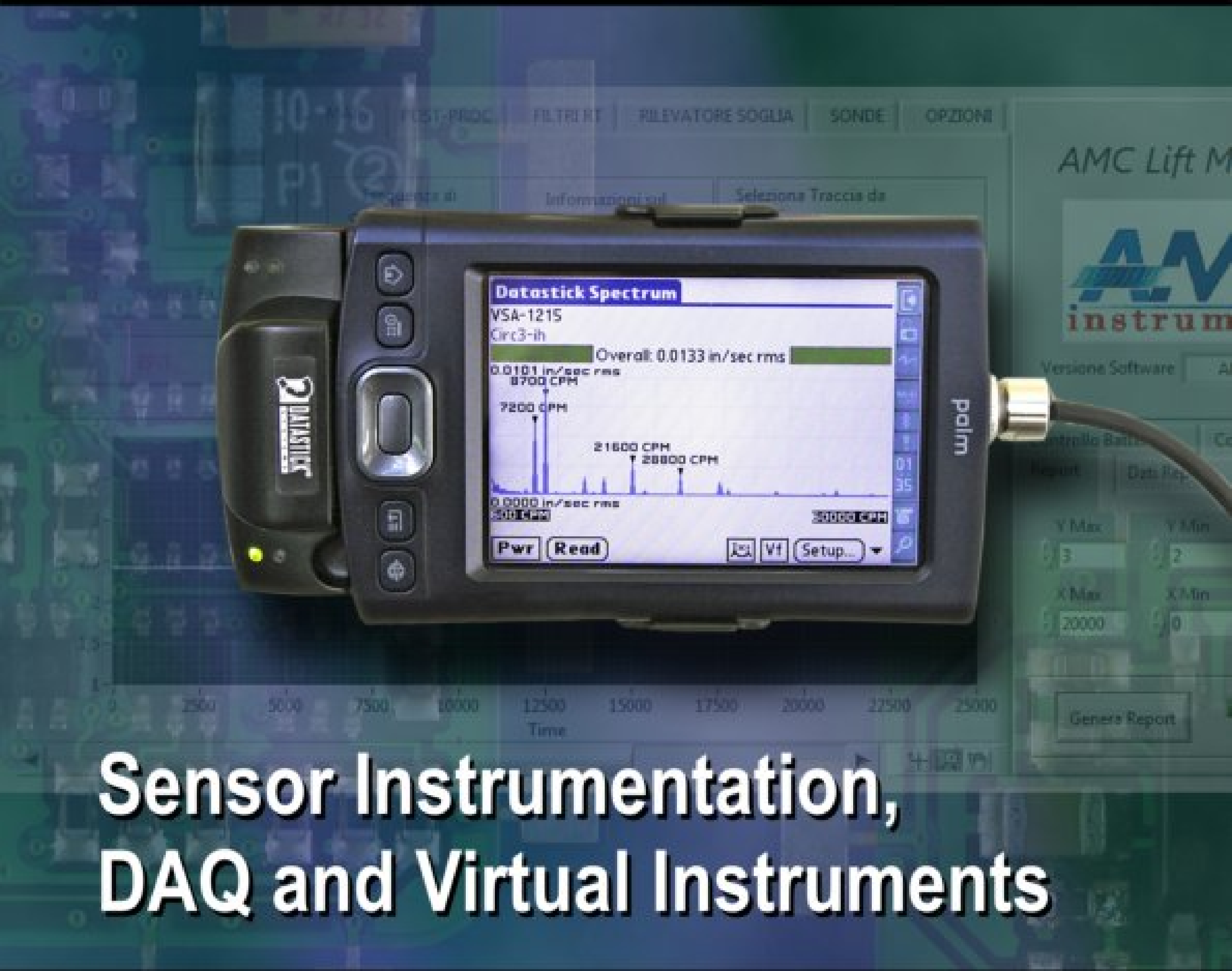

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The Activity Airflow Detection of Vehicle Intake System Using Hot-film Anemometry Sensors Instrument

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Abstract: The goal of this study is to develop an airflow meter sensor for vehicle intake system detection in internal combustion engines. The alumina plate used in this study is produced by polishing an alumina substrate, a platinum film is then deposited on the plate to complete the micro-heater used in the sensor. The study uses micro-electromechanical process technology to develop a hot-film flow meter with an alumina substrate and platinum film heater; the hotline method is used to create a micro anemometry meter sensor relying on variations airflow at the set temperatures. Resistance on the sensor side varies as gas flows through the sensor, and the instrument determines airflow velocity on the basis of the changes in resistance caused by airflow differences. Airflow velocity form 10m/s to 60m/s are used to test. Resistance displays a regular slope, indicating the relationship between airflow velocities varies remain predictable throughout the sensing range. *Copyright © 2011 IFSA.*

Keywords: MEMS, Detection, Anemometry.

