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A Study on Recent Trends in IC-Mems Integration

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Abstract

MEMS devices are incorporated with IC technologies because of its miniature size, efficient functionality and broad range of applications. The technology involved is capable of integrating both electrical and mechanical systems. MEMS are nowadays used extensively in real time applications which outperforms other traditional designs with its innumerous advantages. This paper reviews the various implementation techniques of MEMS sensors integrated with IC's. Electronic Vehicle Identification (EVI) is done with the help of MEMs integrated systems which gives rise to the protection of vehicle from theft and other illegal selling of vehicles. Motion alarming sensitivity is analyzed in this study. A study on humidity sensor performance reveals that capacitive humidity sensors are less sensitive and consumes low power whereas Vertical Parallel Plate sensors (VPP) along with M1,M4,M5 extracts high sensitivity. Integration of Relative Humidity (RH) sensors improves the response time. The review is also contented on Magnetic measurements, thermal stress, inertial device characteristics, and residual stress using Raman spectroscopy as a part of IC-MEMs integration.

Keywords: Embedded system, IoT, MEMS, GPS, Photo chemistry, EVI and IC-MEMs

INTRODUCTION

Automobile Theft is an increasing and persistent issue in recent times. Automobiles are often stolen for purposes of transport, crime and also to dismantle the parts of the stolen vehicle in order to reuse or resell the parts. Forthcoming vehicles come with technological advancements and intelligent computational systems that are supposed to aid in situations such as automobile theft. Several technologies such as Immobilizers, Microdot Identification, EVI, Embedded Systems and Global Positioning System (GPS) have been launched to avoid theft of automobiles. Despite all these advancements, there are factors present that still favor automobile theft [1]. The paper also throws light on the integration of multiple sensing units in a single chip in order to implement a quick responsive humidity sensor [2]. Implementation of a vertically integrated CMOS-MEMS environment sensor, embedding CGSiS with MEMS devices through glass flow process, an integrated wireless capsule system for medical purposes, as well as 3D integration of MEMS sensor has been briefed as part of the integration of MEMS with various technologies.

STUDY

Immobilizers stop a thief from starting the vehicle but cannot prevent the vehicle from being towed away. The immobilizer can also be removed and the vehicle can be sold under a new identity. Identification and verification of vehicles is an easy task with the usage of EVI but this approach does not come in aid in situations where the vehicle parts are dismantled and re-sold. It is also ineffective in countries that do not implement EVI system. Lojack systems take several hours, days, months or forever to track vehicles and also fail to disable its auto

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systems. GPS acts inefficient in forest covers, parking garages and it can also be broken by a thief.

The present technologies intimate the owner only after the theft. To overcome these drawbacks, the development of a new design to prevent automobile theft using MEMS based gravitational lock has been proposed in [1]. MEMS technology uses micro fabrication techniques to form miniaturized mechanical and electro-mechanical elements. MEMS devices vary from a few millimeters to below a micron, simple structures to complex electromechanical systems. Micro-sensors and micro-actuators are the operating elements of the devices. MEMS devices have been found useful in several fields including bio- medical, automotive, and aerospace and so on. Arduino is a publicly available electronic modeling platform that allows users to construct interactive electronic designs. It possesses a microcontroller board and an IDE (Integrated Development Environment) to enter and connect the code to the device.

An integration of MEMS technology that perform motion alarming sensitivity alert and remote fuel cut-off assembly has been explained in this paper. The design provides air gesture key that uses a smart gravitational lock from key fob to the automobile in order to render security to the vehicle. It avoids stealing of key auto systems using air gesture security key with an accelerometer. The existing anti-theft systems do not provide protection when the key fob is robbed and give no possibility of central user interface. Motion sensors and tilt alarms alert any unintentional touch. These drawbacks have been addressed in the proposed design. When the key fob is not in use, the touch screen gets the key gesture. This is used in GPS outage environments and the 3-axis accelerometer also works as a gravity lock system for the vehicle position. To activate the system, the user has to press the parking button or it auto-enables after 10-20 seconds when the vehicle is stable. The vehicle position for gravity lock is taken as the reference value and from then, the current value is compared. Variation in values beyond threshold will alert the user in the form of an SMS. Vehicle movement can be prevented within a particular area with the help of GPS fencing on the touch screen display. The owner is intimated about intentional touch by the thief using the adjustable motion alarm. To prevent hacking and misuse of the vehicle, remote fuel cut-off is used to cut the fuel. The proposed method gives advantages of indoor and outdoor applications, easy installation, low cost, does not require a PC to process information and is easily understandable. Successful implementation of a design that provides efficient reliability and security to the vehicle has been executed [1].

