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Advanced Sensing Technology for Automobile

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1. Introduction

The automobile is made using the essence of many special mechanical techniques and highly developed electric and electronic technologies. The energy saving, safety, comfort, and communication systems of automobiles are progressing with electronic technologies. They are controlled with a lot of electronic devices. On a hybrid vehicle and an electric vehicle, an electric motor, battery, and power device are main components to drive them. ITS (Intelligent Transport Systems) is a communication system in cooperation with public electronic infrastructures. A probe car is expected as the moving sensor on the road.

The research and development of electronic devices and systems for the automobile is strongly required. The control system consists of a sensing (sensor), judgment (CPU), and action (actuator). Therefore, the sensor is a very important device which detects physical and chemical quantities like a human sensory organ. Many kinds of automotive sensors are used because the sensing targets, mounting positions, and environments are in wide range as shown in Table 1. An advanced automobile has more than one hundred sensors. In recent years, the automotive sensors have been developed with the MEMS technology in a complementary style.

2. Sensing Technology for Automobile

The sensors for the VDIM (Vehicle Dynamics Integrated Management) are shown in Fig. 1. The VDIM is a combined system composed of the VSC (Vehicle Stability Control), ABS (Antilock Brake System), traction control, and power steering. In this case, data of a yaw rate, acceleration, wheel speed, steering angle, steering torque, and

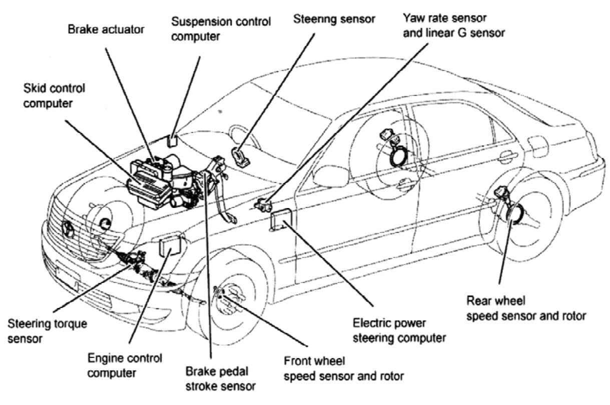


Fig.1 Configuration of VDIM

Table 1 Kind of automotive sensor

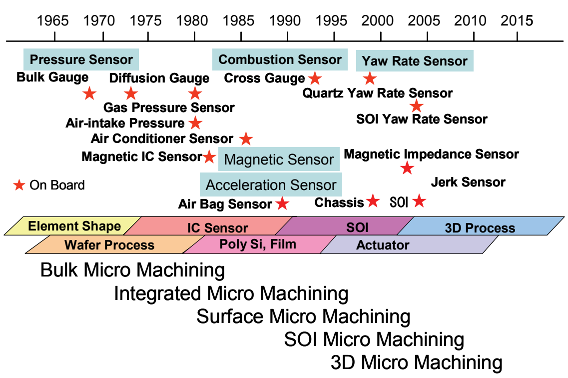
Temperature	Water, Oil, Intake, Exhaust air, Fuel, Cabin
Gas	Oxygen, Lean, NO_x, HC, H_2
Pressure	Intake air, Air flow, Combustion, Supercharging, Brake, Tire, Compressor
Position	Fuel level, Cam, Vehicle height, Seat
Angle	Crankshaft, rotation, Throttle, Steering, Direction
Speed	Engine, Vehicle, Transmission, Wheel
Angular rate	Yaw rate, Rollover
Acceleration	Airbag, Chassis, Suspension
Force, Load	Brake pedal, Steering torque, Loading
Vibration	Knocking
Light, Electric wave, Sound	Laser, Microwave, Visible light, IR light, Solar irradiation, Headlight, Voice, Ultrasound
Others	Glow plug, Particle, Rain drop, Humidity, Antenna, Fingerprint, Current

beak pedal sensors are combined via an automotive LAN (Local Area Network) and are used for the body control.

The history of the MEMS technology with automotive sensors is shown in Table 2. This history is the same as the sensor history of miniaturization, reduction in size and weight, high performance, and low cost. The piezo-resistive effect was used for pressure sensors. A combustion pressure sensor measured the pressure in an engine cylinder, and the combustion of the engine was controlled with the sensor. An acceleration sensor was used for an air bag system, ABS and VSC.

A yaw rate sensor, which is an angular rate sensor well known as a gyro sensor, was used for an advanced safety of an automobile. At first, a quartz yaw rate sensor was developed, which was on-board as the first generation sensor of the VSC. The sensor element and housing are shown in Fig. 2. Next, a semiconductor yaw rate sensor was developed as the second generation sensor for the VDIM. The semiconductor type is made of an SOI (Silicon on insula-