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1. Introduction

In the wake of the recent resource crisis and soaring petroleum prices circumstances, the effective monitoring of engine air intake volume and the resulting energy conversion efficiency will depend crucially on the measurement of air flow rate. Electronic fuel injection control systems are ubiquitous in motor vehicles, and detective sensors play a vital role in these systems. Taking air flow meters as a typical example, flow meters are used to determine the amount of air taken into the cylinder, enabling an automotive electronic fuel injection system to control fuel injection time on the basis of air flow and engine rpm signals. Sensors and transducers produced using micro-electromechanical processes can be integrated with semiconductor ICs to form single-chip systems achieving the goal of system miniaturization.

The physicist Richard P. Feyman first proposed shrinking science and engineering to a microscopic scale at a physics conference in 1959, and suggested that this would be a technological milestone for the future. More than forty years later, the electronics industry is developing process technologies capable of achieving even tinier dimensions [1, 2, 3]. MEMS also represents an improvement on mechanical processing technologies, and offers the advantages of small dimensions, high accuracy, large-scale batch production, and low costs [4, 5]. MEMS technologies are used in an extremely wide range of interdisciplinary applications spanning the areas of physics, chemistry, electronics, machinery, optics, and materials science, etc. MEMS also represents an improvement on conventional mechanical processing technologies, and offers the advantages of small dimensions, high accuracy, large-scale batch production, and low costs. Furthermore, MEMS technology allows the integration of micro-sensors with other circuits or sensors in order to achieve more powerful functions and greater stability and reliability [6, 7]. Adamec *et al.* [8] fabricated a multi-axis hotwire anemometer with four thermo resistor to evaluate flow direction with a power consumption of 25 mW. Makinwa *et al.* [9] presented a circular-type thermal flow sensor consists of a heater to detect flow direction and velocity. Recently, non-thermal gas flow meters have been developed. These devices have the advantages of lower power consumption and an improved potential for integration with other sensors.

2. Design

This study tested sensors with different micro-heater and sensing mechanism orientations, and investigated the sensing characteristics of single-chip and double-chip sensors of different sizes. The micro-gas sensors investigated in this study employed an alumina substrate on which platinum was deposited to produce a micro-heater and sensing mechanism (Fig. 1). Because micro-heaters can continuously produce a controllable, constant temperature environment, providing a stabile power system to the micro-heater can maintain the sensor's operating temperature at the desired level. Wind tunnel experiments were used in conjunction with a connected sensor to observe the amount of temperature varies.

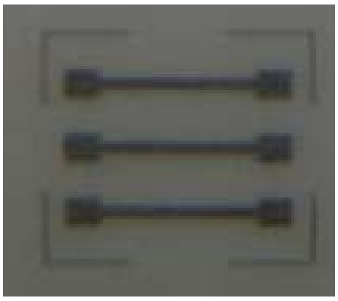


Fig. 1. Physical drawing of single chip (6 mm × 6 mm).

2.1. Hotline Airflow Anemometry Meter Design Principles

Hot-line type anemometry meters include several commonly-seen structures: heater, heat sensor, and temperature compensation resistor. Hotline meters employ three chief sensing principles: constant current, constant temperature, and constant power supply as follow:

1. When there is a constant current, temperature varies caused by the fluid generate different signals.
2. When there is a constant heater temperature, differences in output power can be used to determine the flow rate.
3. When there is constant power, information concerning the fluid can be determined from the effect of the fluid on resistance and current.