Humidity sensors record the humidity of an environment and convert the recordings into an electrical output. They have been found useful in various fields of application such as weather forecast, industrial purposes, and aerospace and so on. These sensors are categorized into capacitive, resistive and piezo-resistive, based on their operational principles. Capacitive sensors exhibit low sensitivity to temperature variations, less utilization of power and no deviation over vast humidity range (0-100% RH). As a result, they are thoroughly investigated. VPP and Interdigitated electrodes (IDE) are two types of sensors. VPP systems render high sensitivity but show deficient performance in response time because of prolonged path for water vapor diffusion. Materials based on polymers and Polyimide(PI) are the best suitable materials for moisture sensitive films as they are well compatible with CMOS platforms and possess wide humidity range [2].

The work in [2] aims to implement and integrate multiple sensing units in one chip and realize a rapid response humidity sensor established on fence-shaped capacitor. The VPP structure is used for the RH sensor in order to enhance the susceptibility and the slender trenches reduce the diffusion path to provide better response time. The RH sensor has two electrodes that are fence-shaped with 5 μm width and act as capacitors. Layers M4 and M1 form the top and bottom electrodes, respectively. The time of vapor diffusion and sensor response are reduced by the slender trenches with the PI filler design. The long M4 electrodes are supported by oxide pillars in order to restrict the change in the gap during absorption and desorption of water. M5 1 μm width serpentine routing is used to vertically integrate RTD and RH sensor. M5 routing resistance varies during temperature change as M5 acts as a temperature detector.

In order to describe the 1.91 μm gaps for dielectric material, the sacrificial layer is removed by internal wet etching process [2]. The PI solution is distributed to fill between the electrode plates by means of pneumatic dispenser. Metal wet etching defines the fabricated chip where it is displayed through optical micrographs while the SEM micrographs show the overview of proposed sensor. To test the characterization of sensor, the chip is fastened on a ceramic substrate and fixed to a PCB which connects LCR meter to a wire for the output reading. The chamber was monitored with a commercial Sensirion SHT21 sensor. The humidity sensing unit's sensitivity was measured at particular intervals at 20° C. The detector's sensitivity recorded was 0.28%/°C. A novel CMOS-MEMS environment sensor of vertical integration has been implemented successfully [2].

This work [3] proposes the usage of glass reflow process to embed composite glass-silicon substrate (CGSiS) to micro components. The conductive material of micro components used is highly doped silicon. In order to fabricate the micro components, glass reflow process is investigated. Improved planarization demonstrated that the change in the total thickness of three substrates was lesser than 10μm. After polishing, the surface roughness of silicon and glass was recorded as 0.5nm and the conductivities of silicon substrates was measured to be 5.35×10^{-3} Ω-cm and 3.34×10^{-3} Ω-cm. This demonstration of CGSiS embedded with micro components are highly useful in MEMS 3D integration [3].

The work [4] discusses a silicon carbide structural layer-based multi-level IC adaptable MEMS surface microfabrication technology. Individual gaps are designed using a fabrication method that ensures efficient electrostatic transduction. Silicon carbide is used as the constructional material as it ensures compatibility with current semiconductor devices and also reports the lowest peak processing temperature (i.e. 200 °C). The paper also discusses the influence of upcoming advancements to the fabrication technology. Although the development of the process resolved many challenges, the technology did not need more than seven photolithographic masks. In order to enable higher Q-devices and minimize mechanical electrode damping, the technology is being improved. The concept have being designed for the realization of sophisticated IC-compatible devices such as 3-axis inertial sensors, multi-throw RF switches and out-of-plane micro-mirrors and provides above-IC compatibility, submicron electrostatic gaps, three-axis transduction and superior mechanical properties. [4].