Table 2 Automotive sensor & MEMS technology



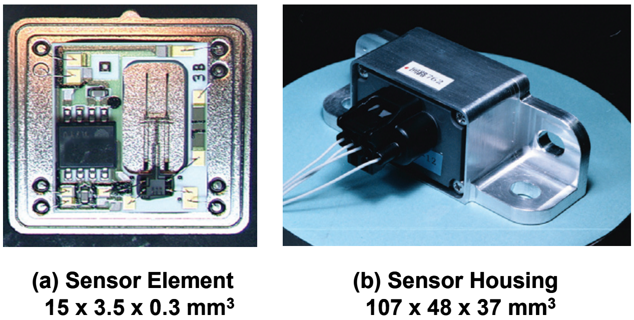


Fig. 2 Quartz yaw rate sensor

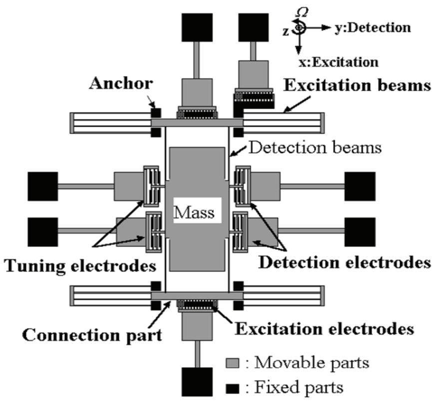


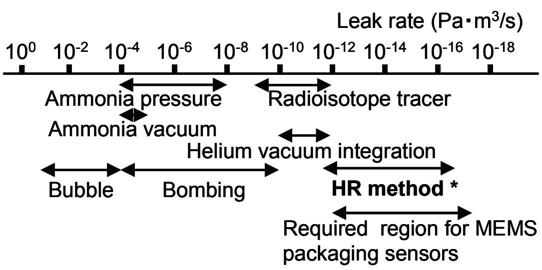
Fig. 3 Structure of semiconductor yaw rate sensor

tor) wafer with the MEMS technology. The structure of the semiconductor yaw rate sensor is shown in Fig. 3.

The yaw rate sensor is generally operated in a vacuum case over long periods of time. In a small package, it was very difficult to evaluate the long term stability of vacuum. There was no good method to detect the very slow leak. An HR method was developed to evaluate packaging MEMS sensors. The HR method is useful in a small leak rate range as shown in Table 3. The detection ability of the HR method is 5 digits higher than conventional methods. Figure 4 shows the configuration of the HR method. The HR method was very useful for the development of the semiconductor yaw rate sensor.

A stiction effect is well known in the MEMS. A small movable structure sticks to the substrate. Surface forces, such as Van der Waals, hydrogen bridges, and electrostatic forces are considered to cause stiction after the movable structure is brought into physical contact with the substrate.

Table 3 Detectable renges of various leak-testing methods



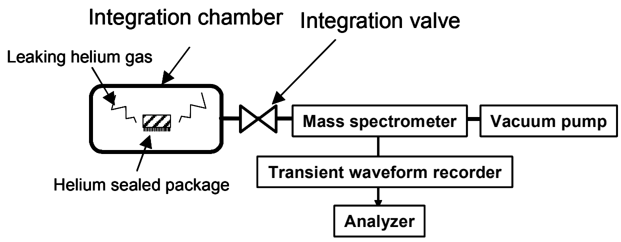


Fig. 4 Configuration of HR method

A convex poly-Si stopper structure for a movable structure was developed for an anti-stiction technology. The convex structure is referred to as a poly-Si mushroom-shaped structure (pSiMS). A fabricated pSiMS with a height of 0.6μm and a diameter of 2.8μm is shown in Fig. 5. The pSiMS has a pileus and stipe with a diameter of 1.5μm. The fabrication method is shown in Fig. 6. Figures 6 (a) and (b) show cross-sectional view of a fabricated mold and a mold refilled with poly-Si, respectively. The pSiMS allowed preventing 2-mm long beams from sticking. This anti-stiction technology improves the reliability of the MEMS device for automobile use.

3. Next generation of the MEMS sensors and actuators

There are so many expecting sensors and actuators developed by MEMS technology. A 3-axis accelerometer and multi-axis angular rate sensor can control a vehicle action in dynamic zone. A laser scanner with an optical MEMS scanner will provide a new system for safety.

4. Conclusions

The sensors for the automobile have been advanced with the MEMS technology. The needs and applications of the sensor and devices are expanding. New sensors and devices will be created with the MEMS progress.

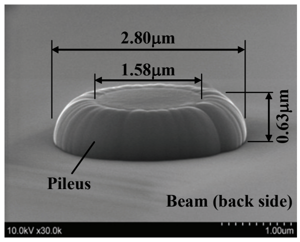


Fig.5: SEM image of a pSiMS fabricated on the beam.

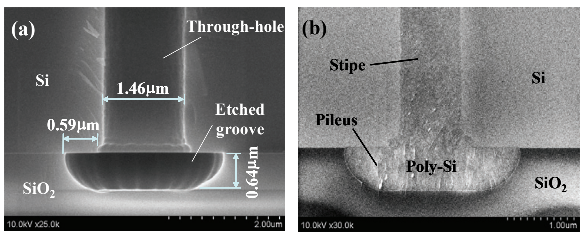


Fig.6: Cross-sectional views of a fabricated mold:
(a) before refilling with poly-Si, (b) after refilling with poly-Si.