The hotline wind speed meter proposed in this study uses a platinum heating resistor that generates heat when a current is flowing. Forced convection will remove the heat, changing the resistance of the heat sensor. In a normal environment, the problem of heat dissipation must be overcome. In Fig. 2, the sum of natural convection QN, heat conduction QC, thermal radiation QR, and forced convection QF is the total heat output of the heater (shown in Equation (1)). A temperature compensation mechanism can be used to deal with the problems of natural convection and thermal radiation and maintain a balance with the environmental temperature.

$$P = QN + QR + QF + QC, \tag{1}$$

where:
QN: Natural convection rate;
QF: Forced convection rate;
QC: Thermal conduction rate;
QR: Thermal radiation losses.

Because the hotline anemometry meters are prone to sense when the environmental temperature varies, a temperature compensation mechanism must be used. Since temperature and resistance will have a linear relationship within a certain range, appropriate calculations can be used to correct the data in line with the environmental temperature. Because the temperature compensation resistance of a meter is the product of the same processes, it must be very close to the resistance of the meter itself. Equation (2) shows the general relationship between resistance and temperature:

$$\alpha = R\,(T - Tc)/\,R_T - R_C\,, \tag{2}$$

where:
R_T: resistance at temperature T;
R_C: resistance at temperature T_C;
α: resistance-temperature coefficient.

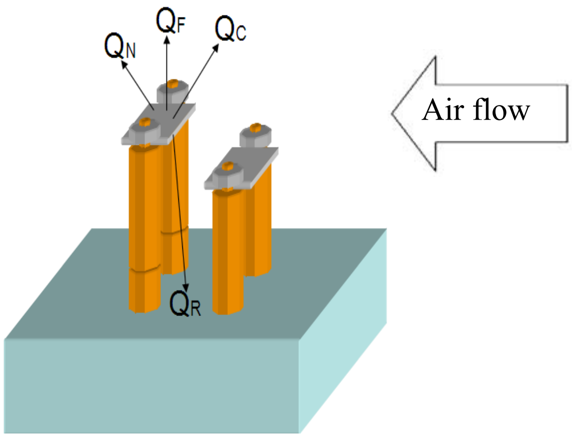


Fig. 2. Principle of hotline wind speed meter operation.

2.2. Design of Hotline Airflow Anemometry Meter Dimensions

Engine loading is transmitted to the electronic control unit by means of intake manifold sensors signals. The anemometry meter sensor is located in electronic control unit which a protected area away from excessive heat and is connected to the system by means of a wiring harness plug. This hotline airflow anemometry meter has a rectangular shape (see Fig. 1). The gray portion consists of the platinum electrodes; all dimensions are in mm. The double chip has dimensions of 2 mm x 6 mm, and the single chip has dimensions of 6 mm x 6 mm.

3. Fabrication and Experiments

The flow sensors of the study are fabricated on alumina and utilize platinum resistors as heating and sensing devices. The chief process steps in the production of the airflow anemometry meter proposed in this study: The alumina substrate was first sent to a wafer fab for polishing (to reduce surface roughness) and cutting to the desired size (50 mm x 50 mm). Before electron beam evaporation, microlithography was employed to delineate the platinum portions. A spin coater was used to apply the photoresist on the substrate. HMDS was first applied for 30 sec. at 3,500 rpm as an adhesive layer, and the substrate was dried for 1 min. at 110 °C before application of photoresist using the same parameters. The photoresist soft bake required a constant temperature of 110 °C for 3 min. Exposure was performed after the completion of coating. After confirming no defects, a developer consisting of AZ-400K developer mixed with water in a 1:3 ratio was used to perform development. A diffusion pump and booster pump were used to evacuate the vacuum chamber to a background pressure of 2 x 10^{-6} Torr. Before deposition of the platinum, a layer of chromium with a thickness of 0.02 μm was deposited on the alumina substrate as an adhesive layer, and electron beam (E-beam) evaporation was used to deposit a platinum layer 0.1 μm in thickness. The lift-off method was used to produce parallel electrodes and micro-heaters in the shape of the pattern (Fig. 3).

(a)

(b)

Fig. 3. Lift-off: (A) before lift-off; (B) after lift-off.

4. Results and Discussion

This study performed wind speed testing using single and double chips separately. The double chips were mounted on a flat surface, and were oriented with either front sensing and rear heating or front heating and rear sensing (shown in Figs. 4-5). As shown, the resistance signals of the increases approximately linearly with increasing airflow velocity, thus confirming the stability and measurement applications (Fig. 6).