This article [5] suggests a wireless capsule microsystem for real-time detection and monitoring of the GI tract's pH, temperature and strain. Sensors along with modulation-based IC circuits, a microcontroller and a transceiver with a meandered conformal antenna are all incorporated into the capsule system's growth. This integration forms a basis for future multisensory microsystems. Miniaturization of systems, increased sensitivity and resolution of sensors, and reduced power consumption of interface circuits are also discussed. The wireless capsule has a diameter of 13mm and a length of 28mm when it is packed. A data receiver and recorder system is also designed to obtain physiological data from the capsule and send it to a computer for real-time display and recording. The microcontroller's processed data is sent via wireless transceiver. The experiment was carried out in vitro using a stomach model and minced pork as tissue simulating material. The pH levels of high acidic pH range from 1.0 to 4.0, Thermal values ranged from 25°C to 50°C, and pressure sensor values ranged from 50 kPa to 200 kPa [5].

In [6], Micro electron mechanical systems (MEMS) technology is used for the integration of an amorphous wire Giant magneto-impedance (GMI) magneto sensor. Developing new design materials and methodologies for GMI sensors have found a great deal of importance in intensive research of weak magnetic measurements [1]. The design uses a loop excitation and non-diagonal extraction method which consists of a signal conditioning circuit to preprocess the output voltage, a crystal oscillator circuit to generate excitation current, an improved diode detection circuit to demodulate the magnetic field in output signal, and a sensor system. The device dimensions are

5.6mm*1.5mm*1.1mm. After analyzing the signal conditioning circuit and sensing principle, testing and calibration of output is executed. The device supplies an excitation current frequency of 60MHz in the form of a square wave signal, 4.8V/Oe sensitivity and 40nT resolution. It is able to measure a range of -0.5Oe to 0.5Oe weak magnetic field [2]. The proposed design uses simple circuits and MEMS methodologies to provide high integration and resolution, thereby saving cost and time of manufacturing, attaining device miniaturization and uniformity [6].

This work in [7] proposes the integration of MEMS Inertial Measurement Unit (IMU) and IC's (ASIC) using a 3D stacking technique to evaluate the integration impact on its output performance. This 2.5D/3D integration method provides wafer level package (WLP) development and miniaturization of inertial MEMS devices. Wafer level packaging of the integrated sensors are done using SiOx air-gapped Si-TSV based interposer. In order to determine how thermal stress affects the inertial device, four thermal stress simulation models are built and compared. Raman spectroscopy is used to measure the residual stress of Si-TSV. Using flip-chip process, the MEMS inertial sensor and ASIC are deposited on interposer and contain Au bumps on their metal terminals. A large deformation of large-scale sensitive structure is formed because of the introduction of under-fill. The distribution of 3D interconnection structures is optimized, and the substrate thickness is increased to reduce deformation and bending to about 8nm and 4nm, respectively. The proposed 3D integration design has been tested and is suitable for the integration of MEMS inertial sensor dies and IC dies [7]. The implementation of MEMs in IoT is useful in the integration of automated vehicles, Batteries, nanotechnology. MEMs in IoT also subsidizes its development in photochemistry, medical applications, transportation, and measurement of various parameters and in real-time applications [8-26].

CONCLUSION

MEMS sensors are used in many applications mainly because of its small size and less power consumption. It is also cost-effective and easily integrated. This paper has reviewed the applications of MEMS in detection of automobile theft using a gravitational lock which works on a motion sensor and other examples. A fast response humidity sensor is integrated in a CMOS for measuring the humidity of the environment. MEMS are also amalgamated with substrates to study the process of glass reflow. The fabrication technology is improved with the inclusion of MEMS with ICs. MEMS sensors are also used in biomedical applications to monitor the gastrointestinal tract's pressure and temperature. ICs in conjunction with IMU can be 3D integrated to assess and improve the output performance.

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