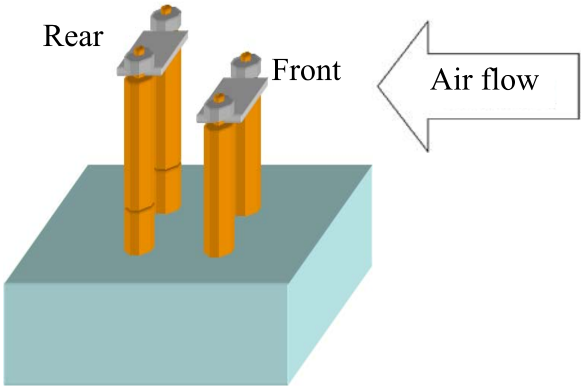


Fig. 4. Schematic diagram of sensing mechanism.

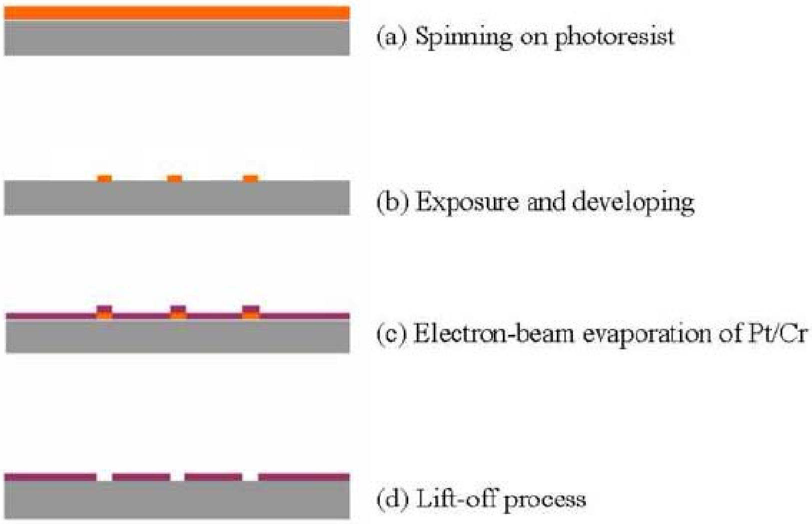
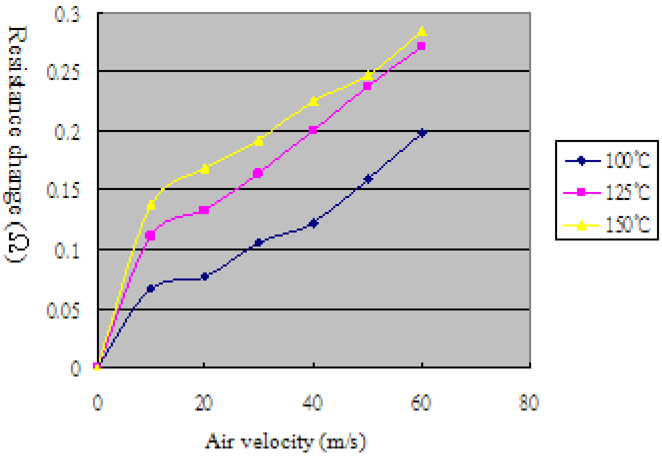


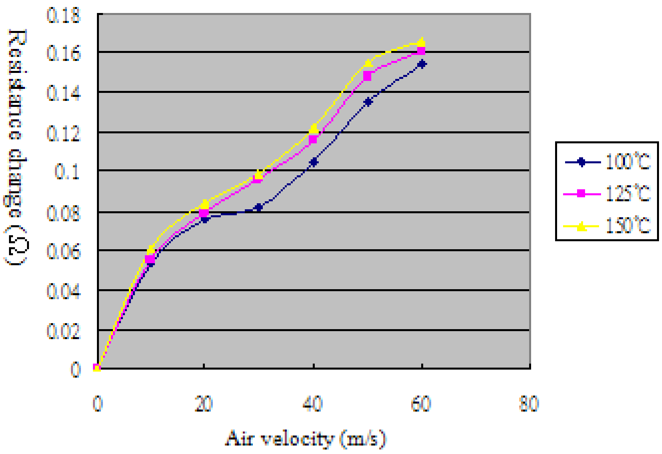
Fig. 5. Overview of fabrication steps for airflow meter sensor.



100 °C→0.0038 Ω/ms^{-1}
125 °C →0.004 Ω/ms^{-1}
150 °C →0.0041 Ω/ms^{-1}

Fig. 6. Front 30 Ω sensing, rear 40 Ω heating.

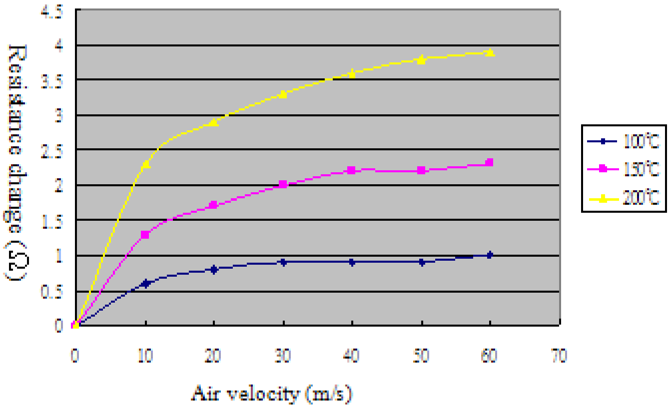
Testing was performed using chips with different resistances in different environmental temperatures to compare the chips and perform optimization. As shown, the resistance signals of the increases approximately linearly with increasing airflow velocity, thus confirming the stability of the sensor for gas flow rate measurement applications. It can be clearly shown from Fig. 7 that front sensing and rear heating yields the best performance.



100 °C →0.0023 Ω/ms^{-1}
125 °C →0.0025 Ω/ms^{-1}
150 °C →0.0026 Ω/ms^{-1}

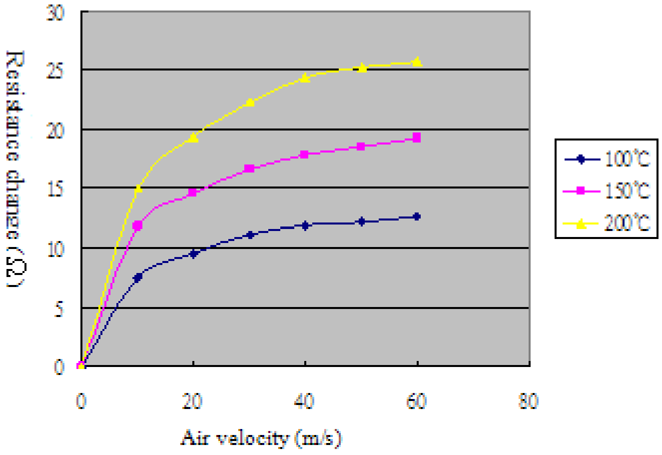
Fig. 7. Front 20 Ω sensing, rear 30 Ω heating.

The single chips were then tested because it was known from testing the double chip that front sensing and rear heating yielded the best performance, the single chips were tested only in the front sensing and rear heating orientation. The results show the faster heat transfer and the faster response to the airflow rate. Experimental data were plotted of the relationship between the airflow anemometry and measured resistance (shown in Figs. 8-9).



100 °C →0.0132 Ω/ms^{-1}
150 °C →0.0329 Ω/ms^{-1}
200 °C →0.055 Ω/ms^{-1}

Fig. 8. Front 40 Ω sensing, rear 120 Ω heating.



100 °C →0.1768 Ω/ms^{-1}
150 °C →0.265 Ω/ms^{-1}
200 °C →0.3661 Ω/ms^{-1}

Fig. 9. Front 120 Ω sensing, rear 40 Ω heating.

Compare all the results, It can be found the response of the single-chip type of the flow sensors are faster due to their stronger heat conduction effect. The results reveal that the sensitivity increases as the resistance of the sensing element increases.

5. Conclusions

This study successfully employed MEMS technology to produce an airflow anemometry sensor, and also varied parameters including resistance, size, direction, interval, and angle, and therefore deforms the piezoresistors patterned on their upper surfaces to observe the effect on sensing characteristics, and determine the best parameter values and greatest sensitivity. The distance between the electrodes and sensing electrodes was found to be the main influencing factor, and the higher the environmental temperature, the better the performance. This work will aid the design of future vehicle airflow anemometry meters.

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